Self-reported upper body discomfort due to driving: effect of driving experience, gender and automobile age.

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Abstract

This study investigated the human upper body discomfort caused by automobile driving. Both global and local discomfort estimates were achieved by means of a self-administered questionnaire. The questionnaire used a Borg CR10 scale to evaluate human discomfort, and contained sections to gather information regarding the driving experience, gender and most frequently used automobile of the respondent. The geographic area surveyed was the city of Turin, Italy, and data from a total of 269 drivers was analysed. For all subgroups analysed, the back region was reported to suffer the greatest discomfort, followed in order of decreasing discomfort by the neck, shoulder, arm, hand-wrist, forearm, head, chest and mandible. Generally, female drivers provided higher discomfort responses than male drivers. Subdividing the data according to driving experience lead to large and statistically significant ($\alpha<0.05$) differences in both global and local discomfort. Subdividing by gender suggested some significant differences, while subdividing by automobile age produced few differences. The results suggest the usefulness of controlling for test subject driving experience and gender when performing subjective evaluations of automobiles. Further, comparison of the global and the local discomfort responses suggested that individuals were able to form a stable estimate of global discomfort based on the sensations perceived in each of the individual body regions involved. This suggests the interesting possibility that global evaluations may not always provide an accurate understanding of human discomfort since situations can be imagined in which different distributions of upper body discomfort might produce the same, global, response.

Relevance of industry: Vehicle development programmes make extensive use of test juries and of subjective evaluation methods, and numerous questions arise regarding the effects of jury composition and of subjective measurement technique on the results. This research provides a first evaluation of the differences between global analysis and local analysis of upper body discomfort, and of the effect of the factors: driving experience, gender and vehicle age.

Keywords: discomfort, driving, automobile, experience, gender, Borg

1. Introduction

Several subjective evaluation methods have been developed to measure human responses ranging from mild discomfort to pain (Corlett and Bishop, 1976; Krist, 1994; Ebe and Griffin, 2000). When the discomfort is caused by automobile driving, the most commonly used method of evaluation has been the self-reported questionnaire. Examples of self-reported questionnaires developed to evaluate passenger discomfort in transport environments include those of Oborne and Clarke (1973), Oborne (1977), Corlett and Bishop (1976), Lusted et al. (1994), Mansfield and Marshall (2001) and Porter et al. (2003). Given the widespread use of such questionnaires, several studies have addressed the question of their applicability and general validity. An example of the findings is provided by Myers and Schierhout (1996) who suggested the validity of self-reported questionnaires when applied to large test groups.

Of the self-reported questionnaires, one of the most frequently encountered examples is the Standardised Nordic Questionnaire (Kurionka et al., 1987). The original Nordic Questionnaire included sections for the evaluation of both general and body part discomfort, and has been widely applied to the evaluation of the incidence of musculoskeletal disorders. Similar methods have been applied to the evaluation of automotive driving discomfort. Research investigations which have used Nordic Questionnaires, or modified derivatives of the Nordic Questionnaire, for the purpose of evaluating driving discomfort include the studies by Magnusson et al. (1996), Porter and Gyi (2002), Pietri et al. (1992) and Bovenzi and Hulshof (1998). The findings suggest an association between automobile driving and low back pain, with professional drivers having been observed to declare greater levels of discomfort than non-professional drivers.

Several researchers have suggested possible factors which affect human discomfort during the driving task. Personal factors identified by the scientific research include: body mass (Fairley and Griffin, 1989), age (Jensen et al., 1996), gender (Matthews et al., 1999), driving experience (Hedberg, 1987) and smoking (Lindal and Stefansson, 1996). Factors related to the driving environment include: the possibilities for seat adjustment (Park et al., 1999), the sitting posture (Alm and Magnusson, 1992; Wilder et al., 1994), the resulting pressure distributions acting on the body (Porter et al., 1999), the time duration of the drive (Falou et al., 2003), the forces exchanged with the vehicle (Mourant and Sadhu, 2002) and the possible presence of vibration at the seat and steering wheel (Houston et al. 2000, Nishiyama et al., 2000).

For the designers of road vehicles one of the most important systems to consider is the steering. When considering the possible effects of steering system design parameters on human discomfort, several questions come to mind which have not been adequately answered by previous research. First and foremost is the variation of discomfort which occurs across different regions of the upper body during driving, and how these regional variations might be affected by the design of the steering system. Research reported in the literature has conclusively indicated a correlation between vehicle driving and low back pain, but none of the investigations which dealt specifically with the activity of vehicle driving subdivided the upper body into individual units to establish the regions of greatest discomfort. The ability to localise the discomfort, and the ability to relate these values to the parameters of the steering system, would prove highly beneficial to designers. Further, debate often arises regarding the possible inter-subject variation that can occur during subjective evaluations of the steering. In particular, the manufacturers of road vehicles are often, of necessity, confined to using expert opinion from test drivers or from other driving professionals. In such cases, questions can arise regarding how representative the opinion of the professional drivers is with respect to average drivers. Knowledge of the possible extent of such variations in self-reported discomfort would also prove beneficial to the steering system designer.

This study represents a first attempt to answer some of these questions. The primary aim was to establish if different levels of human discomfort are perceived in different upper body regions when driving automobiles. The secondary aim was to investigate whether driver experience, driver gender and automobile age should be considered factors which affect the level and distribution of upper body discomfort.

2. Discomfort survey

2.1 Questionnaire

A self administered questionnaire was developed and applied to investigate the level of discomfort experienced in the human upper body by non-professional drivers and by individuals who drive as part of their job. Individuals considered to be professional drivers included taxi drivers, police officers, and commercial and sales personnel who make use of an automobile as part of their daily work activities. The objective of the questionnaire was to gather upper body discomfort data in a quick and efficient manner.

Of the four basic types of measurement scale (nominal, ordinal, interval and ratio), a ratio scale was desired for use in the study due to its properties of order, distance and a natural origin to represent zero amount of the stimulus (Gescheider, 1997). Subjective evaluation methods based on category scales use verbal categories provided by the researcher. When the category labels are well chosen, these methods have the important advantages of clarity and simplicity. The disadvantage is the limited number of analytical transformations which can be applied to category data. In the case of ratio scale methods, the test subject is normally requested to report a numerical value expressed as a ratio of the value of the standard stimulus adopted for the study. This form of test can be more difficult for the test subject, but does provide data which can be manipulated using the widest possible range of analytical transformations. The Borg CR10 scale (Borg 1998) was defined so as to approximate the ease-of-use of a category scale while achieving the analytical flexibility inherent in numbers reported using a ratio scale. By assuming that people use semantic labels such as “weak” and “very strong” to signify similar quantities across different stimuli modalities, and by assuming that the range of perceived sensation varies from a minimum value to a maximum value which are similar for most people, Borg combined the characteristics of the two systems to produce the CR10 (Category-Ratio anchored at 10) scale.

Figure 1 presents the Borg CR10 scale, which consists of 17 level points (9 labelled and 8 unlabeled). The value of 10 represents the maximum suggested intensity, but greater values can be chosen if the test subject so wishes. From their study of the human perception of hand-arm vibrational discomfort, Wos et al. (1988) claimed that the Borg CR10 scale is highly reliable, with reliability coefficients ranging from 0.841 to 0.986. Neely et al. (1992) have reported coefficients of determination (r^2) of 0.79 between Borg CR10 results and subjective data obtained by means of a visual analogue scale, and have also reported typical retest coefficients of determination of 0.98. The Borg CR10 scale has been widely applied in the fields of physiology, psychology and ergonomics to rate sensations of pain, fatigue, physical exertion and discomfort (Ulin et al., 1993; Smutz et al., 1994; Miedema et al., 1997; Dimov et al., 2000).

[INSERT FIGURE 1 HERE] [INSERT FIGURE 2 HERE]

Figure 2 presents the English language version of the questionnaire used in the study. It consisted of four sections which were structured to gather data regarding the respondent, the respondent's most frequently used automobile, the driving conditions under which the respondent may have formed his or her understanding of driving discomfort, and discomfort estimates for several upper body regions.

The first section included six questions regarding the respondent: age, gender, height, occupation, smoking habits and any physical condition which the respondent felt might affect his or her responses to the discomfort questions. The second section consisted of five questions which would help to classify the automobile that was most frequently used by the respondent. The automobile characteristics considered were: size (small, medium, large), age (year of registration), mileage, the presence of power steering and the shape of the steering wheel. The third section gathered information about the general class of road over which the respondent most frequently drove (urban, suburban or motorway) and the average amount of time spent driving each day (less than 30 minutes, less than 1 hour, less than 2 hours or more than 2 hours). The fourth, and primary, section of the questionnaire requested responses regarding the typical discomfort sensations that occur when driving, and the intensity with which the participant normally grips the steering wheel while driving. Participants were invited to rate their typical perceived discomfort for each of nine upper body segments (hand/wrist, forearm, chest, arm/elbow, shoulders, low back, neck, mandible and head) using a Borg CR10 scale. They were also requested to provide an estimate of the overall level of upper body discomfort which occurred during normal driving. The nine regions were chosen following the major anatomical subdivisions of the elements of the human upper body. The nine region subdivision represents a simplification of the scheme previously reported by Giacomin and Abrahams (2000) which is regularly used by the authors in studies of human response to hand-arm vibration. A final information that was gathered was the grip intensity which the respondent judged to be the most frequently used with the right, and the left, hands when holding the steering wheel while driving.

A preliminary survey was performed with a sample of twenty participants in order to assess the suitability of the questionnaire. Based on feedback from the participants, and from data analysis, changes were made to the semantics of some questionnaire items in order to increase readability. The time required to complete the questionnaire was found, on average, to be approximately 14 minutes.

2.2 Survey sample

The geographic area in which the survey was performed was the city of Turin, Italy. The questionnaires were directly administered at public locations such as shopping malls, parks, petrol pump areas and car washing centres. The sample consisted of 370 drivers of which 250 declared themselves to be non-professional drivers and 120 professional drivers. In order to reduce the possible influence of medical condition or disability on the survey results, data was not analysed for those respondents who indicated a continual use of prescribed medicines or an important physical disability. Data from smokers was also eliminated from the survey since research has suggested that nicotine from smoking can lead to increased reporting of discomfort in humans (Leino-Arjas, 1998; Cole and Rivilis, 2004). Elimination of people with disabilities, people with medical conditions and smokers from the survey lead to a final set of 269 drivers whose data was analysed and whose general characteristics are summarized in Table 1. Only the discomfort responses and the data regarding driving experience, gender and automobile age were analysed, and are reported here. The number of questionnaire respondents in each of the subgroups obtained by dividing the survey sample according to the three factors of driving experience, gender and automobile age is provided in Figure 3.

[INSERT TABLE 1 HERE] **[INSERT FIGURE 3 HERE]**

3. Results

3.1 General Statistics

Figure 4 presents the mean value and the 95% confidence interval determined for each upper body region from the responses of all the non-professional (n=186) and all the professional (n=83) drivers. The region of the back was consistently indicated to be the region suffering the greatest discomfort, with a mean response between “weak” and “moderate” on the Borg CR10 scale. In descending order of mean discomfort, the other upper body regions followed as neck, shoulder, arm, hand-wrist, forearm, head, chest and mandible. The mandible and the chest regions were characterised by the lowest discomfort, ranging from “null” to “just noticeable”. Comparing the mean response of the non-professional drivers to those of the professional drivers, the non-professionals indicated lower levels of discomfort for the back and the shoulder, but higher levels elsewhere.

Figure 5 presents the mean value and the 95% confidence interval determined for each upper body region from the responses of all the male (n=179) and all the female (n=90) drivers. Grouped by gender rather than driving experience, the back region was again reported to suffer the greatest discomfort, with a mean response ranging from “weak” to “moderate”. In descending order of mean discomfort, the other upper body regions followed as neck, shoulder, arm, hand-wrist, forearm, head, chest and mandible. Again, the mandible and chest were characterised by the lowest discomfort, ranging from “null” to “just noticeable”. Comparing the mean response of the male drivers to those of the female drivers, the males consistently provided lower levels of discomfort across the complete set of upper body regions.

Figure 6 presents the mean value and the 95% confidence interval determined for each upper body region from the responses of all individuals who declared that their most regularly driven automobile was more than 4 years old (n=168) or less than 4 years old (n=101). Grouped by automobile age, the responses again suggested that the back region was characterised by the greatest discomfort, with a mean response ranging from “weak” to “moderate”. In descending order of mean discomfort, the other upper body regions followed the same sequence of neck, shoulder, arm, hand-wrist, forearm, head, chest and mandible. Again, the mandible and chest were characterised by the lowest discomfort, ranging from “null” to “just noticeable”. Comparison of the mean response of the drivers who declared their automobile to be more than 4 years old to the mean responses of the drivers who declared that their automobiles were less than 4 years old indicated lower levels of discomfort for the arm and mandible regions, but higher levels elsewhere.

Preliminary inspection of the data of Figures 4, 5, and 6 suggested important differences in mean discomfort across the nine upper body regions. Further, the differences in mean discomfort also suggested the importance of all three influencing factors (driving experience, gender and vehicle age). Given the limited size of the sample, it was thought useful to perform the necessary tests of statistical significance using a data resampling method so as to increase the statistical power of the analysis.

[INSERT FIGURE 4 HERE] [INSERT FIGURE 5 HERE] [INSERT FIGURE 6 HERE]

3.2 Bootstrap tests

Data resampling methods are becoming increasingly popular and are sometimes referred to as modern methods of data analysis (Fox and Long, 1990). Efron (1979) has proposed a method called the bootstrap in which resampling with replacement is used to estimate the sampling error and the confidence intervals for any statistic considered. Following Efron and Tibshirani (1993), if two data samples {x, y} which contain a total of N and M mutually independent values, respectively, are from possibly different probability distributions F and G, the null hypothesis H_0 of no difference between them

$$H_0 : F = G \qquad (1)$$

can be tested by means of the bootstrap procedure. A fixed number of bootstrap resamples are determined by random sampling, with replacement, from a combined data set consisting of all values of x and of y. Each bootstrap resample consists of a first set of N values, followed by a second set of M values. A statistic such as the difference in mean value

$q = \bar{x} - \bar{y}$ can be used to compare the bootstrap sets to the original data sets x and y. Assuming $q*$ to be the value of the statistic computed considering all bootstrap sets, and q to be the observed value of the original data, the hypothesis test of H_0 consists of computing the achieved significance level (ASL), which may be defined as the probability of observing a value of $q*$ that is larger than q

$$\text{ASL} = \text{Prob}_{Ho}\{q* > q\} \qquad (2)$$

The greater the value of the ASL, the stronger the evidence of H_0. If the ASL is greater than a conventional threshold α, then H_0 is accepted. Approaches such as the bootstrap are sensitive to the number of resamplings used to determine the ASL. Based on their experience, Efron and Tibshirani (1993) proposed that a number of resamplings as small as 25 was sufficient in many applications, that 50 was often optimal, and that few data sets had been encountered which required more than 200 resamplings.

For the analysis of the upper body discomfort data a 5% threshold value ($\alpha<0.05$) was used and the number of bootstrap replications was conservatively chosen to be 3000. The possible influence of the three factors of driving experience, gender and automobile age, was evaluated for each upper body region. Tests for statistically significant differences were performed between all data subgroups defined by these three factors (see Figure 3 for the number of questionnaire samples in each group). All possible subgroups were tested starting from the data sets: all non-professional drivers vs all professional drivers, all males vs all females, all drivers of automobiles with more than 4 years of age vs all drivers of automobiles with less than 4 years of age.

Table 2 summarises the results of the bootstrap significance tests. The first column indicates the comparison performed, while the second column presents the names of the upper body regions where statistically significant differences occurred in the self-reported driving discomfort responses. Table 2 presents only those regions where the differences were significant at a confidence level greater than 5%, the confidence levels actually achieved being presented next to the name of each body region in parenthesis. All subgroupings of non-professional versus professional drivers produced statistically significant differences at confidence levels greater than 5%. Further, statistically significant differences were also obtained in the case of male versus female drivers, but no grouping based only on automobile age produced statically significant differences.

Figures 7 and 8 present a graphical summary of the upper body regions in which statistically significant differences (see Table 2) were found. As suggested by Figure 7, the forearm and neck are regions in which significant differences in discomfort occurred between non-professional and professional drivers. The forearm, neck and hand are instead regions in which significant differences were found between males and females. Figure 8 suggests, instead, a possible role of the automobile towards increasing the differences in response between non-professional and professional drivers. No statistically significant differences assignable only to the age of the automobile were found.

[INSERT TABLE 2 HERE] [INSERT FIGURE 7 HERE] [INSERT FIGURE 8 HERE]

4. Discussion

The results confirm the initial hypothesis that different regions of the human upper body experience different levels of discomfort due to the driving activity. The regions associated with the highest levels of mean self-reported discomfort were the neck, back and shoulder regions spanning a range of Borg CR10 values from 1.35 to 2.31. The regions found to be associated with the lowest levels of discomfort were the mandible, chest and head, spanning Borg CR10 values from 0.18 to 0.79.

Of the three possible influencing factors considered in the current study (driving experience, gender and automobile age), a bootstrap analysis performed using 3000 resamples and a 5% confidence level suggested that both the largest, and most strongly significant, differences occurred between the subgroups which had been divided according to driving experience. For example, when considering both sexes and all automobiles the mean neck discomfort was 1.93 for non-professional drivers but 1.46 for professional drivers, a difference of approximately 33%. For the forearm region the same comparison lead to a difference of 94%, with mean discomfort increasing from 1.00 in the case of non-professional drivers to 0.51 for professional drivers. A possible conclusion is that this factor should be controlled when establishing juries for use in evaluating automobile design parameters which effect the upper body.

The second most influential factor was found to be gender, with female drivers consistently having indicated higher levels of discomfort than male drivers in all upper-body regions. From the bootstrap analysis, the regions in which the differences were found to be statistically significant at a 5% confidence level were the hand/wrist, the forearm and the neck. For these regions females reported 44% greater discomfort for the hand/wrist region (mean value of 1.07 as opposed to 0.74), 23% greater discomfort for the forearm (mean value of 0.98 as opposed to 0.79) and 39% greater discomfort for the neck region (mean value of 2.21 as opposed to 1.59). Such gender-based differences would appear to be in agreement with the results of a literature review performed by Treaster and Burr (2004) in which extensive evidence was found to support the position that females report more musculoskeletal discomfort and pain of the upper extremities than males. A possible conclusion is that it may prove useful to control this factor when establishing juries for use in evaluating design parameters which effect the upper body.

Of the three factors considered, the least influential was found to be the age of the automobile. Subdividing the complete survey sample into the two categories “automobiles less than 4 years old” and “automobiles more than 4 years old” suggested small differences in the mean discomfort response of each of the 9 upper body regions (see Figure 6). Bootstrap analysis using 3000 resamples and a confidence level of 5% suggested, however, that the differences were not statistically significant. Age of the automobile did, however, serve to increase the differences between non-professional and professional drivers (see Table 2 and Figure 8). Non-professional drivers reported significantly different levels of discomfort with respect to professional drivers in the forearm, arm, shoulder and neck when their automobile was more than 4 years old, but only in the forearm and back when the automobile was less than 4 year old.

As a final topic for discussion, no significant differences were found between the global self-reported discomfort level and the mean value obtained by considering the individual responses of each of the nine upper body regions. While differences between the two mean values exist, bootstrap analysis did not find these differences to be significant at a 5% confidence level. Further, these differences remained non-significant after subdivision of the original sample survey into subgroups according to the three factors considered (driving experience, gender and automobile age). As an example, Figure 9 presents the results in terms of mean value and 95% confidence interval for four subject groups. The findings suggest that individuals are able to form a stable estimate of global upper body discomfort based on the sensations perceived in each of the individual body regions involved. Further, this suggests the interesting possibility that global evaluations of driving discomfort may not always provide an accurate understanding of the effects of steering system design parameters on the human body. Situations can be imagined in which very different distributions of upper body discomfort, due to very different interactions with the steering system, could nonetheless provide the same, global, discomfort response.

[INSERT FIGURE 9 HERE]

5. Conclusions

Both global and local human upper body discomfort associated with automobile driving were investigated. A self-administered questionnaire used a Borg CR10 scale to evaluate discomfort, and contained sections to gather information regarding the driving experience, gender and most frequently used automobile of the respondent. For all subgroups analysed, the back region was reported to suffer the greatest discomfort, followed in order of decreasing discomfort by the neck, shoulder, arm, hand-wrist, forearm, head, chest and mandible. Female drivers were found to provide higher discomfort responses than male drivers, and all study results suggest the usefulness of controlling for test subject driving experience and gender when performing subjective evaluations of automobiles. Comparison of the global and the local discomfort responses suggested that individuals were able to form a stable estimate of global discomfort based on the sensations perceived in each of the individual body regions involved. This suggests the interesting possibility that global evaluations may not always provide an accurate understanding of human discomfort since situations can be imagined in which very different distributions of upper body discomfort might produce the same, global, response.

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Subgroups	Number of samples	Age [years] (mean ± SD)	Height [m] (mean ± SD)
Non-professional drivers - all	186	33.7 ± 12.4	1.73 ± 0.08
Professional drivers - all	83	39.9 ± 11.7	1.74 ± 0.07
Non-professional drivers - male	114	35.1 ± 13.3	1.77 ± 0.07
Non-professional drivers - female	72	32.3 ± 11.1	1.66 ± 0.07
Professional drivers - male	65	41.4 ± 11.7	1.76 ±0.07
Professional drivers - female	18	34.6 ± 9.3	1.69 ± 0.07
Non professional drivers - male - automobile age > 4 years	74	33.9 ± 13	1.78 ± 0.07
Non professional drivers - male - automobile age < 4 years	40	37.4 ± 13.6	1.77 ±0.07
Non professional drivers - female - automobile age > 4 years	48	33.3 ± 11.4	1.65 ± 0.06
Non professional drivers - female - automobile age < 4 years	24	30.3 ± 10.4	1.69 ± 0.1
Professional drivers - male - automobile age > 4 years	39	41.1 ± 12.4	1.76 ± 0.07
Professional drivers - male - automobile age < 4 years	26	41.9 ± 11.7	1.77 ± 0.08
Professional drivers - female - automobile age > 4 years	7	36 ± 13.3	1.69 ± 0.07
Professional drivers - female - automobile age < 4 years	11	33.7 ± 6.2	1.69 ± 0.07

Table 1) Summary of the sample group analysed (n=296).

Factors tested	Upper body parts which presented differences in self-reported discomfort
Non Professional *vs* Professional (all)	Forearm (0.009), Neck (0.02)
Female *vs* Male (all)	Hand/Wrist (0.03), Forearm (0.0001), Neck (0.02)
Non Professional *vs* Professional (male)	Neck (0.03)
Non Professional *vs* Professional (female)	Neck (0.04)
Non Professional *vs* Professional (automobile age>4 y)	Forearm (0.0023), Arm (0.01), Shoulder (0.01), Neck (0.03)
Non Professional *vs* Professional (automobile age<4 y)	Forearm (0.037), Back (0.04)

Table 2) Regions of localised discomfort for which the null hypothesis was rejected based on the bootstrap analysis, along with the achieved significance levels.

0	No exertion at all
0.3	
0.5	Extremely weak
1	Very weak
1.5	
2	Weak
2.5	
3	Moderate
4	
5	Strong
6	
7	Very strong
8	
9	
10	Maximal exertion
11	
•	Absolute maximum

Figure 1) Borg CR10 scale.

POLITECNICO DI TORINO

Dipartimento di Meccanica

UNIVERSITY OF SHEFFIELD

Dept. of Mechanical Engineering

DRIVING MUSCULOSKELETAL TROUBLES QUESTIONNAIRE

This questionnaire is being administered as a part of a scientific research project investigating upper body driving comfort. Please complete all sections of the questionnaire. Your support and contribution is greatly appreciated. All data is for purposes of statistical analysis only and is strictly confidential.

The undersigned ______________________________________ understands the aims and the intended use of collected information and agrees to participate in the study.

Date ____ / ____ / _______   Signature _______________________________________

Part 1 **– PERSONAL DATA**

1.1 Age: ___________ [years]   *1.2* Gender: M ☐ F ☐

1.3 Height: _________ [metres]   *1.4* Work activity: _________________________

1.5 You are: Smoker No Smoker Ex Smoker

1.6 Do you regularly take any medicine or do you have any physical condition which you feel may influence your discomfort responses? NO ☐ YES ☐ If yes, please specify _____________________

Part 2 – **VEHICLE CHARACTERISTICS**

2.1 Automobile size: Small ☐ Medium ☐ Large ☐

2.2 Registration year: ☐☐☐☐   *2.3* Automobile mileage: ☐☐☐☐☐☐

2.4 Power steering YES ☐ NO ☐

2.5 Steering wheel shape:

 ☐  ☐  ☐

Part 3 – **DRIVING CONDITIONS**

3.1 Which type of road do you most often drive on?

Urban ☐ Suburban ☐ Motorway ☐

3.2 On average, how many hours do you spend driving your car per day?

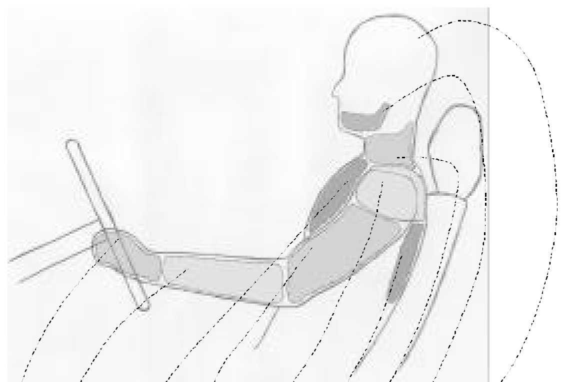
Less than 30 minutes ☐ Less than 1 hour ☐ Less than 2 hours ☐ More than 2 hours ☐

Figure 2) Questionnaire used in the research study.

Part 4 – **DRIVING DISCOMFORT**

4.1 Based on the road type chosen in the question 3.1 and the daily use indicated in response to question 3.2, please indicate the discomfort level you perceive at the end of drive in each of the body regions indicated below:

(Please first locate the correct verbal expression, then choose the numerical value)



4.2 Please indicate the intensity with which you normally grasp the steering wheel during your drive:

Left hand	Right hand				Hand/wrist	Forearm	Chest	Arm and elbow	Shoulders	Back	Neck	Mandible	Head	GLOBAL RESPONSE
		0	**Null**	**0**										
		0.3		**0.3**										
		0.5	**Extremely weak**	**0.5**										
		1	**Very weak**	**1**										
		1.5		**1.5**										
		2	**Weak**	**2**										
		2.5		**2.5**										
		3	**Moderate**	**3**										
		4		**4**										
		5	**Strong**	**5**										
		6		**6**										
		7	**Very strong**	**7**										
		8		**8**										
		9		**9**										
		10	**Extremely strong**	**10**										
			°Absolute maximum											

° Indicate your maximum value (i.e., 11, 12, …)

Figure 2) Continued.

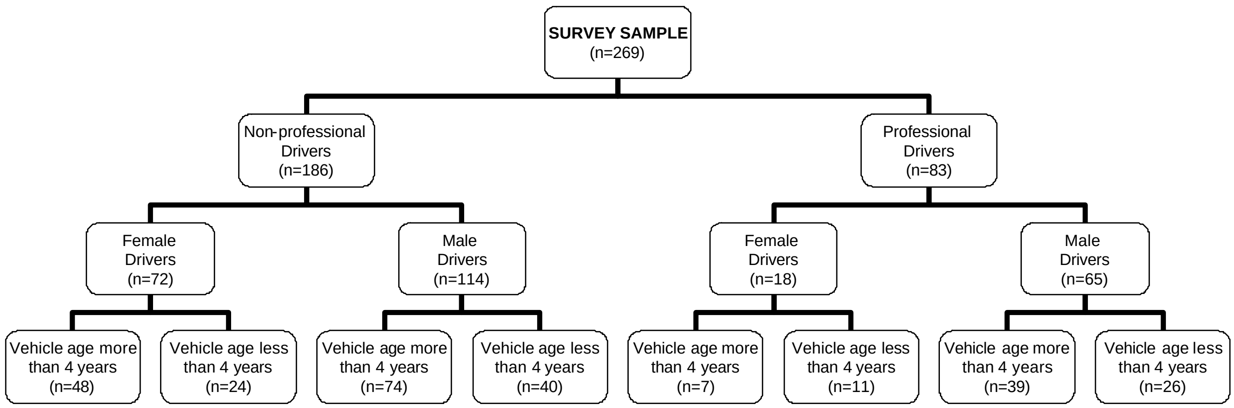


Figure 3) Subgroups which were statistically analysed.

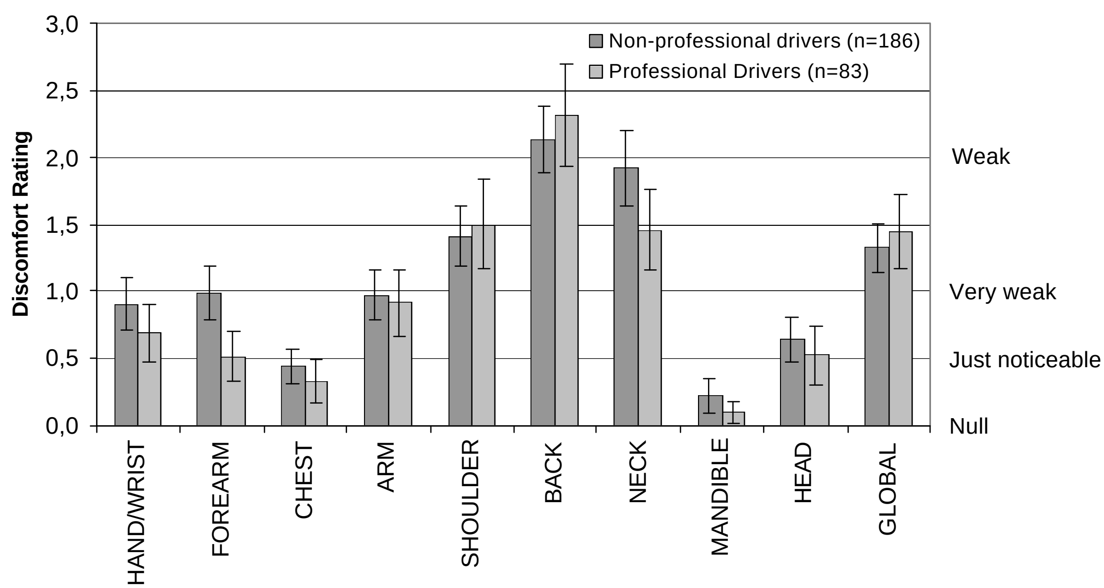


Figure 4) Comparison of discomfort responses of non-professional and professional drivers.

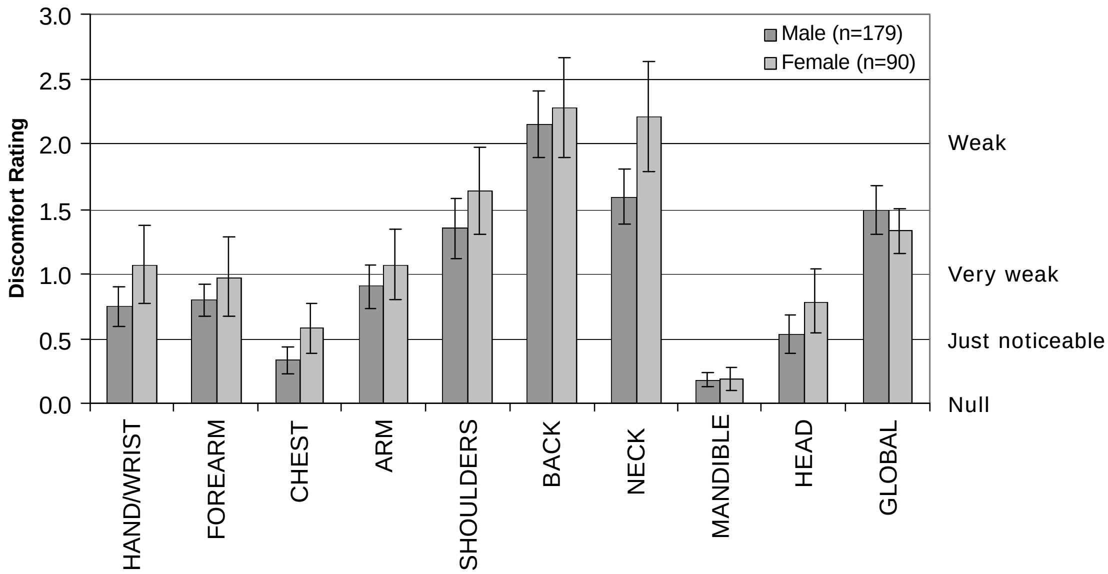


Figure 5) Comparison of discomfort responses of male and female drivers.

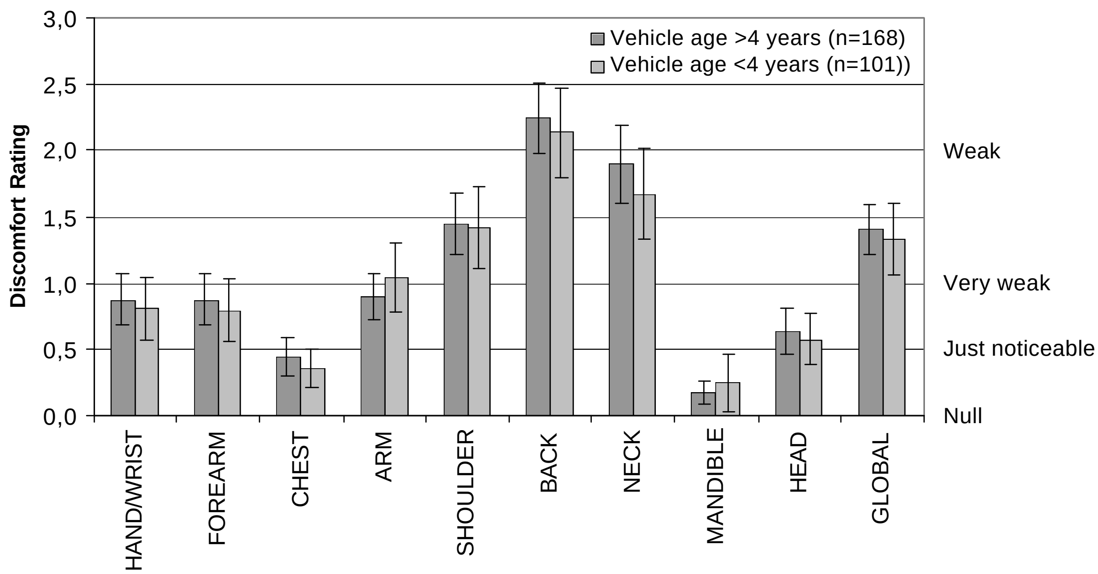
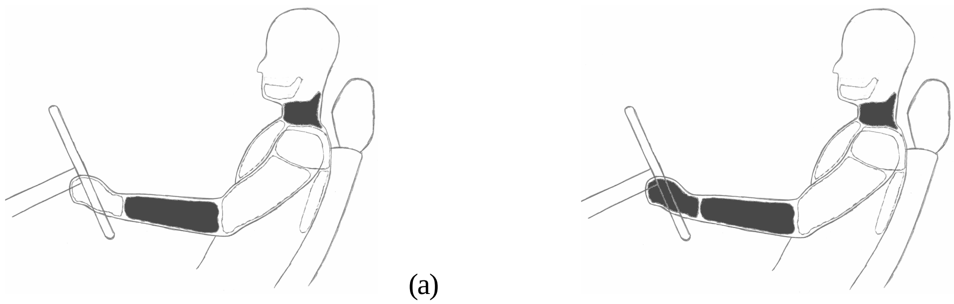
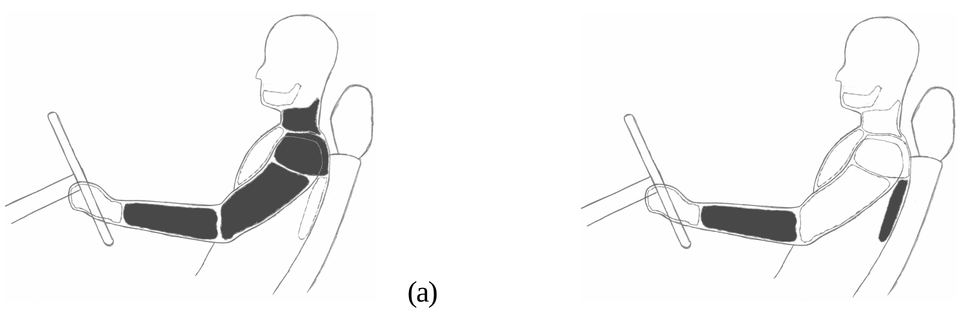


Figure 6) Comparison of discomfort responses associated with automobiles of different age.



(a) (b)

Figure 7) Regions of localised discomfort in which statistically significant differences were found when comparing a) non-professional drivers vs professional drivers; b) male drivers vs female drivers.



(a) (b)

Figure 8) Regions of localised discomfort in which statistically significant differences were found when comparing a) non-professional drivers vs professional drivers (driving automobiles with more than 4 years of age); b) non-professional drivers vs professional drivers (driving automobiles with less than 4 years of age).

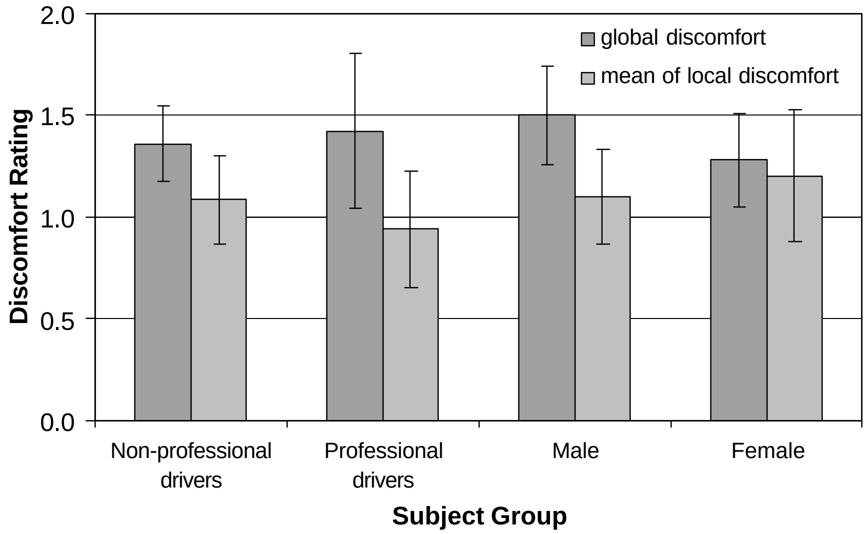


Figure 9) Comparison of the mean global discomfort response, and the mean of the mean local discomfort responses, for four subject groups.