Original Article

Investigation of Temperature Indicators, Thermal Comfort, and Mental Performance Parameters among Taxi Drivers in Winter

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Abstract

Aim: Safe driving is influenced by various factors, including the driver's level of cognitive performance and thermal comfort. The aim of this study was to investigate temperature indicators, thermal comfort, and mental function parameters among taxi drivers in winter. **Methods:** This cross-sectional study was performed on 30 taxi drivers in the morning and evening (8–9AM, 4–6PM). In this study, temperature parameters, including dry-bulb temperature and relative humidity, thermal comfort indices, demographic parameters and cognitive performance parameters, including accuracy, work speed, attention, number of errors, mental fatigue, concentration skills, and auditory short-term memory, were measured. Statistical analyzes were performed using SPSS version 26. **Results:** The average dry-bulb temperature and relative humidity inside the cabin in the morning and evening were 23.2%, 22.1%, 22.3%, and 21.3%, respectively. The results showed that the drivers' dissatisfaction with the temperature in the morning and evening shifts was 6% and 5.6%, respectively. There was no statistically significant difference in the measured parameters in the morning and evening shifts ($P > 0.05$). The results showed that there was a significant relationship between age and some cognitive function parameters ($P < 0.05$). **Conclusion:** More than 90% of drivers feel comfortable when the average dry bulb temperature of 22%–23% can be used to adjust the optimal temperature of the cabin vehicle in winter. Age is an effective factor in the cognitive performance of drivers and the cognitive performance of the drivers was not in a favorable condition, which requires further study to investigate the causes of this issue.

Keywords: Cognitive function, dry temperature, predicted mean vote, predicted percentage of dissatisfied

Introduction

According to the World Health Organization, 1.3 million people die in traffic accidents each year.[1] Driving is a complex task that requires the use of various senses, attention, cognitive-motor skills, memory, and quick decision-making.[2] Four main factors, including human factors (driver characteristics and behavior), the vehicle, the environment (weather conditions), and technical factors, are cited as causes of traffic accidents.[1]

In-car air quality, which affects driver productivity and efficiency, includes parameters such as noise and vibration, lighting, temperature conditions, and levels of air pollutants.[3] Thermal comfort has been introduced as one of the factors of indoor climate, which can be determined by factors such as ambient temperature, humidity, and airflow.[4]

According to the reports, human factors are cited as the cause of 65%–95% of traffic accidents.[5] Cognitive function includes various mental processes that involve areas such as perception, learning, memory, attention, decision-making, etc.[6] Studies have presented factors such as gender, education level, alcohol consumption, some diseases, work experience, age, and nationality as factors affecting cognitive function, which ultimately affects the performance of individuals.[7,8] In one study, work experience was mentioned as a factor

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/ijehe.ijehe_17_22

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How to cite this article: Dabaghi E, Dehghan H, Shakerian M. Investigation of temperature indicators, thermal comfort, and mental performance parameters among taxi drivers in winter. Int J Env Health Eng 2022;11:14.

Received: 29-04-2022, **Accepted:** 01-08-2022, **Published:** 29-11-2022

affecting physical performance and cognitive function, and a history of more than 15 years was introduced as a factor affecting cognitive and physical performance in men.[9] In the results of another study, the number of years of education was mentioned as a factor affecting the cognitive function of individuals and reducing the rate of decline in cognitive function with age.[10] The results of a review study that examined the effect of age on cognitive function reported that cognitive function (such as information processing speed, working memory, etc.) changes with aging and changes in brain structure.[11]

While driving, many factors affect the safe driving of people, which leads to the right decisions within a short time. In addition to the driver's experience, a safe driving depends on their physiological condition and comfort.[12] The factors affecting the safe behavior of drivers are temperature and thermal comfort. The temperature inside the cabin depends on the climate and the season. The human body responds physiologically, psychologically, and mentally to ambient temperature.[13]

One of the transportation systems in the country is the taxi system, which is used by many people every day. Note that driving is an occupation that involves different dimensions of human cognitive performance. Also, these parameters are affected by various factors. The thermal comfort of drivers is also a parameter that its investigation helps in reducing accidents and fuel consumption. Several studies have been conducted to investigate thermal stress and cognitive performance,[14,15] but few have been undertaken under real conditions and on occupations with significant mental performance. No study has been performed either to determine the level of thermal comfort of drivers in winter in Iran. Therefore, this study was conducted with the aim of investigating the cognitive performance of taxi drivers, as well as investigating the effect of demographic parameters on the aforementioned parameters and investigating the thermal comfort of drivers so that the results can be used to reduce driving accidents and employ the workforce.

Methods

This cross-sectional study was conducted on 30 taxi drivers in Isfahan (Iran) in winter 2021 during part of February and March in two shifts morning and evening (8–9AM, 4–6PM). There were eight taxi lines in the city, but as no list of people was available, the samples were selected by the authorities of six lines according to the inclusion criteria. The study inclusion criteria were general health, no disease such as cardiovascular diseases, mental disorders, diabetes, thyroid, and multiple sclerosis, having an adequate sleep and rest last night, and consent to participate) Information about the test and signing the consent form(.[16-18] General health questionnaire was used to investigate the general health of the subjects; the subjects who obtained the required score (<22) were included in the study.[19] Other criteria were also asked verbally from the subjects. The study exclusion criteria were noncooperation and incomplete questionnaires by the subjects.

The parameters used in this study to investigate mental function included mental fatigue, short-term auditory memory, concentration skills, attention, precision, number of errors, and speed of performance. The concentration skills questionnaire was applied to explore concentration. This questionnaire consists of 13 questions, including two subscales, of which eight questions are related to the subscale of voluntary concentration and five questions to the subscale of involuntary concentration. A person's high score in the voluntary concentration domain indicates that the person perceives and responds appropriately to external and internal stimuli. A high score in the area of involuntary concentration indicates that the person is mentally preoccupied and can be distracted.[18]

In order to investigate mental fatigue, the mental fatigue questionnaire was used. 15-item Mental Fatigue Questionnaire includes no work performance, mental fatigue, mental fatigue recovery, concentration difficulty, memory problems, reduced thinking, stress sensitivity, emotionality, mood trouble, light and sound sensitivity, reduction of the night sleep time, increase of the sleep time and 24-h changes.[21] Wechsler standardized test was employed to examine short-term memory. This test has seven sub-tests, each investigating different parts of memory. In this study, only the digit repetition test, also known as the range of digits, was used. Briefly, a list of three to nine numbers was read to the participant calmly and loudly, and the participant recited the numbers in the same way the first time after hearing each list, and the second time after reading the list to the participant, he recounted the numbers upside down. This test measured his short-term auditory memory.[20]

Toulouse-Pieron test was used to evaluate the precision, attention, number of errors, and speed of performance of the participants. The test consists of a number of consecutive squares where the participant crosses squares similar to the pattern for 5 min. Then, his speed of performance was measured through counting the total number of squares crossed. The number of errors was measured by counting the number of squares he crossed incorrectly and not according to the pattern. Furthermore, precision was obtained from the formula, the number of correct cases minus the number of errors divided by the number of correct cases multiplied by one hundred.[23] Furthermore, to determine the parameter of attention, 0.5 negative score was considered for each wrong or forgotten choice, while a positive score was considered for each correct choice, which was obtained from their algebraic sum.[24] Wet bulb globe temperature meter (model Cassela made in china) was used to measure the Dry-bulb temperature and relative humidity.[25] Two thermal comfort indicators, including predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD), were utilized to investigate thermal stress. In order to determine PMV, the subjects were asked to rate their emotion using a 7-point scale that included cold, cool, slightly cool, balanced, slightly warm, warm, and hot, with PMV values of − 3, −2, −1, 0, 1, 2 and 3, awarded to each of the above respectively. Then, after determining the above data obtained based on the participants' comments, the values were used to determine PMV. In this way, the total number of people at each point of the scale was multiplied by the value of PMV and then the results of each degree were summed up together and divided by the total number of participants. In order to determine PPD, after determining PMV, its value was determined using the relevant formula, which is <10% according to ISO 7730.[26]

$$PPD = 100 - 95 \times e^{-(0.03353 \times PMV^4 + 0.02179 \times PMV^2)}$$

To declare the outside temperature of the car, the measurement report of the Isfahan meteorological station was used at 9:00 AM and 6:00 PM. The recorded dry temperature Between February 19 and March 20 was extracted from the system in two measurement times.[27] All the tests were done inside the car cabin and in the presence of the participant.

Then, information such as age, level of education, work experience, cooling-heating system, habit of using the cooling-heating system, weight, height, and weather conditions inside each cabin was recorded. The procedure of the test is shown in Figure 1.

SPSS software version 26 was used for statistical analysis. Kolmogorov–Smirnov test was used to determine the normality of the distribution of data, and then parametric and nonparametric tests were used based on the normality.

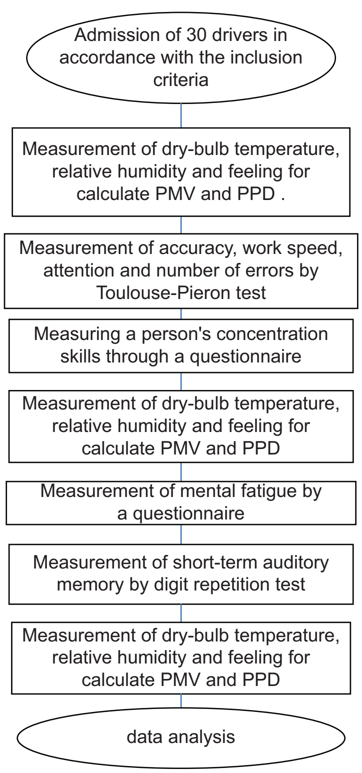

Figure 1: Steps to measure the parameters in the morning and evening

Descriptive indicators of mean and standard deviation were applied to describe quantitative data, while percentage index was used to describe qualitative data. Morning and evening data were compared using the paired *t*-test and Wilcoxon test, while the relationship between the data were assessed using Pearson's and Spearman's correlation coefficients, the independent *t*-test, and the Man–Whitney test. The significance level of the statistical test used was $P < 0.05$.

Results

This study was conducted on 30 male taxi drivers with a mean mental health of 18.26 and a standard deviation of ± 4.65. Further details on drivers' demographics are provided in Tables 1 and 2.

The car heating system of all participants was turned off during the measurement. The average dry-bulb temperature inside the cabin in the morning and evening (8–9 am, 4–6 pm) was 23.2% and 22.1%, respectively, and the mean and standard deviation of dry outside temperature was 15.2 ± 4.7 at 9 am and 10 ± 4 at 6 pm. The weather in the morning in 80% of cases was clear and 20% cloudy. In the evening, 66.7% was clear, 23.3% cloudy, and 10% rainy. Further, 50% of drivers were accustomed to using the vehicle cooling-heating system, while 50% of drivers were not. The cooling-heating system

Table 1: Number and percentage of parameters of education level and clothing coverage in winter (*n*=30)

Parameter	*n* (%)
Education level	
Primary level	14 (46.7)
Elementary level	3 (10)
Diploma	9 (30)
Associate degree	2 (6.7)
B.A	2 (6.7)
Clothing	
Morning	
Winter clothing	30 (100)
Summer clothing	0
Evening	
Winter clothing	29 (96.7)
Summer clothing	1 (3.3)

Winter clothing: Jacket, thick clothing and pants (Clo (Clothing resistance to heat transfer)=1.5), Summer clothing: Shirt and pants (clo=0.5)

Table 2: Mean and standard deviation of drivers' demographic parameters (*n*=30)

Variable	Mean±SD
Age (year)	52.7±8.5
Weight (kg)	81.2±10.6
Height (cm)	173.6±10.4
BMI (kg/m^2)	26.9±2.7
Work experience (year)	18.6±9.4
Sleep (h)	7±0.9

BMI: Body mass index, SD: Standard deviation

Table 3: Mean and standard deviation of drivers' cognitive function parameters and temperature indicators inside the car cabin in the morning and evening (n=30)

Parameter (morning)	Mean±SD	Parameter (evening)	Mean±SD	*P*
Speed of performance	80.3±22.7	Speed of performance	77.8±23.5	0.071
Precision (%)	−75±98.9	Precision (%)	−90.8±107.3	0.036
Attention	18.6±34	Attention	12.9±38.3	0.082
Number of errors	121.1±22.8	Number of errors	123.3±23.5	0.203
Voluntary concentration skills	27±6.8	Voluntary concentration skills	26.5±6.5	0.528
Involuntary concentration skills	12.7±3.8	Involuntary concentration skills	13.4±3.4	0.295
Mental fatigue	9.7±5.7	Mental fatigue	9.8±6.7	0.827
Short-term auditory memory	8±1.9	Short-term auditory memory	7.7±1.8	0.272
Dry-bulb temperature (C)	23.2±4.8	Dry temperature (C)	22.1±3	0.268
Relative humidity (%)	22.3±8.1	Relative humidity (%)	21.3±11.5	0.646
PMV	0.1±0.33	PMV	0.1±0.3	0.793
PPD	6±1.5	PPD	5.6±1.4	0.206

SD: Standard deviation, PMV: Predicted mean vote, PPD: Predicted percentage of dissatisfied

in 93.3% of the vehicles was healthy and broken in 6.7% of the vehicles. More information on the mean and standard deviation of the thermal comfort, temperature, and relative humidity parameters in the morning and evening, as well as the comparison of the mean of the above parameters between the two times, is presented in Table 3.

Table 3 presents the mean and standard deviation of drivers' cognitive performance, including speed of performance, precision, attention, number of errors, voluntary concentration skills, involuntary concentration skills, mental fatigue, and short-term auditory memory in the morning and evening shifts plus comparison of drivers' cognitive function differences between the morning and evening shifts ($P < 0.05$).

The present study showed that 36.7% of the subjects had no problem with mental fatigue in the morning, 60% had minor problems, and 3.3% had relatively minor problems. Also, in the evening, 43.3% of the subjects had no problems, 53.3% had minor problems, and 3.3% of had relatively minor problems.

The mean voluntary concentration skills in the morning and evening shifts were 27 and 26.53, respectively, of which 46.66% and 50% had higher skills, respectively, while 52.33% and 50% had lower skills, respectively. The mean values of involuntary concentration skills in the morning and evening shifts were 12.73 and 13.4, respectively, of which 56.66% and 36.66% had higher skills, while 43.33% and 63.33% had lower skills, respectively.

No significant difference was found between the mean number of errors, speed of performance, attention, voluntary and involuntary concentration skills, mental fatigue, and short-term auditory memory in the morning and evening ($P > 0.05$), but a significant difference was observed between the mean precision of drivers in the morning and evening ($P < 0.05$). Note that the negative mean of the precision data is due to a higher number of errors than the number of correct answers, with the number of errors being calculated by counting the number of incorrect patterns and incorrect patterns. The number is also reported as a percentage.

The results showed that there was a significant relationship between the cognitive performance parameters of the number of errors, speed of work, accuracy, attention, and mental fatigue and the parameter of age ($P < 0.05$) and that there was no significant relationship between age and other parameters of mental performance ($P > 0.05$). There was no significant relationship between work experience and all mental performance parameters ($P > 0.05$). To investigate the relationship between the level of education and the parameters of mental performance, first the level of education was divided into two groups: above the diploma and below the diploma; then two tests of Mann–Whitney and an independent *t*-test were used to investigate this relationship. The results showed that there was no significant relationship between educational level and mental performance parameters ($P > 0.05$). More details on the relationship between the age, work experience, and education level parameters with mental performance parameters are shown in Table 4.

Discussion

The objective of this study was to investigate temperature indicators, thermal comfort, and mental function parameters among taxi drivers in winter. It should be mentioned that both temperature indicators and thermal comfort indices measured in the morning and evening shifts were not significantly different from each other. In other words, the changes in dry temperature and relative humidity during the measurement times were not significant in both times, which ultimately caused the thermal comfort of people to be almost the same in both times. The results of the present study show that more than 90% of drivers perceive thermal comfort at a mean temperature of 22%–23% and a mean relative humidity of 21%–22%. The results of this study are consistent with the results of the study by Shin *et al.*, which showed that most drivers perceived thermal comfort at 16.5%–30% in the vehicle cabin. The measured temperature of the present study is within the range of the thermal comfort temperature declared by the mentioned study.[15]

Table 4: Investigating the relationship between age, work experience, and educational level with mental performance parameters (*n*=30)

Parameter	Age		Work experience		Education level	
	r	*P*	*r*	*P*	MD	*P*
Speed of performance	−0.368	0.046	−0.266	0.155	−6.6	0.435
Precision (%)	−0.367	0.046	−0.259	0.167	-	0.869
Attention	−0.406	0.026	0.278	0.137	−11.26	0.379
Number of errors	0.430	0.018	0.284	0.128	8.3	0.329
Voluntary concentration skills	0.271	0.148	0.158	0.404	2.5	0.314
Involuntary concentration skills	0.04	0.832	−0.298	0.110	0.4	0.743
Mental fatigue	−0.373	0.042	−0.339	0.067	−1.6	0.452
Short-term auditory memory	−0.194	0.303	0.233	0.216	-	0.457

MD: Mean difference, *r*: Correlation coefficients

The results of measuring the mental fatigue of drivers showed that more than 50% of the drivers had different degrees of mental fatigue. The results of this study are consistent with the study of Lopez *et al.*, which showed that professional drivers suffer from mental fatigue more than other workers in the study, which reduces the accuracy of their performance.[14] Both studies show degrees of mental fatigue in drivers, which needs to be investigated in future studies to investigate the causes of this level of mental fatigue in drivers. Voluntary and involuntary concentration skills as well as short-term auditory memory of drivers, were moderate, such that on average, drivers were able to obtain half of the maximum score of the relevant tests. According to the test results related to the parameters of precision, attention, speed of performance and number of errors, drivers had no desired level, which requires investigating the relevant causes. All measured parameters except precision in the morning and evening shifts were not significantly different. The decrease in the accuracy of drivers on the evening shift compared to the morning shift can be due to the increase in the fatigue of the drivers on the evening shift, which has decreased the accuracy of the drivers due to the increase in fatigue of the drivers. Many studies have been conducted to understand the behavior as well as the functional and cognitive capacity of drivers to improve driving and road safety.[28] The results of the present study were different from the findings of Pietraszewski *et al.* on perceptual processes of football referees in terms of line speed, number of errors, precision, and attention, which could be due to age differences in the two studies as well as differences in the sites. Specifically, the mean age in the study was 32.7 years, and mean age in the present study was 52.73 years. The site of the present study was real, but that study had been performed *in vitro*.[23] Studies have shown that aging affects cognitive function.[11]

The fatigue of the person during the work shift affects the parameters of mental performance.[29] Therefore, in order to eliminate the confounding effect of this parameter on the parameters of mental performance, the relationship between age, work experience, and education with the parameters of mental performance was studied only in the morning shift.

The results showed that age is a factor affecting the parameters of accuracy, speed of work, attention, number of errors, and mental fatigue. In other words, accuracy, speed of work, and attention of drivers decrease with age and the number of errors increases. The results of this study are consistent with a study conducted by Muzammil, which showed that there is a significant difference between the reaction time of old and young people when driving, and that age was introduced as an effective factor in cognitive function. The results also showed that mental fatigue is inversely related to age and decreases as drivers age.[30] The results of the present study and the aforementioned study show that increasing age causes deterioration of cognitive function parameters investigated in both studies. According to the results of other studies, mental fatigue depends on other parameters such as stress, workload, weather conditions, physiological disorders, and so on. Therefore, to investigate the difference between the results of this study and other studies, it is necessary to investigate other parameters in future studies. The results of the present study show that there is no significant difference between the level of education (below diploma and above diploma) and the mental performance parameters of drivers. In other words, the level of education does not affect the mental performance of drivers.

The results of the study by Chen *et al*. show that the effect of education on cognitive functions in old age is indirect and intuitive. And due to the influence of education on the structure of the brain, older people with higher education are more efficient than their peers with lower education.[31] The results of both studies show that an increase in the level of education does not directly increase the cognitive performance of people. It is also stated in the mentioned study that the effect of the level of education is indirect, so that older people with a higher level of education than their peers have better cognitive performance. In order to draw a more accurate conclusion, this issue needs further investigation with a larger study population. The present study has shown that there is no significant relationship between any of the measured parameters of mental function and work experience. In other words, work experience as a cab driver does not affect the mental performance of drivers. A study by Min *et al*. showed that the relationship between work experience and cognitive performance is not direct and there is a curvilinear relationship between the two parameters.[9] The results of both studies overlap to some extent, showing that there is no direct relationship between work experience and cognitive performance. It is suggested to study this issue in a larger population of drivers.

The limitations of this study included the lack of cooperation of some drivers to participate in the study and the existence of many factors that would affect cognitive performance; indeed, disregarding all these factors has been one of the limitations of this study. It is suggested that other parameters such as sound intensity and illuminance be measured in future studies and this study be repeated among female service drivers. It is also recommended to measure stress and fatigue during the shift and their relationship with other parameters to be measured.

Conclusion

It was concluded that more than 90% of drivers feel comfortable when the average dry bulb temperature of 22°C –23°C can be used to adjust the optimal temperature of the cabin vehicle in winter. The cognitive performance of the drivers was not in a favorable condition, which requires further study to investigate the causes of this issue.

Age is an effective factor in the cognitive performance of drivers, and with the increase in the age of drivers, some parameters of the cognitive performance of drivers decrease, and the results can be used in the planning and employment of human resources.

Due to the fact that the parameters of mental performance have an influence on the occurrence of accidents and changes in these parameters increase the number of driving accidents, it is necessary to plan an improvement of the situation and conduct further studies to identify and control effective factors.

Acknowledgments

Hereby, the authors appreciate all the drivers who participated in this study. This study is part of the MSc. dissertation No. 399934 and the code of ethics IR.MUI.RESEARCH.REC.1399.715.

This work was supported by the Isfahan University of Medical Sciences under grant (number 399934).

Financial support and sponsorship

The financial support of the vice chancellery for research of Isfahan University of Medical Sciences are greatly acknowledged (Grant No: 399934).

Conflicts of interest

There are no conflicts of interest.

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