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Assessing the Effect of Lack of Sleep on Driver's Performance: A Simulator Study

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HIGHLIGHTS

- Current research assesses the effect of fatigue on drivers' performance.
- The results show that the level of alertness has decreased in fatigued driving.
- Male participants have showed better response time when compared to female participants.
- Young participants are more affected by fatigue driving than older people.

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ABSTRACT

Science evidence suggests that fatigue due to lack of sleep is a major cause of most traffic accidents. Fatigue can arise when people do not get enough sleep, which is at least 7 hours, and this deprivation can impair body performance physically and mentally while driving. This study investigated the effect of sleep deprivation fatigue on driving performance. Experiments were performed for two types of tasks, Fatigue driving tasks (sleep deprivation) and non-Fatigue driving tasks (without sleep deprivation) on a driving simulator at the University of Technology, in which 42 participants; aged (19-55) took part with an average age (mean = 33.14, SD = 10.26). Driver performance was assessed using descriptive methods to verify response time and subjective behavior methods using the Stanford Drowsiness Scale. The results showed a gradual increase in the average response time of the fatigued drivers compared to the non-fatigue drivers. The results of the response time indicated that all groups were affected by the test conditions, through the variation in the average response time between the two tasks. In a related context, the results of the Stanford Drowsiness Scale show a significant increase in the average degree of drowsiness for fatigue drivers, as it was greater than for non-Fatigue drivers.

1. Introduction

Driving is a daily activity practiced by drivers around the world[1– 3]. But driving, in general, requires important motor and cognitive skills, including the ability to visual space, memory, information processing, and rapid reaction, all of which involve mental stimuli. The different meanings of terms such as alertness, fatigue, excitement, and activation can lead to some confusion when it comes to understanding these phenomena [4].

The literature sheds light on two broad concepts of wakefulness: first, the physiology of wakefulness and alertness, and second, information processing and sustained attention [5]. For a long time, a lack of alertness and fatigue were thought to be possible causes of car crashes.

While there is a great deal of literature on the issue of alertness and its consequences for transportation activities, driver fatigue and drowsiness driving have received increased attention recently [6]. Chronic, drug abuse [7– 9]. Driver fatigue is known to occur when driving requires sustained focus for an extended time [10] and has a direct effect on the driver's physiology while driving.

Although the exact contributions of these factors to auto accidents have not yet been determined through research, there is a growing consensus among researchers that they pose significant road safety risks. Driver fatigue causes the results to deteriorate, which poses a significant safety risk. As a result, finding signs of burnout is important for enhancing driver safety on the roads. Moreover, having a good view of the limits of exhaustion will help determine when drivers should be told to take a break [11].

In order to know the effect of fatigue caused by sleep deprivation on the cognitive behavior of the driver, and since the reaction time is sensitive to sleep loss and the resulting fatigue, chose this study to determine the consequences of sleep deprivation and compare them with adequate sleep status, and also the sleepiness scale was used the Stanford Sleepiness Scale (SSS) to assess drivers' sleepiness in three states of arrival, after training driving, and after main driving.

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2. Literature review

Several studies have shown a close association between the duration of driving and the development of fatigue through the use of objective and subjective methods to describe the development of body fatigue. Among the many cognitive and perceptual tests, the reaction time test is a simple and visual test for safe driving purposes on the road.

As it has been proven [10] through a study that response time is closely related to road accidents. Where [12] tested 25 participants in a driving simulator, the results showed an increase in the cognitive time of the participants, as the increase was estimated at 3.6 milliseconds per hour of driving in fatigued driving tasks. [13], [14] Every hour of waking up those drivers spend leads to a decrease in alertness and an increase in drivers' response time, the increase was estimated at 0.78% for cumbersome driving tasks.

And [15], after testing 30 participants, showed a clear increase in cognitive time for drivers in tiring driving tasks compared to non-fatigue, as the increase was estimated at 0.31 milliseconds. In addition, [11] tested 30 participants in a driving simulator in fatigued driving tasks and alert driving tasks, the results showed a clear and tangible increase in the response time, as the increase was estimated (0.5) milliseconds. [16] also tested 22 participants with a driving simulator with multiple driving tasks, including fatigued and non-fatigue driving tasks.

The results revealed a higher reaction time for fatigued driving tasks compared to non-fatigue driving tasks. Also, [12] tested 10 male participants in three different tracks for fatigued driving tasks. The results concluded that there is an increase in drivers' response time. As for cognitive tests, researchers indicated that the degree of sleepiness was affected during the period of driving, as Stanford Sleepiness Scale (SSS) was approved to assess drivers' sleepiness. Where [15], [17] tested 30 of the participants with a driving simulator, where the deviation in the degrees of sleepiness of the participants increased than it was before the examination, but in the tasks of non-fatigued, the increase was slight. [18] Measured the change in participants' feelings of sleepiness using a driving simulator for 22 participants for fatigue driving tasks and concluded that sleepiness was high in strenuous driving tasks. Several studies in Iraq dealt with traffic issues and traffic transportation problems, such as[19]–[21]. However, they did not address the study of drivers' behavior using a driving simulator, as this study is the first of its kind in this field.

3. Materials and Methods

3.1 Participants

The total number of participants (42) participated in the task of testing the effect of fatigue on the behavior of drivers. Their ages ranged between (19-55) years and their average ages (average = 33.14, SD = 10.26). The test sample consisted of (29) males (69%) and (13) females (31%), and the groups were represented in different proportions, where the category (19-29) was represented by (40.48%) and the group (30-39) was represented by (30.95%), and the (40-49) group is represented by (21.43%), and the 50-55 category is represented by (7.14%). The mean years of experience of the participants were (mean = 9.83 years, SD = 8.44) and accident rate (mean = 1.45, SD = 1.38. As shown in Figure (1).

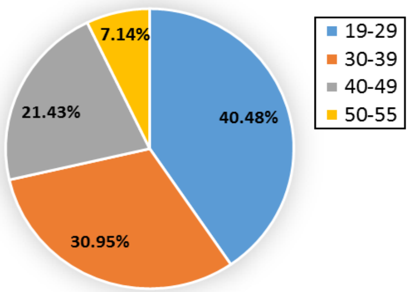

Figure 1: Participants by age categories

3.2 Apparatus

3.2.1 Equipment

A static driving simulator manufactured and assembled by a researcher at the University of Technology was used to measure the effect of fatigue on drivers' behavior. The structure of the device is made of iron, as it consists of a mobile base, a vertical armrest, and three-screen stands. This device consists of three screens installed on-screen stands. It also contains a steering wheel, pedals, and a gearbox, which supports normal and automatic driving from the Logitech g920 company. These devices are installed with a cockpit made of steel. The device is also equipped with a folding cockpit that sits on a movable base and the cockpit is characterized by its variable dimensions and can be scaled and enlarged where the dimension is placed. Depending on the size of the participant, it gives great freedom of use. The device also contains an advanced display device called TripleHead2Go, which is used to distribute the image to the three screens while giving a realistic character to driving, as the right screen mimics the right side of the car, the left screen is stitched to the left side of the car and the front (middle) screen is stitched to the front of the car. This device also provides a distinctive sound system that provides engine sound and surrounding noise to the participants to make driving more realistic. The validity of this device has also been verified before it is used for testing purposes. As shown in Figure (2).

Figure 2: Driving simulator device

3.2.2 Driving Scenario

In this study, the city car driving program was used; the home version is a Russian program that was designed in 2007. This program contains several maps. In this study, a test environment consisting of a 20 km highway consisting of straight lines with few horizontal curves was used. The road consists of three 3.5-meter-wide lanes with road shoulders and the test lane includes typical objects such as traffic lights and road signs. The surrounding areas also contain large billboards and maintenance centers that give a realistic sense of driving. The following figure (3) is a picture taken of the test track.

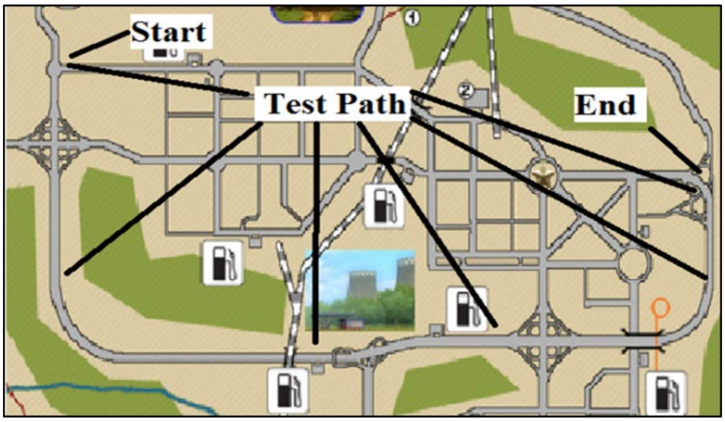

Figure 3: Test path (20 km) (simulator program screenshot)

3.2.3 Measured variables

In this study, two methods were used to distinguish fatigue, subjective and objective methods;

3.2.3.1 Stanford Sleepiness Scale (SSS)

Liker's seven-point scale is used to assess the extent of a person's sleepiness in a variety of areas. This scale consists of seven levels ranging from (1 active and in a state of high alert to 7 in a state of extreme sleepiness) [20] see Table 1. The question (What level of sleepiness do you feel) was asked where the participants rated their degree of sleepiness three times when Arrival, after the training drive (pre-test), and after the main drive (post-test).

Table 1: Stanford Sleepiness Scale [22]

Scale	Description
1	Feeling active, vital, alert, or wide awake
2	Functioning at high levels, but not at peak; able to concentrate
3	Relaxed, awake but not fully alert; responsive
4	Little foggy
5	Foggy, beginning to lose track, having difficulty staying awake
6	Sleepy, woozy, fighting sleep; prefer to lie down
7	Cannot stay awake, sleep onset appears imminent

3.2.3.2 Response time

It is defined as the period of time from raising the foot from the gasoline pedal to placing it on the brake pedal. This method is one of the objective methods used to measure the deterioration in drivers 'response over the length of the driving period. Studies indicate [12], [22] that response time is very important for safe driving, and thus the simplified reaction test was used to assess drivers' attention. In this study, response time was used to assess drivers' attention in both tasks. The participants' response time was measured over the length of the test, which was 90 minutes, and over six periods (every 15 minutes). The mechanism used for the measurement was to rely on a voice command issued by the researcher every 15 minutes in this voice command asking the participant through the word (stop) at this moment, the researcher operates the watch in order to measure the time required for the driver to react to the issued command by raising his foot from the gas pedal to the brake pedal.

3.2.4 Experimental Design and Procedure

In order to study the effect of fatigue on the participants' behavior, two driving tasks were assigned, one fatigue and the other non-fatigue. The whole experience lasted about 120 minutes, including 90 minutes, main driving, 30 minutes driving simulator. The test procedure was as follows

1. Participants in fatigue driving tasks were asked to sleep for four hours on the night of the test, while being prevented from consuming caffeine-containing substances such as coffee and tea, and forbidden from consuming energy drinks, as well as a softener from taking a nap during the day.
2. In non-fatigue driving tasks, participants were asked to sleep for eight hours on the night of the test, while not drinking caffeinated beverages such as tea and coffee, as well as energy drinks, and not drinking alcoholic beverages, as well as a softener from taking a nap during the day.
3. Participants arrived at 12:30 pm. Participants filled out a Stanford Sleepiness Scale questionnaire (SSS) to assess their degree of sleepiness
4. The leading participants on the training driving simulator for half an hour, where the participants introduced him to the parts of the device and the mechanism of using the controls with some instructions.
5. Participants completed a Stanford Sleepiness Scale questionnaire (SSS) to again assess their sleepiness in front of the main driving.
6. The participants were instructed to stop when they heard the word stop, as the researcher issued the sound, and with it a meter was opened to measure the response time required to move the foot from the accelerator to the brake. Pedal, where the sound was emitted every quarter of an hour for an hour and a half.
7. After driving on the simulator, and after completing the main driving task, the participants were asked to fill out a questionnaire (SSS) for the third time after the main tests shown in Figure (4).

Figure 4: Participant during the test

4. Results

4.1 Stanford Sleepiness Scale results (SSS)

The results showed a decrease in the level of drivers 'alertness in the tiresome driving tasks, compared to the non-fatigue driving tasks, where the results were

1. In the non-fatigued driving tasks, the average answers for the three cases (arrival, pre-test, post-test) were close, with a slight increase in the average of their answers, as it was (average = 1 for the arrival status, average = 1.21 for the pre-test condition, and average = 2.38 for Post-test the case).
2. In the Fatigue driving tasks, the average of the answers for the three cases (arrival, pre-test, post-test) was higher than the average for the non-fatigue driving tasks, as the average = 2.04 for the arrival status, the average = 3 for the pre-test condition, and the average = 6.07 for the post-test case). By comparing the results, it is clear that the level of alertness has changed dramatically for Fatigue driving compared to non-fatigue driving, and these results are consistent with the results of the researchers' findings [15], [18], [23]. As shown in Figure (5).

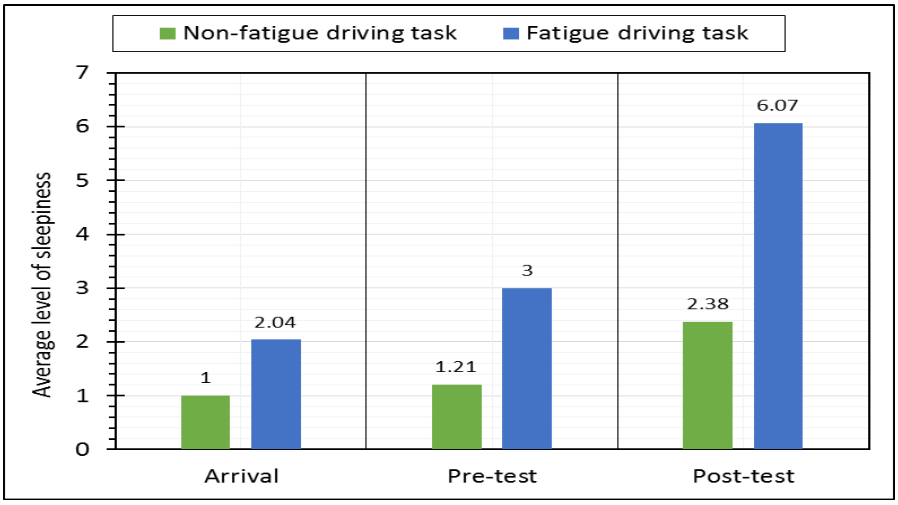

Figure 5: Change in mean Stanford sleepiness scale score for all participants and both tasks

4.2 Response time results

4.2.1 For all participants

The results in this study showed differences in average response time between fatigued and non-fatigue driving tasks. Where the results showed the approximation of the average response time, with some differences recorded for every 15 minutes. As for the tiresome driving tasks, the results showed a clear and tangible increase in the average response time than it was in the non-fatigue driving task, where the increase in response time increased gradually, with the highest average response time being recorded in the last quarter of an hour, where the average response time was 1.23 seconds. The results in this study are in agreement with the findings of the studies[11], [15], [24], where the reason for this increase is attributed to mental fatigue resulting from driving conditions represented by lack of sleep and examination time, which represents the second peak of sleep fatigue, as shown in Figure (6).

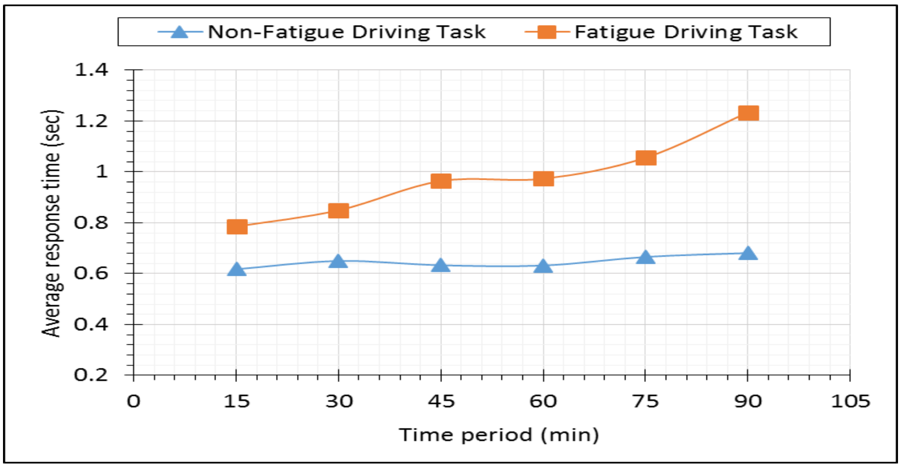

Figure 6: Change in the average response time for all participants

4.2.2 By gender (29 males, 13 female)

The results of this study showed that when comparing the average cognitive time for fatigued and non-Fatigue driving tasks, there was a clear change in the response time for the participants. The results showed that the non-fatigued driving gels showed that males had a faster response than females. In the Fatigue driving tasks, the results showed that females were more affected than males in the task, as they scored the highest average response time than males. The results in this study are in agreement with the findings of the studies [11][25], where he indicated that males are more affected by the Fatigue driving task. As shown in Figure (7).

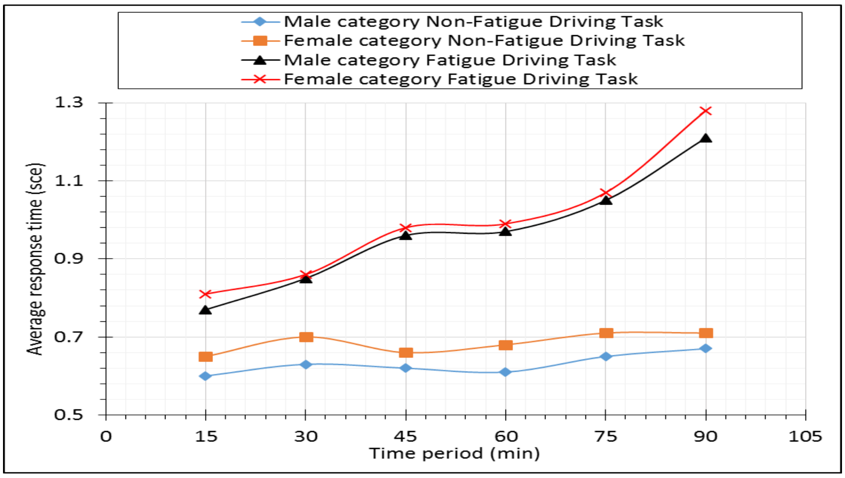

Figure 7: Change in the average response time for gender

4.2.3 Age groups

The results reported clear differences when comparing the age groups with each other, as the results showed that the average cognitive time for fatigue driving tasks was higher than it was in the non-fatigue driving task, and the results indicated that the groups most affected by the task of fatigued driving are the groups (19-29) (30-39) and to a lesser degree (40-49). As for the elderly group, it was affected, but to a lesser degree. The results in this study are in agreement with the findings of the studies[26], [27], where it showed that the reason behind this effect is the noisy lifestyle of youth and adolescents compared to the elderly and that these conditions generate severe weakness in the performance of driving as shown in Figure (8).

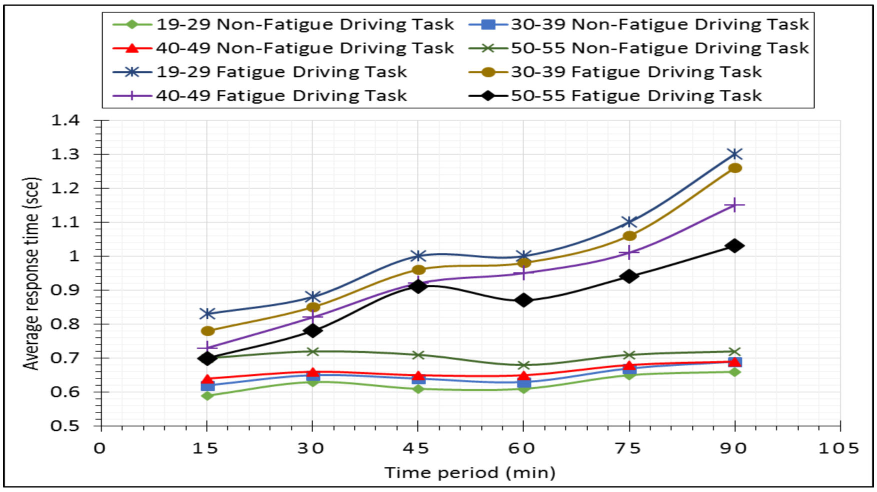

Figure 8: Change in the average response time for Age groups

5. Conclusions

1. A gradual change in the degree of participants' drowsiness in the non-fatigue driving tasks for the three cases (arrival, preliminary and post-test) with slight differences compared to the Fatigue driving tasks for the same three cases (arrival, pre-test, and post-test) where the difference in the average responses of the participants was higher than what was on him in the case of untiring driving.
2. Increased average response time for strenuous driving tasks compared to non-fatigue driving tasks, as the increase was gradual in tiring driving tasks. As for the fatigue-free driving tasks, the average responses were approximate, with some differences. The reason for this increase in cumbersome driving tasks was the mental fatigue that the participants experienced.
3. The results showed a clear and significant increase in the response time for cumbersome and non-fatigued driving tasks when comparing males and females. The results showed that females were affected more than males with the highest mean cognition time.
4. The results showed that the young age groups are affected by the Fatigue driving conditions represented by sleep deprivation and examination time. The reason is that the lifestyle of youth and adolescents is noisier than the elderly group.

6. Future work

1. As for future work, it is possible to add the development of the driving mission by conducting an examination after midnight and knowing the effect of the first prime time on behavior.
2. Some algorithms used to detect drowsiness could be developed.
3. Medical devices can be used to detect fatigue, as this is done through devices used to measure the waves emitted from the brain, which are Alpha, Beta, and Kamas, which can be used to detect fatigue.
4. The fatigue driving task can also be developed by giving a nap to the participants after the main driving task, and after the nap, the test can be repeated to see the effect of the nap on the driver's performance, as it is believed to improve drivers 'performance.

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Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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