The influence of music tempo and traffic density on driver performance using galvanic skin response method

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ABSTRACT

The number of traffic accidents in the city of Surabaya during the period 2021 to 2022 tends to increase. Human factors contribute the largest percentage that causes traffic accidents. Some of the causes are impaired driver alertness and stress when driving due to congested road conditions. Listening to music is a distraction while driving because the tempo of the music can affect the driver's cognitive abilities. This research aims to determine the effect of music tempo and traffic density on driver performance. The stress level of the driver's performance will be measured through the result of changes in sweat gland activity using the galvanic skin response method. The data collection process was carried out experimentally using a driving simulator. Data processing was carried out using two-way ANOVA tests. The results show that music tempo and traffic density do not have a significant effect on driver stress levels and driver performance. The results obtained in this test were carried out on 10 respondents and the experiment time was quite short, so the results obtained can still change and the experiment must be repeated using the same method to ensure that the results obtained are valid and reliable.

1. Introduction

The number of traffic accidents in Surabaya City from 2021 to 2022 tends to increase. In 2021 there were 1262 cases, and in 2022 there were 2132 cases (Maulana, et al., 2023). There are several factors that cause traffic accidents, including driver factors (human factors), vehicles used (vehicle factors) and the environment (road conditions and natural conditions). Based on these factors, human factors account for the largest percentage that causes traffic accidents (Halim & Handoyo, 2022). In his book, Campbell (2001) explains that the tempo of music can also affect a person's cognition. One of the second causes of traffic accidents in America is rock music in the vehicle, which causes drivers to step on the gas pedal more deeply. Aggressive music and music with a fast rhythm will depress a person, on the contrary, music with a soft soothing rhythm and slow tempo can have a relaxing effect, releasing positive feelings (Kamagi & Sahar, 2021).

This disruption of the driver's vigilance while driving can ultimately cause great losses, such as human lives and vehicle damage. Fakhri et al (2022) explained that individuals aged between 18-37 years old have higher aggressive driving behavior than those of older ages. Aggressive driving behavior is an act of driving that is influenced by the driver's emotional instability so that it can pose a risk to others and the surroundings (Monica et al, 2023). One of the factors that can lead to aggressive

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driving is drivers who experience stress while driving. One source of stress on the road is excessive traffic density that can cause congestion.

The level of driver alertness can be affected by various distractions, such as visual, audio, thought, and other psychological distractions (Budiawan et al, 2017). The psychological aspects of the driver can be measured using the Galvanic Skin Response (GSR) method. GSR method is a change in the electrical characteristics of human skin caused by the interaction between the event environment and the psychological state of the individual as a result of changes in sweat gland activity (Imamullah et al, 2022). Sweat glands will be active when a person's body is under pressure or stress so that it can be an indicator of stress measurement through skin touch. (Maulana & Widasari, 2023). Sweat gland activity is partly controlled from the sympathetic nervous system. If anxiety occurs, there will be a rapid increase in skin conductance. The more anxious a person is, the higher his body resistance value (Rosdiana et al., 2022).

Therefore, the researcher wishes to determine the effect of music tempo and traffic density on driver performance. The driver's performance level will be measured by changes in sweat gland activity (psychological aspect) using the GSR method. This research also uses the help of a driving simulator to facilitate data collection by paying attention to health and safety aspects. Driving simulator is a device that allows users to experience the real experience of driving a real vehicle in a controlled virtual environment. A complete simulator set consists of steering wheel, gearshift, and pedals. (Yusran, Nirvana, & Parenreng, 2020) With this research, it is hoped that it can reduce the chance of accidents so that it can increase a sense of security and peace when driving.

2. Methods

Subjects dan Objects of Research

The research subjects were Industrial Engineering students from the class of 2020 who have a driver's license A, can drive a manual transmission car, have a height of 156 cm - 182 cm, and do not have a history of hyperhidrosis and heart disease. The object of the study is the stress level and driver performance in normal and heavy traffic conditions while listening to slow and fast tempo music and without listening to music.

Sample and Population

The population in this research are general public who have driving license for car (SIM A). Because there are so many people who match the criteria, so this research use saturated sample technique. After distributing the questionnaires, the number of populations that met the criteria was 10 respondents. The sampling technique uses a saturated sample technique so that the sample used is the entire population (Thoybah, 2020).

Research Instruments

There are seven items that used as research instruments, such as :

1. Driving simulator, a driving simulation tool that respondents will use during the experiment
2. Galvanic skin response, serves to detect the driver's stress level through sweat glands.
3. Arduino Uno, serves to process data from the galvanic skin response tool.
4. Arduino IDE software, serves to process the data from the galvanic skin response tool so that it can be displayed on the monitor.
5. City Car Driving software, is a simulation game used by respondents to drive using a driving simulator.
6. Microsoft Excel software, used to recap and process data on stress levels and number of driver errors.
7. SPSS software, used to process data in statistical tests.

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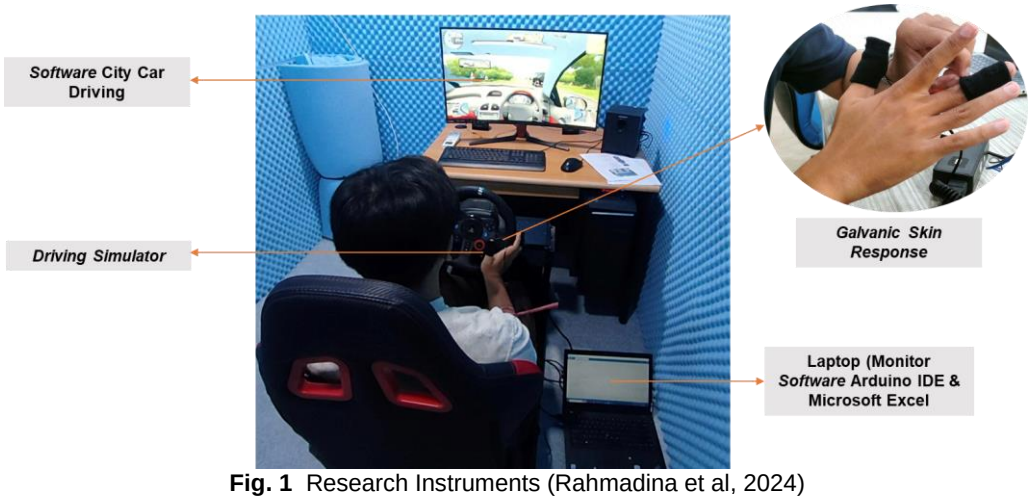

Fig. 1 Research Instruments (Rahmadina et al, 2024)

Research Design

This research was conducted at Laboratorium Sistem Industri & Ergonomi UPN "Veteran" Jawa Timur. This research uses an experimental method that will be carried out on respondents to determine the level of stress and driver performance. Experiments in this study consisted of 4 treatments interspersed with breaks in each treatment. The first thing to do is the introduction stage which aims to allow respondents (drivers) to adapt and get used to the research instrument. This introduction stage was carried out for 10-15 minutes. Treatment 1 was conducted with respondents driving without music interference, treatment 2 was conducted with respondents driving while listening to slow tempo music, and treatment 3 was conducted with respondents driving while listening to fast tempo music. All treatments were conducted for 3 minutes each and under normal traffic and heavy traffic conditions.

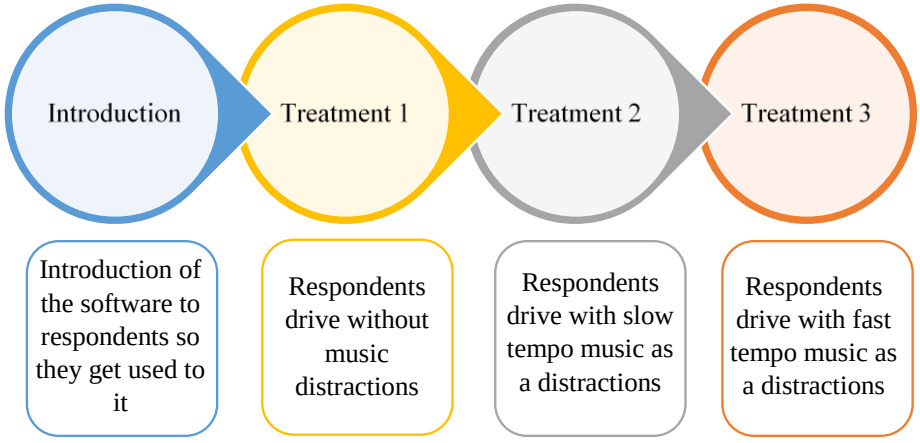

Fig. 2 Research Experiment Design (Rahmadina et al, 2024)

Data Processing Stage

1. The data were processed based on the results of stress levels measured using the galvanic skin response (GSR) tool and the number of errors made by the driver while driving. According to Suryandaru (2021), the classification of stress levels using GSR is as in Table 1.

Table 1 Galvanic Skin Response Stress Level Classification

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Subject Condition	GSR (Bit)
Normal	0-300
Rilex	301-525
Low Stress Level	526-600
Medium Stress Level	601-725
High Stress Level	726-825
Very High Stress Level	826-1023

Source: (Suryandaru, 2021)

2. Statistical tests were conducted with data normality test, data homogeneity test, and two-way ANOVA test. The data used in the statistical test is the result of the driver's stress level using GSR. In this study, the hypothesis structure that will be used is as follows:

H0a : there is no difference in driver stress levels based on the level of traffic density.
H1a : there is a difference in driver stress levels based on the level of traffic density.
H0b : there is no difference in driver stress levels between the treatment condition without music tempo interruption and the treatment condition with music tempo interruption.
H1b : there is a difference in driver stress levels between the treatment condition without music tempo interruption and the treatment condition with music tempo interruption.
H0c : there is no interaction between the factors of traffic density and music tempo distraction on driver stress level.
H1c : there is an interaction between the factors of traffic density and music tempo disturbance on the driver's stress level.

3. Results and Discussion

Galvanic Skin Response Data Recapitulation Results

The results of the galvanic skin response data recapitulation were obtained through recording from the galvanic skin response device used by respondents while driving. There are 6 treatments carried out by respondents when driving using a driving simulator. Each treatment has a duration of 3 minutes. The results of measuring psychological changes in the skin due to sweat gland activity using a galvanic skin response device produce raw data displayed on the arduino IDE software in the form of numbers that come out every 3 seconds. The value that comes out shows the resistance value on the skin. The data is then processed into an average value per each respondent. The following are the results of the galvanic skin response tool data processing:

Tabel 2 Results of Galvanic Skin Response data processing

Respondents	Normal Traffic			Heavy Traffic		
	1	2	3	1	2	3
1	521	494	612	622	621	622
2	493	494	647	586	489	602
3	497	488	506	537	504	575
4	513	446	538	547	525	591
5	571	540	606	569	550	633
6	519	511	592	622	557	650
7	568	481	579	578	562	592
8	558	557	565	567	558	660
9	562	535	590	571	562	580
10	575	554	567	595	567	611
Average	**538**	**510**	**580**	**579**	**550**	**612**

Source : (Rahmadina et al, 2024)
Description : 1 = No Music; 2 = Slow Tempo Music, 3 = Fast Tempo Music

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From Table 2, it can be seen the average recapitulation results of psychological changes in the skin of each respondent. The overall average result of respondents when driving in normal traffic without music is 538, by listening to slow tempo music of 510, and by listening to fast tempo music of 580. While the overall average result of respondents when driving in heavy traffic without music is 579, by listening to slow tempo music is 550, and by listening to fast tempo music is 612**.**

Data Normality Test

After the results of galvanic skin response data processing obtained, then a normality test will be carried out to make sure the data used have a normal distribution. Here are the result of data normality test:

Tabel 3 Tests of Normality

	Kolmogorov-Smirnov			Shapiro Wilk		
GSR	Statistic	df	Sig.	Statistic	df	Sig.
	0,088	60	0,200	0,986	60	0,697

Source : (Rahmadina et al, 2024)

In this study, the number of respondents was 10 people, so the Shapiro-Wilk test was used. Whether the hypothesis is accepted or not can be seen from the amount of significance in the table, H0 will be accepted if the significance value is greater than 0.05 and H0 will be rejected if the significance value is less than 0.05. It can be seen that from the Shapiro-Wilk test, the significance is 0.697 or greater than 0.05. Therefore, H0 is accepted so that the data tested is normally distributed.

Data Homogeneity Test

After the data is normally distributed, data homogeneity test is carried out to find out the data used is homogeneous or not.

Tabel 4 Levene's test of equality of error variances

F	df1	df2	Sig.
0,510	5	54	0,768

Source : (Rahmadina et al, 2024)

The homogeneity test that has been carried out on the SPSS software uses the Levene test, H0 is accepted if the results obtained are greater than the significant level of 0.05 (Ramadhani & Bina, 2021). In the table above, it can be seen that the significance value is 0.768 or greater than 0.05. Therefore, H0 is accepted so that the data tested is homogeneous.

Two Ways Anova Test

Since the data is normally distributed and homogeneous, the Two Ways Anova Test conducted to find the relation between variables.

Tabel 4 Results of two ways ANOVA Galvanic Skin Response test

Variable	df	F	Sig
Traffic density	1	17,672	0,000
Music tempo	2	19,266	0,000
Traffic density* Music tempo	2	0,729	0,487

After the Two Ways ANOVA test, H0 will be accepted if the significance value is more than 0.05. In the table above, it can be seen that the significance value for the respondent's stress level at traffic density is 0.000 so that H0a is rejected or there is a difference in driver stress levels based on the level of traffic density. This can be caused by different driving abilities and experiences among respondents. The significance value of the respondent's stress level in six different treatments or music tempo variables has a value of 0.000 so that H0b is rejected or there is a difference in driver

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stress levels between treatment conditions without music tempo interference and treatment conditions with music tempo interference. The difference in stress levels that occurs can be caused by different levels of concentration and alertness of each respondent. Meanwhile, from the results of the interaction between the two variables, a significance of 0.487 was obtained so that H0c was accepted so that there was no interaction between the factors of traffic density and music tempo distraction on driver stress levels. This means that music tempo and traffic density do not have a significant influence on driver stress levels. It could be several factors that can cause this result, open subchapter 3.6 for further explanation.

Results of Recapitulation of Respondents' Error Types

The overall driver error results can be seen in the following Table 4.

Table 4 Total Number of driver errors in normal traffic

Error Type	Normal Traffic			Total
	1	2	3	
Changing lanes without turning on the turn signal	44	33	58	135
Unstable Vehicle	10	3	9	22
Stopping at *Crosswalks*	5	2	7	14
Running the Red Light	5	0	3	8
Hitting the Roadblock	12	4	4	20
Abutting Another Vehicle	10	2	3	15
Vehicle Exits Lane	15	9	12	36
Wrong Direction	3	0	2	5
Hitting a Pedestrian	2	0	2	4
Having an Accident	6	2	6	14

Source : (Rahmadina et al, 2024)

Description : 1 = No Music; 2 = Slow Tempo Music, 3 = Fast Tempo Music

From Table 4, it can be seen that driver errors in normal traffic conditions from the most frequent to the least in order are, changing lanes without turning on the turn signal (135 errors), vehicle off the road (36 errors), unstable vehicle (22 errors), grazing the road divider (21 errors), grazing other vehicles (17 errors), stopping at the crosswalk (14 errors), having an accident (14 errors), violating the red light (8 errors), wrong direction (4 errors), and hitting pedestrians (3 errors).

Otherwise, here are the result of driver errors in heavy traffic:

Table 5 Total number of driver errors in heavy traffic

Error Type	Heavy Traffic			Total
	1	2	3	
Changing lanes without turning on the turn signal	29	26	33	88
Unstable Vehicle	6	6	9	21
Stopping at *Crosswalks*	4	3	2	9
Running the Red Light	2	3	5	10
Hitting the Roadblock	8	8	10	26
Abutting Another Vehicle	8	8	5	21
Vehicle Exits Lane	8	3	16	27
Wrong Direction	3	1	1	5
Hitting a Pedestrian	0	0	0	0
Having an Accident	2	3	6	11

Source : (Rahmadina et al, 2024)

Description : 1 = No Music; 2 = Slow Tempo Music, 3 = Fast Tempo Music

From Table 5, it can be seen that driver errors in heavy traffic conditions from the most frequent to the least in order, namely, changing lanes without turning on the turn signal (88 errors), the vehicle left the lane (27 errors), grazed the road divider (26 errors), grazed another vehicle (21 errors), the vehicle was unstable (21 errors), had an accident (11 errors), violated the red light (10 errors), stopped at the crosswalk (9 errors), wrong direction (5 errors), and hit a pedestrian (0 errors).

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Psychological Changes In Skin

After we process the data, it can be summarize the driver stress level in normal traffic such as:

Table 6 Average stress level in normal traffic

Treatment Type	Average Stress Level	Stress Level Classification
Without Music	538	Mild Stress
With Slow Tempo Music	510	Rilex
With Fast Tempo Music	580	Mild Stress

Source : (Rahmadina et al, 2024)

From Table 6 it can be seen that the average stress level of drivers in normal traffic without music interference is 538 so that it can be categorized that drivers experience mild stress. The average stress level of drivers in normal traffic with slow tempo music interference is 510 so that the driver can be categorized in a relaxed state. Meanwhile, in normal traffic with fast tempo music interruption, the stress level was 580 or the driver experienced mild stress. Different levels of stress between each respondent can be caused by different driving skills, driving habits (nature skills), concentration levels, and alertness between each driver. The alertness referred to in this study is alertness while driving or alertness to the situation. Situational awareness is a person's ability to predict and understand future events (Rose, Bearman, & Dorrian, 2018). For example, if the vehicle in front of the driver suddenly stops, the driver must predict and understand the event quickly so that the driver can immediately make decisions and take the right actions to avoid accidents.

The tempo of the music also affects the stress level of the drivers while driving. This is in line with the theory described by Campbell (2001), namely slow tempo music can make the listener calm and fast tempo music can make the listener more excited and rushed. In the treatment without music, the average driver experienced mild stress, but when driving with slow tempo music, the average stress level decreased to a relaxed state. It can be said that classical music has an influence in reducing the stress level of drivers while driving. In contrast, when listening to fast tempo music, the average driver experienced mild stress while driving with a higher stress value than when driving without listening to music.

Although statistically, the interaction between music tempo and traffic density did not have a significant effect on driver stress levels, the values obtained from the measurement of psychological changes in the skin (using galvanic skin response) showed that there was a difference in driver stress levels. Drivers who drive in normal traffic have a lower average stress level than drivers who drive while listening to fast tempo music. Meanwhile, when driving while listening to slow tempo music, the resulting stress level values were lower than when driving without listening to music and when driving while listening to fast tempo music. When listening to fast tempo songs, respondents claimed that they became more rushed because of the music they were listening to. Whereas when driving while listening to slow tempo music, respondents claimed that it can make driving calmer and even cause drowsiness.

Otherwise, it can be summarise that the driver stress level in heavy traffic are:

Table 7 Average stress level in heavy traffic

Treatment Type	Average Stress Level	Stress Level Classification
Without Music	579	Mild Stress
With Slow Tempo Music	550	Mild Stress
With Fast Tempo Music	612	Moderate Stress

Source : (Rahmadina et al, 2024)

In Table 7, it can be seen that the average stress level of drivers in heavy traffic without music interruption is 579 so that drivers experience mild stress. The average stress level of drivers in heavy traffic with slow tempo music interference is 550 so that the driver is driving in a state of mild stress. Meanwhile, in heavy traffic with fast tempo music interruption, the stress level was 612 or the driver

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experienced moderate stress. In heavy traffic conditions, drivers experience a greater increase in stress values than when driving in normal traffic. In accordance with the theory put forward by (Saleh et all, 2020) that noise, crowds, and traffic density can be classified as sources of stress due to the environment. In the treatment without music, the average value of driver stress levels tended to be high, but when driving with slow tempo music the average driver stress level decreased.

Driver Error Analysis

From the result of the driver errors, it can be visualize with the pie diagram like the Fig. 3.

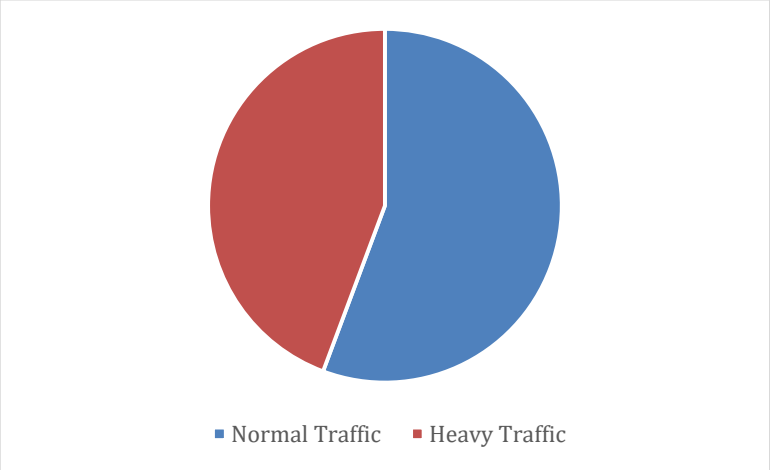

Fig. 3 Error Comparison Chart for Each Traffic Condition
Source : (Rahmadina et al, 2024)

In the Figure 3 above, it can be seen that the total error made by the driver in normal traffic conditions is greater than in heavy traffic conditions. This is because drivers are more careful when the roads are crowded and congested than when the roads are not so crowded and congested. In heavy traffic conditions, the space for driving is very limited and there is often congestion especially at red lights. This excessive traffic density can increase the driver's driving stress, making the driver tired quickly. This fatigue can be avoided by listening to slow tempo music so that the driver becomes calm and can drive peacefully.

Therefore, music tempo and traffic density have a less significant effect on driver performance. For example, when driving without songs, the driver had 6 accidents, driving with slow music tempo had 2 accidents, and driving using fast tempo had 6 accidents, the difference was not too significant. The occurrence of errors made by drivers can be caused by several factors, such as driving ability, driver concentration that is divided due to distraction of songs, and driving habits.

This research was conducted only to determine the relationship between music tempo and traffic density on driver performances using galvanic skin method. Research subject are limited to Industrial Engineering students at UPN “Veteran” Jatim class of 2020, bot men and women, who have driving license (SIM A) and able to drive a manual transmission car, has a height around 156-182 cm (for ergonomic drive using the driving simulator), and not have a history of hyperhidrosis and heart disease. The volume level of music playback in testing is limited to 30-50 decibels (dB).

4. Conclusion

Based on research conducted using the Galvanic Skin Response (GSR) method, it was found that music tempo and traffic density did not have a significant influence on driver stress levels. Different stress levels between each respondent can be caused by different driving skills, driving habits (nature skills), concentration levels, and alertness between each driver. Based on the number of errors made,

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Tempo music and traffic density have a less significant influence on driver performance. For example, when driving without a song the driver had an accident 6 times, driving with slow music tempo had an accident 2 times, and driving using fast tempo had an accident 6 times, the difference that occurred was not too significant. The occurrence of errors made by drivers can be caused by several factors, such as driving ability and driver concentration that is divided due to distraction of songs. Drivers tend to be aggressive when driving under normal traffic conditions. This attitude arises due to the support of fast-tempo music and the less crowded roads that encourage them to act recklessly while driving. Although statistically there is no significant effect between music tempo and traffic density on driver stress levels, the resulting values are in accordance with the theory that slow tempo music has an effect in reducing driver stress levels while driving. In contrast, when listening to fast tempo music, the average driver experienced mild stress while driving with higher stress scores than when driving without listening to music.

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