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Effect of passenger presence towards driving performance level using kss and cnc indicators

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Abstract. Passenger presence does affect car driver performance while driving. However, a different type of conversation between driver and passenger might bring different effects on the performance. This car driver's performance can be measured by the level of sleepiness and the number of accidents experienced by the driver while driving. The level of sleepiness was obtained from the measurement of the driver's alert level using the Karolinska Sleepiness Scale. Furthermore, the number of accidents was obtained from the measurement of the performance level using the Crash-No Crash indicator. This study applied three experiments on a car simulation, i.e., drive alone, drive with a passive passenger, and drive with an active passenger. Results showed that driving alone experienced the highest level of sleepiness than others while driving with active passengers experienced the highest number of accidents than others.

1. Introduction

Distraction can be defined as anything that redirect the driver attention from the normative characteristics to navigate a vehicle. Distraction can also lower the performance and concentration level of the driver. According to [1], fifty-nine percent of accidents are caused by the number of distractions affecting the driver. The distraction usually come from outside the vehicle, such as billboards, collisions, or other incidents that attracts the driver attention [2]. However, distraction can also come from inside the vehicle. Some example of significant in-vehicle distractions are the use of smartphones and the presence of passengers [1]. The passenger presence can lower the performance and the concentration level of a driver, therefore increase the risk of traffic accidents. Driving with passenger increase the risk of vehicle collision by 96% [3].

Distraction caused by a passenger presence can be considered from the behavioural factor (the presence or the absence of passengers), gender, and age. In terms of behavioural factor, teen driver is likely to involve in traffic violation when driving alone, compared to when driving with passengers [3]. This is relevant with the studies conducted by [4], stated that the teen driver is likely to drive at a higher speed and take more risk when driving alone. While being with a male passenger, a male tends to drive at a higher speed with 21,7% higher risk-taking, compared to 5,5% chance while being with a female passenger. On the other hand, a female is likely to drive at a slower speed while being with the same gender with 15,5% driving risk, compared to 12% chance while being with a male passenger. It concludes that a greater risk involved when driving with the same gender of passenger, compared to driving with the opposite [4]. In terms of the age factor, a teen driver behaviour is being observed with the presence of adult passenger. Driving with adults has 67% less chance of being involved in an accident compared to when driving with peers, which has 18% of chance [3].

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According to Oxford dictionary, a passenger is defined as a person who is travelling in a car, bus, train, plane or ship and who is not driving it or working on it. However, a passenger affects the behaviour of the driver indirectly. Driving with peers increases the risk-taking behaviour at a teenage driver, compared to when driving alone. Behaviour and mood of the passenger also affect the driver performance. As passenger actively interacting, while at the same time being in a good mood, the driver tends to speed up more [5].

Prior studies about the effects of passenger distraction toward driver performance have yet suggested the correlation between driver performance and the presence or absence of passenger. Observation about driver state without passenger includes the performance level in an undistracted environment. Meanwhile, the observation about passenger influence includes the implication on the driver performance with the presence of passenger, in which the experiment will be divided into two sections: passive passenger and actively engaged passenger. Passive passenger is limited to passenger who does not interact with the driver during the whole duration of experiment, while the active passenger is defined as someone who is actively engaged on conversation along with the driver during the observation.

This study will observe and analyse the implication of distraction caused by the presence of passenger, and therefore the driver-passenger optimum performance level can be concluded. The data will be collected from Karolinska Sleepiness Scale, which then converted into driver's alertness level. In addition, Crash-Near Crash data will be collected to determine the driver performance level.

2. Method

2.1. Study participants

This research was focused on the driving performance under influence of the presence of passenger. The participants consisted of 10 respondents age of 18-25 years-old. This age range is believed to contribute high number of vehicle collision [6]. The participants joined a simulation in which they can choose which route they will be driving. The condition in which passenger was involved would be adjusted as if it represented the real-life situation.

2.2. Alertness level

Alertness is defined as an ability to recognize unpredictable events. As cognitive neurosciences suggested, alertness is ability to stay intact on situation in a particular period of time [7]. KSS is a tool often used to measure the sleepiness level, in which sleepiness is a parameter to calculate person's alertness level [8]. This study uses 9 points KSS which have been translated to Indonesian, as applied by [9], in order to help the participant to understand the questionnaire better.

Table 1. Karolinska sleepiness scale used in this study

Scale	Description
1	Very alert and awake
2	
3	Alert and awake
4	
5	Not alert, nor sleepy
6	
7	Sleepy but alert
8	
9	Very sleepy and having difficulty to stay awake and alert

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To evaluate the alertness level using KSS, the researcher considered the beginning and the end driving condition. Through the data, a gradient or the rate of change for the corresponding condition was determined.

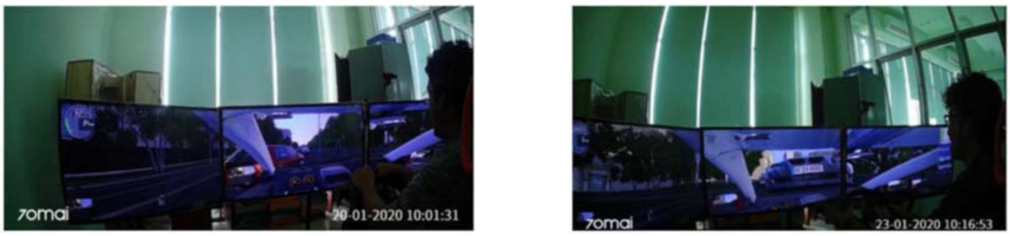
2.3. Performance level
Performance is the result of the process of accomplishing a task or function for a certain goal [10]. According to [10], performance is the amount of effort generated by a person to perform a task. The driver performance was monitored using Crashes and Near Crashes (CNC) experienced by the driver [11]. Crashes is limited to the presence of physical contact with the object during the collision regardless of the vehicle speed, while near crash is similar to crash but with no physical contact. CNC can be used to obtain the performance level by calculating the number of crash and near crash. This performance level was calculated from the overall crash and near crash occur during the whole study duration.

2.4. Experimental design
This research is conducted using simulation and experimental study. According to [12], simulation is specified as the replication or visualization of how system will behave on a certain situation. Thus, it can be assumed that a simulation is a model containing some variable that can demonstrate a real-life situation. [13] stated that an experimental study is deliberately performed by researchers by applying a certain manipulation to the subject on which the implication will correspondingly be observed and measured. Simulation is carried on this research due to the risk when collecting data on the real traffic. The simulation utilizes a software called City Car Driving. This will be applied so that the participant will get the same feeling as driving in the real life.

The study was conducted using counter balance mechanism, whereas the first part of the study was conducted with the driver alone, and the second experiment was conducted using one driver and one passenger. On the second part of the study, passengers were divided into 2 categories: actively engaged passenger, and passive passenger. The experiment involving passive passenger was defined as Study 2A, while the active passenger was defined as 2B.

Timeline of the study was started since the arrival of the participants to the study location. First stage was the preparation, which took 10 minutes. During the preparation stage, the participants were given an inform consent and briefing about the data collection. The next stage was the data collection, which took 60 minutes to complete. In this stage, the participant drove through the driving simulator. CNC data was gathered to evaluate the performance level. CNC data was collected from the record generated by software city car driving, combined with manual data collection. The KSS questionnaire was only given by the researcher at the beginning and at the end of the study.

3. Results and Discussions
Laboratory experiments were run out for several days in the driving simulator. Some crash and near crash incidents were captured by video surveillance, as can be seen in Figure 1.



(a) (b)

Figure 1. Example of crash (a) and near crash (b)

3.1. Alertness level through KSS indicator

The rate of change in KSS values were calculated over the period of time, which then calculated into gradient. Figure 2 shows an example of the KSS alteration along the driving period. This alteration value for each individual was varied. The higher the gradient value, the higher the sleepiness experienced by the driver. The mean was then calculated from the variation of the gradient values gathered in each study. As shown in Figure 3, the mean gradient for Study 1 appeared to be the highest with the value of 1.027, and Study 2B was the lowest with the value of –0.828. It demonstrated that driver will experience the highest sleepiness when driving alone in a period of 1-hour drive, while the driver tended to be more awake when accompanied by a passenger.

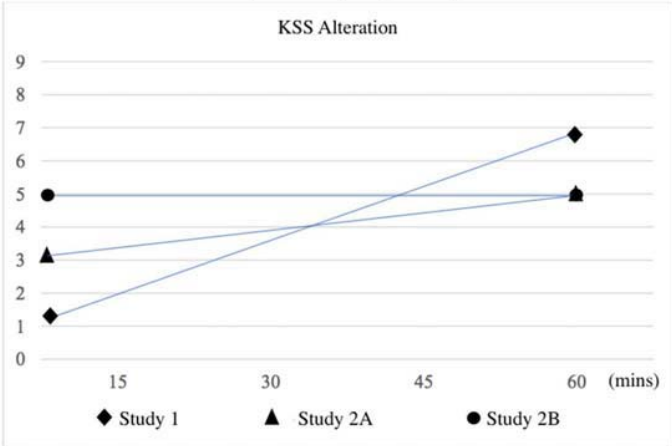


Figure 2. Example of KSS alteration and gradient of one participant

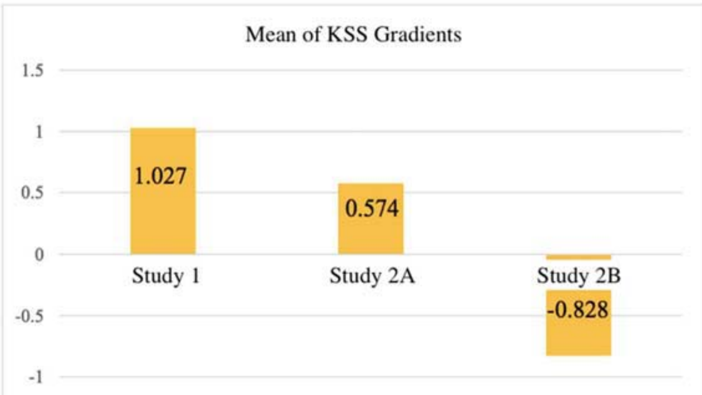


Figure 3. Comparison of mean of KSS gradients for each experiment

The mean gradients were relevant with the paired comparison result. Paired comparison result demonstrates that there was a significant difference between Study 1 and Study 2A, also Study 1 and Study 2B, which generate corresponding p-value of 0.000 ($t = 5.896$, $df = 9$) and 0.034 ($t = 2.494$, $df = 9$) respectively. On the other hand, Study 1 and Study 2A did not have significant difference, which represented by p-value of 0.176 ($t = 1.469$, $df = 9$). The result showed that the driver will experience higher sleepiness when driving alone compared to when accompanied by passenger and experienced far less sleepiness when accompanied by actively engaged passenger.

Paired comparison only showed the impact on the sleepiness level in each study, not the end state of each study. While the mean gradient and the paired comparison demonstrate that the driver on Study 2B was far less sleepy, therefore only Study 1 and Study 2A in which the end sleepiness state were considered. The mean end state of sleepiness level on Study 1 was higher compared Study 2A with the corresponding value of 3.6 and 3, respectively. The result shows that the driver's sleepiness level at the end of study was higher when driving alone, compared to when accompanied by passive passenger.

In this research, the alertness level was determined by considering the driver's sleepiness level. On another point of view, alertness level also can be indicated by the sleep quality, psychophysiology, work fatigue, and monotonous condition of someone [14]. From those few indicators, only the monotonous condition is relevant subject of this study. This was based on the fact that the driving simulation was completed in 60 minutes with free driving condition. That being said, it was possible for the participants to navigate on the same route condition repeatedly during a long period of time. This repeated situation was experienced when the participant is driving alone. Therefore, this further caused the driver to experience the highest sleepiness level compared to when driving with passenger. The implications could be due to the fact that during this study simulation, the driver only had an eye on the road instead of doing anything else for one hour.

This condition also stimulated the KSS value to increase, when comparing the value on the beginning and at the end of the simulation. The increased value of KSS was considered to be significant, as the initial mean of KSS was 4.5, compared to the final mean of 7.1. The overall mean of the specified condition was 5.8. Sleepiness level can be categorized as: alert (KSS 1-5), moderately sleepy ($6 \geq KSS \leq 7$), and very sleepy ($KSS \geq 8$). When referred to the standard valuation of sleepiness level, it was categorized as moderately sleepy.

Meanwhile, the driver with active passenger was not exposed to monotonous condition that can lead to sleepiness during the study. The participant experienced different situation. Driver who was actively engaged in a conversation with the passenger experience the lowest amount of sleepiness [15]. The passenger was considered to cause a distraction towards the driver. During the simulation, the driver did not only pay attention, but also responded to the passenger conversation. Hence, the driver experienced only a small amount of monotonous condition. Furthermore, the presence of active passenger can lower the value of KSS during the simulation. The value decreased significantly, as the mean KSS on the beginning of the simulation was 5.6 and the mean at the end was 3.5. Therefore, the mean KSS of all time was 4.55. When referred to the classification mentioned previously, this can be categorized as alert.

3.2. Performance level through CNC indicator

In this study, the driving performance was estimated from the number of Crash and Near Crash occurred during the simulation [11]. CNC data was collected using dash camera installed in the back of the driver facing the display simulator.

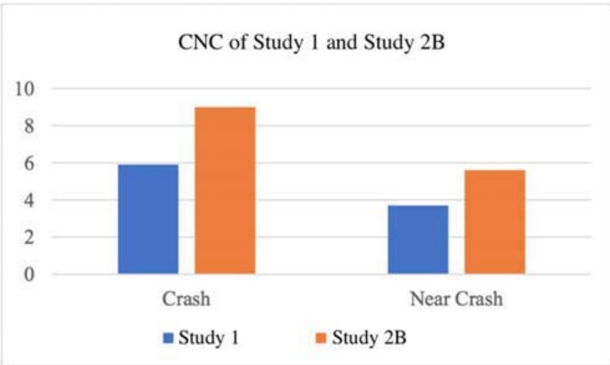


Figure 4. Comparison of crash and near crash incident frequencies between

CNC value of each participant differed in each study, so did the alteration. As an example, participant C experienced four crashes in Study 1, five crashes in Study 2A, and seven crashes in Study 2B. Further paired comparison was made to understand the implication of the presence of passenger in regard to driving performance in each study. Paired comparison showed that there was no significant difference between CNC on Study 1 and Study 2A, as well as Study 2A and Study 2B. The result showed the opposite when comparing Study 1 and Study 2B, where there was significant difference between both studies. Figure 4 graphs the comparison. The corresponding p-value of each Crash and Near Crash was 0.010 (t = -0.328, df = 9) and 0.006 (t = -3.612, df = 9), respectively. This infers that the presence of active passenger can increase the number of crash as well as near crash occurred compared to condition in which the driver is alone and with passive passenger. The result was relevant with [16], which stated that the passenger who is actively interacting with the driver can increase the risk of collision compared to the passive passenger.

When driving alone, the mean value of crash was 5.7, compared to 7.3 when driving with active passenger. Meanwhile the mean value of near crash was 3.7 when driving alone and 5.6 when driving with active passenger. There was 16% increase for crash and 19% increase of near crash when the driver is accompanied with active passenger. This correlated with [17] research which conclude that CNC value will be higher when accompanied with active passenger, compared to driving alone.

The case where the driver was solely present shows to have less crash and near crash. This was due to the fact that the driver will only focus on the road, and therefore minimizing the crash and near crash. In addition to that, the lone driver tends to have risk-averse towards the road situation [18], hence the low probability of crash and near crash. On the other hand, the active passenger showed to have higher crash and near crash number. Factors that contribute are the presence of distraction, lack of focus, and cognitive load. Distraction appeared when the passenger tried to engage in conversation. This distraction led to lack of focus, since the driver frequently diverted the attention away from the road to respond the passenger conversation. Hence, higher crash and near crash occurred. Furthermore, [18] stated that when accompanied with actively engaged passenger, the driver was likely to drive with higher risk-accepting. This implied that the presence of active passenger can arguably increase the probability of crash and near crash.

3.3. Problem solution

Participant was directed a simulation for one hour in free driving mode. To determine one hour of driving time seemed to imply monotonous activity for the driver. The road congestion was set to be 50% on the software to imitate the real traffic situation. Based on the respected condition, the problem solutions were designed to accommodate problem statement and repress the number of crash and near crash.

In order to prevent the sleepiness when driver is alone, some preventive measure can be implemented. First, when the driver is experiencing fatigue that leads to sleepiness, it is better to pull over and take a short break. The short break can be used to perform some light stretching and increase the water intake to lower the sleepiness and fatigue [19]. Second, driver can listen to music to lower the sleepiness using radio or cell phone while driving. Listening to music can induce the feeling of relaxation and arguably increase the attention level. Third, driver can prevent the fatigue by applying some aromatherapy essence in the car, such as peppermint as studied by [20], or ylang-ylang as studied by [21]. Aromatherapy could increase β-wave on the brain to stimulate the alertness. Last, sleepy driver can also take simple, relatively cheap, easy to find countermeasure such as coffee, as concluded by [22].

According to Figure 4, to reduce the risk of vehicle collision, it is best to limit the driver-passenger conversation level. The study showed that the conversation with passenger appears to keep the driver awake but increase the risk of crash. That being said, it is not recommended to have continuous driver-passenger conversation when driving in order to minimize the danger. The conversation should be kept light and not involving any serious matter. The involved conversation can lead to lack of focus on the road. When passenger is able to obey this, the effect of distraction can be minimized. Furthermore, when distraction is kept low, the attention of the driver can be focused on the road solely. Hence, the lower risk of vehicle collision.

This study resulted on the sleepiness level was experienced higher when driving alone, compared to when accompanied by passenger. On the other hand, when passenger was actively engaged in conversation with driver, it reduced the sleepiness but at the same time increase the risk of vehicle collision. Based on the evaluation and problem solution mentioned previously, an optimum condition is examined. The optimum condition is therefore applied to driver with passenger but with minimum amount of interaction and light conversation. In this condition, the driver will be kept alert and promote the lower risk of vehicle collision.

4. Conclusion

The presence of active passenger (Study 2B) could affect the alertness level of the driver indicated by the KSS. The lone driver had higher significance compared to driver with active passenger (t = 5.896, df = 9, p-value = 0.000). Furthermore, driver with passive passenger had higher significance compared to driver with active passenger (t = 2.494, df = 9, p-value = 0.000). It could be concluded that active passenger can lower the driver's sleepiness level.

The presence of active passenger influenced the driving performance as examined from CNC indicator. Driver with active passenger had higher crash significance (t = -0.328, df = 9, p-value = 0.010) and near crash (t = -3.612, df = 9, p-value = 0.006), higher than the value when the driver was alone. There was 16% increase in crash and 19% increase in near crash when the driver was accompanied by active passenger. It could be concluded that the presence of active passenger could lead to higher risk of vehicle collision.

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References

[1] Carney C, Harland KK, McGehee DV 2018 Examining teen driver crashes and the prevalence of distraction: Recent trends, 2007–2015 *Journal of Safety Research* **64** 21–7.
[2] Mahachandra M, Aji TW, Prastawa H, Suryoputro MR 2020 Assessing driver distraction on simulated driving *Int J Adv Sci Technol* **29(3)** 2714-20.
[3] Rosenbloom T, Perlman A 2016 Tendency to commit traffic violations and presence of passengers in the car *Transportation Research Part F: Traffic Psychology and Behaviour* **39** 10–8.
[4] Simons-Morton B, Lerner N, Singer J 2005 The observed effects of teenage passengers on the risky driving behavior of teenage drivers *Accident Analysis & Prevention* **37(6)** 973–82.
[5] Rhodes N, Pivik K, Sutton M Risky driving among young male drivers: The effects of mood and passengers 2015 *Transportation Research Part F: Traffic Psychology and Behaviour* **28** 65–76.
[6] NHTSA Traffic Safety Facts 2009 *National Highway Traffic Safety Administration*.
[7] Oken B, Zajdel D, Kishiyama S, Flegal K, Dehen C, Haas M et al 2006 Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life *Alternative Therapies in Health and Medicine* **12** 40-7
[8] Kaida, K., Takahashi, M., Akerstedt, T., Nakata, A., Otsuka, Y., Haratami, T., & Fukusawa, K 2006 Validation of the karolinska sleepiness scale against performance *Clinical Neurophysiology 117* 1574-1581
[9] Mahachandra, M., Sutalaksana, K., & Suryadi, K 2011 Sleepiness pattern of indonesian professional driver based on subjective scale and eye closure activity *International Journal of Basic & Applied Sciences* **11** 87-96.
[10] Rivai V *Manajemen Sumber Daya Manusia Untuk Perusahaan* 2004 PT. Raja Grafindo Persada.
[11] Dingus TA, Klauer SG, Neale VL, Petersen A, Lee SE, Sudweeks J, et al 2006 The 100-Car Naturalistic Driving Study: Phase II - Results of the 100-Car Field Experiment *PsycEXTRA Dataset 2 American Psychological Association (APA)*
[12] Syaefudin U, Syamsuddin A perencanaan pendidikan pendekatan komprehensif 2005 *PT Remaja Rosdakarya*.
[13] Jaedun A Metodologi Penelitian Eksperimen, Pelatihan, Penulisan Artikel Ilmiah 2011 *LPMP Propinsi Daerah Istimewa Yogyakarta*.

[14] Budiawan W, Prastawa H, Kusumaningsari A, Sari D 2016 Pengaruh monoton, kualitas tidur, psikofisiologi, distraksi, dan kelelahan kerja terhadap tingkat kewaspadaan *J@ti Undip : Jurnal Teknik Industri* **11** 37-44.

[15] Matthews RW, Kontou TG, Naweed A, Sargent C, Roach GD 2018 Driving when distracted and sleepy: The effect of phone and passenger conversations on driving performance *Chronobiology International* **35** 750–3

[16] McEVoy, S., Stevenson, M., & Woodward, M 2007 The contribution of passengers versus mobile phone use to motor vehicle crashes resulting in hospital attendance by the driver. *Accid Anal Prev* **11** 70-76.

[17] Simmons, B., & Ouimet, M 2017 Teen driving risk in the presence of passengers. *Research, practice, policy, and directions* 80-97.

[18] Bingham, R., Simmon - Morton, B., Pradhan, A., Li, K., Almani, F., Falk, E.,Albert, P. 2016 Peer passenger norms and pressure: Experimental effects. *Transportation Research* **41** 124-137

[19] Schmidt, E. A., Schrauf, M., Simon, M., Fritzsche, M., Buchner, A., & Kincses, W. E. 2009 Drivers' misjudgement of vigilance state during prolonged monotonous daytime driving. Accident Analysis & Prevention **41**1087- 1093.

[20] Mahachandra M, Yassierli, Garnaby ED 2015 The effectiveness of in-vehicle peppermint fragrance to maintain car driver's alertness. Procedia Manuf **4** 471-477.

[21] Moss, M., Hevitt, S., & Moss, L 2008 Modulation of cognitive performance and mood by aromas of pepermint and ylang-ylang *International Journal of Neurosciene* **118** 59-77.

[22] Mahachandra M, Munzayanah S, Yassierli 2017 The efficacy of one-time and intermittent intake of coffee as a countermeasure to sleepiness on partially sleep-deprived drivers. *Int J Technol* **8** 300-310