International Journal of Technology 14(5) 1029-1038 (2023)
Received March 2021 / Revised March 2022 / Accepted July 2023

International Journal of Technology

http://ijtech.eng.ui.ac.id

The Effects of Using Electronic Maps While Driving on The Driver Performance

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Abstract. The development of information technology has provided electronic maps (e-maps) via mobile phones that help drivers find the travel destinations, but using mobile phone also can disturb the driver's concentration. The aims of the research is to analyze the effects of using e-maps while driving on driver performance. The respondents were private car drivers, and as many as 325 respondents filled out the questionnaire. The drivers answered the questions about their experience using e-map while driving and particular behavior. As many as 45.54% of drivers involved in undesired circumstances such as changing lanes or slowing down suddenly and 20.00% involved in a near-miss accident. Meanwhile 39.94% of drivers stated to never be involved in any adverse event. The group of drivers who have aberrant behavior was involved in adverse event more often than the group of drivers who obey the rules (t-test, α=0.000). Regression analysis is performed to analyze the correlation between four types of aberrant behavior and the driver violations, there were moderate correlations between the research variables. The use of e-maps do not increase traffic violations when applied by obedient traffic rule drivers, but it does increase when applied aberrant behavior drivers.

Keywords: Aberrant behavior; Driver behavior; Error; Electronic map; Violation

1. Introduction

Using electronic maps (e-maps) via mobile phones helps drivers find travel destinations. These applications often used by drivers for guidance while driving. Using e-maps while driving is a secondary task; all activities that is done while driving-not related to controlling or maneuvering the vehicle and monitoring the traffic are considered as secondary tasks in driving. Secondary tasks can disturb the driver's concentration and cause longer driver reaction times (Kaber *et al.*, 2012). Driving a vehicle is a complex task that requires not only physical skills for controlling the direction and speed of a vehicle, but also mental skills for sustained monitoring of integrated perceptual and cognitive inputs that allow a driver to make time-appropriate decisions. The use of mobile phones while driving interferes concentration and it can cause the driver experience a near miss or even an accident.

Drivers' impaired concentration while driving is caused by external factors unrelated to driving activities. Concentration disorders affect drivers' abilities to make decisions and decrease their performance while driving (Zuraida, Wijayanto, and Iridiastadi, 2022; Prat *et al.*, 2017; Zuraida Iridiastadi, and Sutalaksana, 2017; Misokefalou *et al.*, 2016; Eliou and

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doi: 10.14716/ijtech.v14i5.4778

Misokefalou, 2014; Kaber *et al.*, 2012; Owens, McLaughlin, and Sudweeks, 2011). Included in this task are talking to passengers, smoking, listening to music, and using a mobile phone. The secondary tasks that require visual attention and psychomotor coordination significantly decrease driving performance, but the secondary tasks that only require memory scanning and the use of auditory modality, such as listening to music or the radio, do not decrease driving performance (Rodrick, Bhise, and Jothi, 2013).

Distraction is the process of breaking down the attention to driving activities, which reduces the awareness, readiness, and performance of drivers, making the driver's reaction takes longer time when an event occurs. When distracted, the driver's attention moves from the traffic to objects that interest them such as objects, advertising, or other things. Distraction increases errors in driving and leads to accidents (Young and Salmon, 2012). Distraction can cause cognitive failures that leads to errors on simple tasks that should be easily accomplished. Cognitive abilities can vary between people depends on their habits and skill mastery. Cognitive failure scores are strongly correlated with the error rate in driving, but it is not correlate with accidents experienced by drivers. In a study by Allahyari *et al.* (2008) stepwise regression analysis was performed for scoring factors that have strong correlations with driving errors, and only the factors of lack of concentration and social interaction had strong correlations with driving error rates (Allahyari *et al.*, 2008). Distraction in the form of spatial reasoning tasks, such as the driver's secondary tasks, decrease the driver's performance of the primary task of driving: in research by (Hurts, 2011) demonstrated the spatial reasoning version of the secondary task forced the participants to think about the east–west orientation of familiar cities, data of reduced scores of driving skills were measured with the Lane-Change Task.

Smartphone use makes drivers divide their attention. Smartphones allow drivers to access information unrelated to driving activities, such as entertainment or social media. Included in entertainment activities are listening to or watching content related to music, the radio, and information. Research about mobile phone use while driving has been conducted by several researchers. Mobile phone use decreases driver performance, reaction time, and awareness (Prat *et al.*, 2017; Oviedo-Trespalacios *et al.*, 2017). According to research by (Van-Dam, Kass, and VanWormer, 2020), audible text messages decrease the driver's awareness and increase the speed of the vehicle for 10 seconds after the driver gets a message notification. Mcnabb and Gray (2016) stated that there a decrease in driver performance when using mobile phones as assessed from brake reaction times, which significantly greater for drivers who use smartphones to read information or text-based conditions than for those who -use smartphones to obtain information by viewing images or image-based conditions, or in conditions of not using a mobile phone while driving. Image-based mobile phone use is a safe way to stay connected with information via mobile phones while driving. Lady and Susihono (2019) examined the use of e-maps on smartphones while driving and calculated the increase probability of a traffic accident use the Human Error Assessment and Reduction Technique (HEART); the result of human error probability was 0.0106. According to the drivers' reports, they never experience accidents, but sometimes another driver warns them because they inhibited the traffic.

According to Sucha, Sramkova, and Risser (2014), there are some factors causing aberrant behavior in driving: dangerous violations; dangerous errors; and not paying attention ~~to~~ driving, straying, and loss of orientation. Included in the dangerous violation category is the act of intentionally breaking the rules. Dangerous errors a type of violation that–involves absentminded of the driver. Driver Behavior Questionnaire (DBQ) divides driving offenses based on the level of awareness of the driver making the offense. This questionnaire is already used to survey driving behavior in various countries. Research by

Harrison showed high level of internal consistency for each item scales in the DBQ, and the results support the use of the DBQ as a questionnaire outcome measure in an evaluation study (Harrison, 2009). Researchers from several countries showed that the DBQ had a high level of validity and reliability. The translation of the DBQ is also addressed by Harrison (Harrison, 2009) this questionnaire shows a high level of reliability when translated into Finnish and Dutch.

The use of e-maps in the form of Global Positioning System (GPS) navigation can improve the driver performance (Cochran and Dickerson, 2019), (Dickerson, 2020), but also interferes the driver concentration. Higher interference is experienced when driving in urban areas (Yared and Patterson, 2020), and using small GPS displays also add distraction to drivers. Interference due to the use of GPS navigation can cause eye glances and decrease driving performance (Jensen, Skov, Thiruravichandran, 2020). The impact of using e-maps on driver performance has not been specifically studied. Driving distractions due to the use of mobile phones should be considered for driving safety when using the e-map. The hypothesis in this study is the increase use of e-maps while driving is suspected to disrupt driver concentration as well as the use of mobile phones while driving and resulting in an increase in driving violations. The a of the research is to evaluate the psychological effects of using e-maps while driving on driver, analyzing the effects of using e-maps while driving on driver involvement in adverse event, identify types of aberrant behavior of drivers and analyze the factors that cause drivers to make violations.

2. Methods

This study analyzed the driving conditions experienced by drivers while driving using an e-map. The study also identified drivers' violation habits while driving. Driver involvement in adverse event and habits of violations were obtained from respondent answer based on their experiences.

2.1. Respondents

Respondents of this study were passenger car drivers who lived in several cities in Indonesia. Respondents included men and women with an age range between 18 and 66 years old. All respondents were confirmed to have a driver's license, have more than six months of driving experience, and have used e-maps via mobile phones while driving.

Some questionnaires were given directly to the respondents and for others respondent who lived in different cities from researcher, the questionnaires distributed through google form.

There were 325 respondents who filled out the questionnaire, but 5 questionnaires were not processed further because the respondents had never used an e-map while driving. There were 72.31% male respondents and 27.69% female respondents in the research.

2.2. Research Location

The dissemination of questionnaires was conducted in several cities in Indonesia. The data illustrated driving habits and e-map use in developing countries with heavy traffic, limited pedestrian facilities, and lack of public transport. Many people in Indonesia prefer to use passenger cars for transportation rather than public transport because the availability of mass transportation is still limited and the level of service is still need to be improved. The public transport trips within the cities have not yet been integrated from origin to destination.

2.3. Questionnaire

The questionnaire consists of three parts. The first section contains respondent data covering age, gender, education level, length of driving experience, city of residence, and ownership of a driver's license. The second section contains some questions about the effects of using e-maps on incidents and accidents that the driver has experienced while driving. According to the Health and Safety Executive (HSE, 2004) there are two adverse events in accident investigations, namely incidents and accidents. Two types of incidents are near-miss accident and undesired circumstance. A near-miss is a condition that has the potential to cause injury but which has a short interval of time separating it from being an accident. An undesired circumstance is a set of conditions or circumstances that have the potential to cause injury such as changing lines or slowing down suddenly. An accident is a condition that results in losses for all parties involved in the accident, including the driver, the system, and the company in which the accident occurred.

The third section is questions about driving habits. The questions in this section developed from the Driver Behavior Questionaire (DBQ). The DBQ is a self-report questionnaire developed as a measurement of aberrant driving behaviors (Eliou and Misokefalou, 2014; Sucha Sramkova, and Risser, 2014). The questions in the questionnaire compiled by grouping drivers' aberrant behavior into four types of wrong driving habits: errors, lapses, violations, and aggressive violations. The main distinction between these four types involves were the degree of planned action and conscious decision making. Errors characterized by unplanned actions. Lapses are aberrant behavior regarding failure to pay attention to traffic and recall failure. Violations are aberrant behavior which the driver intentionally and consciously done. DBQ uses a six-point Likert scale (1=never; 2=hardly ever; 3=occasionally; 4=often; 5= frequently; 6=nearly all the time) (Sucha Sramkova, and Risser, 2014; Martinussen *et al.*, 2013). Likert scale with even numbers rather than Likert scale with odd numbers of choices, because the Likert scale with odd number of choices give respondents a choice of neutral answers. Respondents were asked to answer any misconduct statements according to their tendencies.

2.4. Data Processing

The first stage of data processing was to calculate the percentage of each adverse event experienced by respondents. The assessment was carried out on aberrant behavior of respondents and tested the difference between groups of respondents. The respondents were grouped by gender and their experience in adverse event. Male and female have different daily activities tendencies, male often involved more to outdoor activities compared to female. Reaction time recorded by men was significantly faster than women (Jain *et al.*, 2015; Lipps, Galecki, and Ashton-Miller, 2011). High frequency of activity in outdoor affects the speed of a person's movement so it is suspected that this condition also affects the driving agility and the level of involvement of both groups of respondents in undesirable conditions while driving. A person's habits is influenced by the motivation to act safely or unsafely manifested in all of their activities (Hendratmoko, Guritnaningsih, and Tjahjono, 2016). The differences in the involvement of the two groups of drivers in undesirable conditions were statistically tested using two tails of t-test. It was found that there were differences in driving experience in adverse event based on person's behavior. Linear regression was used to see if aberrant behavior had an effect on driver involvement in adverse event.

3. Results and Discussion

Respondents independently reported their experiences of driving. Some respondents claimed to have been involved in adverse event. Regression analysis was used to describe the effects of using e-maps while driving on respondents' involvement in adverse event.

3.1. Effects of Using E-maps while Driving

Aberrant behavior was done by some of drivers who used e-maps while driving. Sometimes the aberrant behavior were caused of the drivers lack of concentration on the traffic. The effects of using e-maps on driver performance were assessed on four types of adverse event: the frequency of driver involvement in a near-miss accident condition, frequency of driver involvement in an undesired circumstances such as changing lines or slowing down suddenly and got horns from other drivers, frequency of driver involvement in an accident, and increased traffic violations. Driver involvement in a near miss condition was quite high, at 20.00% of the respondents have involved in range of frequency from hardly ever until often. Data the effects of using e-maps on driving experiences is shown in Table 1.

Table 1 The effects of using e-maps on driving experiences

No	Adverse event while using e-maps	Percentage of respondents got the adverse event
1	Involved in a near-miss condition	20.00%
2	Involved in an undesired circumstance	45.54%
3	Involved in an accident	3.69%
4	Make violations in driving	32.62%
5	Haven't involved in any adverse event	39.94%

An analysis of driver reports due to e-map use while driving found it had an effect on the increase in traffic accidents. A total of 3.69% of respondents reported being involved in an accident while using an e-map.

An accident is a terrible event that inflicts material harm on the person involved and the system in which the person works. The use of e-maps while driving has a considerable effect on increased driver involvement in near-miss and undesired circumstances and a lower effect on increased accidents.

Although the use of e-maps while driving had a low effect on traffic accidents, it caused more traffic disruptions, as 20% of respondents had involved in near-miss and 45.54% of respondents reported involved in undesired circumstances and getting horns. Some secondary tasks cause drivers to not pay attention to the traffic, such as not giving signal when turning or changing lanes, driving at slower speeds, or reacting more slowly. Not focusing while driving makes drivers involved in undesired circumstances. Traffic violations are intentional and conscious acts by the drivers, 32.62% of respondents felt they had made traffic violations at an increased rate while driving and using e-maps.

Some respondents said they had been involved in one or two adverse event, even some of other respondents said they had experienced in all these adverse events. But on the other hand 39.94% of respondents stated that they had never been involved in any adverse event. When driving using e-map, they never experience incident, accident, and they also have not done traffic violations.

3.2. Driver Behavior

Respondents reported their wrong driving habits through the statements in the DBQ. There are 8 questions in each group of error and lapse, and there are 6 questions in each group of violations and aggressive violations.

Table 2 gives information about the average of respondents' answers about four types of aberrant behavior while driving.

Table 2 Average driver aberrant behavior while driving (in a six-point Likert scale)

Aberrant Behavior	Gender		Adverse event	
	Male	Female	Had involved	Never involved
Error				
Ignoring the speed of other vehicles	2.233	2.333	2.492	1.96
Not using the rearview mirror when switching lane	1.953	1.770	2.075	1.648
Forgetting to signal	1.879	1.690	2.011	1.568
Overtake other car that have given a sign	1.728	1.483	1.893	1.328
Near to brake a car in front	1.684	1.506	1.796	1.392
Not seeing the pedestrian	1.832	1.966	2.048	1.584
Braking too fast	1.913	1.851	2.086	1.632
Near breaking other car when turning	1.905	1.885	2.128	1.56
Average of error	**1.891**	**1.810**	**2.066**	**1.584**
Lapse				
Driving in the wrong gear	1.983	1.954	2.163	1.811
Go into wrong line at intersection	2.082	2.069	2.225	1.820
Forgetting where parking the car	2.466	2.586	2.725	2.198
Making driving mistakes on certain roads	2.155	2.103	2.382	1.847
Forget turning the signs	2.172	2.264	2.376	1.973
Misreading traffic signs	2.306	2.126	2.427	2.027
Forgetting the road that have passed	2.543	2.678	2.837	2.243
Not see something and brake it	1.991	1.943	2.146	1.685
Average of lapse	**2.212**	**2.216**	**2.410**	**1.950**
Violation				
Ignoring the speed limit	2.280	1.552	2.343	1.775
Driving through red lights	2.030	1.759	2.146	1.712
Overtaking other vehicles from the left	2.422	2.276	2.607	2.063
Driving in drunk	1.147	1.034	1.130	1.126
Ignoring the highway speed limit	2.405	1.793	2.376	2.036
Driving near to front car	2.039	1.839	2.213	1.640
Average of violation	**2.054**	**1.709**	**2.136**	**1.725**
Aggressive				
Honking the horns to show dissatisfaction	2.871	2.897	3.107	2.568
Cut into queueing	1.845	1.621	1.972	1.559
Driving on the roadside	2.366	1.989	2.371	2.153
Anger toward other drivers and showing resentment	2.401	2.149	2.461	2.054
Anger toward other drivers and racing them	1.819	1.391	1.876	1.414
Racing after traffic light	1.647	1.494	1.775	1.360
Average of aggresive	**2.158**	**1.923**	**2.260**	**1.851**
Average	**2.075**	**1.927**	**2.218**	**1.778**

The research identified two groups of drivers which based on gender and their experience involved in adverse event while driving using e-maps. Two groups of drivers based on their experience involved in adverse event were the group who had involved in and who had never been involved in any of adverse event. The first group said they had been involved in near-miss condition, undesired circumstance, accident, or made an increase of traffic violations. And the second group had never been involved in any of undesirable conditions.

The error and lapse group were characterized by accidental aberrant behavior. The error includes ignoring the speed of other vehicles when overtaking, not using the rearview mirror when switching lanes, forget to give signal, and braking too fast. Included in the lapse group are driving equipped with the wrong gear, making driving mistakes on certain roads, forget to turn on the turn signal. The violation and aggressive violation group was deliberate actions. The violations such as speeding and crossing red lights and aggressive violation involve aggression towards other road users, for example, sounding the horn to display aggression, to drive on the roadside to avoid traffic jams, and showing resentment.

Male and female groups have the same level of frequency of making errors and lapses when they drive. However, males are significantly more likely to do violations (α=0.00) and aggressive violations (α=0.014) than females. Both violations and aggressive violations are intentional and conscious acts done by the drivers to achieve their specific aims while driving. Some groups of men are impatient with the characteristics of other drivers, want to to drive at high speeds, driving emotionally, and so on.

Driver behavior in both groups of experience in incidents and accidents are compared and found the level of aberrant behavior were higher on the group who had involved in adverse event.

The lapse group was the most aberrant behavior that drivers made when they drove using e-maps. A lapse is a mistake caused by forgetting or not knowing about something; it is an accidental act by the driver in facing traffic conditions.

3.3. Influence of Driving Habits on Driving Irregularities when Using E-maps

Daily driving habits influenced the driver behavior while driving using e-maps. Four groups of aberrant behavior in driving: errors, lapses, violations, and aggressive violations were partially tested their difference between the groups of drivers involved and never involved in adverse events. The t-test output on each type of aberrant behavior as the significance value (α) presented in Table 3.

Table 3 Difference of drivers' habits on groups of drivers had involved in adverse event

Aberrant Behavior	Group of respondents	Mean	Standard deviation	Sig. 2-tailed (α)
Error	Involved in adverse event	2.062	0.606	0.000
	Never involved	1.584	0.478	
Lapse	Involved in adverse event	2.388	0.677	0.000
	Never involved	1.950	0.632	
Violation	Involved in adverse event	2.125	0.644	0.000
	Never involved	1.723	0.646	
Aggressive	Involved in adverse event	2.254	0.752	0.000
	Never involved	1.863	0.730	

The aberrant behavior that drivers show in daily driving and their experience when they drove using e-maps are closely related. Statistical analysis using t-tests was partially conducted between two groups of drivers based on their experience driving using e-map. There was a significant difference in the level of aberrant behavior between groups of drivers who were involved in adverse event and those who never get involved. Significant differences were found in the four types of driving habits (α=0.000 for all of aberrant behavior type: error, lapse, violation, and aggressive violation). The aberrant behavior of group that had been involved in adverse event when using e-maps was higher than those who does not get involved in adverse event.

The involvement of adverse event when using e-maps occurred in groups of drivers who had aberrant behavior, meanwhile there was no involving in adverse event while

driving using e-maps on drivers who had good behavior. Groups with aberrant behavior will do traffic violations easily when using e-map, meanwhile groups that have good behavior will still follow the traffic rules. The driver who use an e-maps while driving will not hampere the traffic because the compliant driver will still run the traffic rule even when using the e-map, so there will not be a traffic violations increasement. The increase in violations only occured by the drivers who have aberrant behavior in daily driving, so it is necessary to improve the aberrant behavior of drivers in driving.

Regression analysis was conducted on the driver involvement in adverse event as dependent variables and the aberrant behavior of errors, false, violations, and aggressive violations as independent variables. The output of the regression analysis was multiple R = 0.48, which explains the relationship between dependent variables involvement in adverse event and independent variables at the moderate level.

The Planned Behavior Theory describes a person's habits influenced by the intention to perform an action. This theory is used as the basis for how a person does aberrant behavior and unsafe actions in driving (Hendratmoko, Guritnaningsih, and Tjahjono, 2016). Intention represents someone's motivation to act safely or unsafely that consciously planned to do. Intentions formed by three variables: attitude, subjective norm, and perceived behavior control. Attitude is defined as the positive or negative beliefs to display a certain behavior; Subjective Norm is a person's perception of the social pressure to perform or not perform the behavior; and Perceived Behavior Control described as the perception of the behavior of ease or difficulty. The intention to perform an action in this case can be seen from the motivation of drivers to act unsafely which indicated by the high frequency of aberrant behavior carried out by them.

Lowering the negative effect of using e-maps on safety in driving could be done in two approaches. The first approach was by focused on the driver. Driving safety is influenced by the intention of each individual to act safe or unsafe. Driving safety could be achieved through individual approaches by improving the basic human values and risk perception of the individual (Sutalaksana, Zakiyah, and Widyanti, 2019). Increased driver discipline in driving and driver knowledge of traffic rules was the first solution. The second approach was carried out to the process of using e-maps in driving, by creating a Standard Operation Procedure (SOP) for using of e-maps. The SOP explains the steps taken by drivers in two stages: the preparation stage for using e-map and the driving stage.

4. Conclusions

Using e-maps while driving decrease the drivers' performance and increase their involvement in adverse event in some drivers. As many as 45.54% respondents said they have involved in undesired circumstance in range of frequency from hardly ever until often. As many as 32.62% of respondents said they have made increasing violations and 20% of respondents have involved in a near-miss condition. On the other hand, as many as 39.94% of respondents stated they had never been involved in any adverse event. Aberrant behavior and the drivers' involvement in adverse event have a medium correlation. Involvement in adverse event experienced by the wrong habit of drivers. Drivers who have never been involved in adverse event when using e-maps have a good traffic habit. The use of e-maps by good habit drivers didn't impede the traffic. In order of using e-map not to interfere with traffic, it is necessary to increase awareness of drivers who have aberrant behavior in driving.

Acknowledgments

Thank you for assistancing in collecting data for assistants of Ergonomics and Work Design Laboratorium in 2020, University of Sultan Ageng Tirtayasa - Indonesia.

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