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Cognitive failure and driving distraction on private car drivers using naturalistic driving study

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ABSTRACT

Driving requires the driver to have physical and cognitive readiness. Cognitive failure can impact driving performance and lead to accidents. This study aims to identify factors that cause cognitive failure, determine the average score of cognitive failure in private car drivers, and identify distractions frequently experienced by drivers during driving. For data collection, the observer rode as a passenger in the respondent's car and identified driving distractions using a checklist. Cognitive failure rates were measured using the Cognitive Failure Questionnaire (CFQ). The distribution of questionnaires to drivers occurred after naturalistic driving. The research found that driver cognitive failure is at a high to moderate level, with distractibility being the dominant factor. The distractions experienced were predominantly internal. The adolescent group experienced more driving distractions than the adult group.

1. Introduction

Increased community mobility aligns with economic growth, driving the growing need for personal transportation. The high number of car owners negatively affects road safety, contributing to the rising number of vehicle accidents. It is crucial to minimize these risks. One key factor in driving is the driver's alertness; the driver must be in good health and maintain concentration. Cognitive failure in the driver can decrease performance while driving. Driving requires both physical and cognitive readiness. Cognitive ability involves the process of acquiring, storing, retrieving, and using knowledge and information. Everyone has different levels of cognitive abilities and failures. The higher a person's cognitive failure rate, the more vulnerable they are to making inappropriate responses or actions, as cognitive failure influences the ability to think and act in various situations [1]. Socio-economic, lifestyle, and cultural factors, along with general driving style and skills, influence driving habits within community groups [2]. Research on interprovincial bus drivers in the Jabodetabek area found that the dominant factors affecting driver concentration were vehicle conditions (31%) and driver health conditions (23%) [3].

Cognitive failure is characterized by a loss of attention, memory, and motor function. Excessive workload can increase the likelihood of cognitive failure. A person may experience cognitive failure if they fail to properly carry out the processes of knowing, understanding, and deciding, leading to errors in thinking and action. Generally, cognitive failure refers to mistakes related to thoughts and actions that could be performed without error under normal circumstances. This should not be considered trivial, as cognitive failure can lead to work accidents and excessive stress [4].

Cognitive failure can occur when a person lacks energy due to information processing or excessive cognitive demands. According to cognitive theory, this is an effort to prevent energy deficiency. Flexible work arrangements, such as the implementation of flexible working hours, can provide employees with more control over their energy use, potentially reducing cognitive failure rates. Research by Hsu, Chen, and

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Shaffer [5] found that flexible work hours can reduce cognitive failure rates.

Research on cognitive disorders in KAI (*Kereta Api Indonesia*) employees found no influence of age or position on the rate of cognitive failure [6]. Based on reaction time measurements, employees generally had slower reaction times compared to the average human reaction time under full concentration (above 0.268 seconds), due to easy disruptions in attention and low concentration. Evaluations of employee and technician performance showed moderate to high levels of cognitive failure among employees [7]. Cognitive failure correlates with the speed at which workers make decisions [8]. Secondary tasks requiring visual attention and psychomotor coordination most affected driver performance, whereas tasks involving memory scanning and auditory functions had less impact on driving performance [9]. Drivers' performance on cognitive and sensorimotor tasks is correlated with their overall driving performance and safety [10].

Research on employee cognition while working from home by [4] found that flexible work arrangements can increase an individual's perception of control over work, leading to a decrease in work-related cognitive failure. However, it was not associated with a decrease in housework-related cognitive failure. Additionally, flexible work arrangements did not improve individuals' perceptions of control over housework, which could reduce cognitive failure both at work and at home [4].

Driving is a task that requires concentration and full attention, especially in monotonous environments. It involves complex cognitive processes used to make decisions and requires emotional maturity to avoid accidents. Drivers must also maintain attention and concentration to detect changes in their environment and potential hazards. Driver distractions, which can include visual, auditory, and cognitive impairments, affect driver alertness and performance, ultimately reducing awareness on the road [11], [12], [13]. Allahyari found that while cognitive failure did not correlate with accidents, it was related to human error in Tehran, Iran [14].

To address the issue of traffic accidents caused by drivers, this study aims to determine the average level of cognitive failure in private car drivers, identify factors influencing cognitive failure, and examine the distractions that frequently occur during driving.

2. Material and method

2.1. Data collection

To measure the rate of driver cognitive failure, this study used the Cognitive Failure Questionnaire (CFQ). The questionnaire was used to assess the type and rate of driver cognitive failure, as well as the most common driving distractions. It was distributed to drivers in Serang city, with most respondents being those whose driving activities predominantly took place there. A total of 30 respondents were selected using purposive sampling.

Researchers participated as passengers in the car driven by respondents and observed driver activities and driving disorders experienced during the trip. Each respondent carried out driving activities for one hour around the city of Serang. Encounter driving distraction is recorded in a checklist that has been prepared for collecting of distraction along driving.

The check-sheet was made based on driving distractions experienced by drivers in several previous studies on driving distractions. Driving distractions are conditions or activities that come from outside oneself whose purpose to hinder or weaken a desire or progress to be achieved. This can be caused by the internal condition and external condition of the vehicle. Distractions in the internal condition of the vehicle are distractions that occur in the vehicle, such as eating, smoking, talking, drowsiness, using the radio, and talking to passengers. Distractions in the external condition of the vehicle are distractions that occur outside the vehicle, such as seeing the conditions around the road and billboards along the road [15].

2.2. Subjects

The subject criteria for this study are drivers who have held a private car driver's license for at least one year, are in good health at the time of the research and are within the productive age range of 18 to 55 years. Respondent sampling was determined using purposive random sampling. The purposive sampling technique is a non-random sampling method where researchers select respondents based on certain characteristics that align with the research objectives.

In addition to using questionnaires, this study also employed observation techniques to identify secondary tasks performed by drivers that could cause driving distractions. Concentration distractions affect the driver's decision-making ability and decrease performance while driving [15], [16]. Driving distractions include talking to passengers, smoking, listening to music, drinking, and other activities.

2.3. Questionnaire

Respondents' cognitive failure rates were measured using the Cognitive Failure Questionnaire (CFQ). The CFQ assesses how respondents perceive their surrounding environment and make decisions based on these conditions. It measures a person's level of attention in daily life and has been shown to have excellent psychometric properties, making it suitable for use in both laboratory and field studies as a measure of cognitive failure in everyday life [17]. The CFQ evaluates three factors: distractibility, forgetfulness, and false triggering. Distractibility refers to the tendency to be distracted by environmental factors, such as noise or light, causing the individual to uncontrollably shift focus to other activities. Forgetfulness relates to a person's ability to retain and

recall information about past events. False triggering involves disruptions in the process of cognitive or motor actions [18].

The CFQ consists of 25 questions regarding mistakes that frequently occur in everyday life. It is designed to measure deviations in perception, memory, and motor skills in daily activities. CFQ scores have been found to correlate with psychiatric symptoms related to stress, with higher scores indicating increased susceptibility to stress. Respondents were asked to indicate the frequency of errors they made in routine activities over the past six months. The questionnaire uses a 5-point Likert scale, ranging from 0 (never) to 4 (very often). The minimum and maximum possible scores are 0 and 100, respectively, where a lower score indicates fewer errors, and a higher score indicates more frequent errors. In the CFQ assessment, cognitive failure is categorized into three levels. Scores of 1-35 are categorized as low cognitive failure, 36-59 as moderate cognitive failure, and 60-100 as high cognitive failure.

2.4. Statistical test

Statistical tests are conducted to assess the validity and reliability of the questionnaire used. The validity test determines the degree of accuracy of the research instrument in measuring the actual content on the CFQ questionnaire, while the reliability test evaluates consistency, which refers to the stability, consistency, predictability, and accuracy of the CFQ questionnaire. The validity and reliability tests are performed using IBM SPSS Statistics V22 software. Validity is tested using the Pearson correlation coefficient with a two-tailed significance test, while reliability is assessed using Cronbach's alpha. The next statistical test is a difference test, which examines differences in cognitive failure while driving and driving distractions between teenage and adult age groups. This difference test uses an independent samples t-test and is also conducted using IBM SPSS Statistics V22.

3. Results and discussions

There are 30 respondents who participated in the research. Among them, 19 respondents were in the adolescent group, and 10 respondents were in the adult group. One respondent, who was over 50 years old, was not included in either group. Each respondent had held a driver's license for more than 1.5 years. The respondents' occupations varied, including students, private employees, government employees, teachers, housewives, and others.

3.1. Validity and reliability test

Validity testing for the questionnaire was carried out to test that the questionnaire can measure what it wants to measure. Validity test on the questionnaire using Pearson correlation coefficient with two-tailed significance test. Based on the r table at a significant level of 5% using IBM SPSS statistics V22 software, all questions in CFQ are valid. Reliability tests are conducted to measure the stability and consistency of respondents in answering questions in questionnaires. Reliability testing using Cronbach alpha. The reliability testing on the Cognitive Failure Questionnaire (CFQ) is carried out on all question items. Because the correlation value > 0.70 then it is declared reliable, more than value of r table at a significant level of 5%. The validity and reliability test using IBM SPSS V22 for statistics.

3.2. Cognitive failure

Respondents answered the Cognitive Failure Questionnaire (CFQ) using a 5-point Likert scale from 0 to 4. The following on Table 1 are the results of the overall answers of 30 respondents on CFQ. Based on the Table 1, the average score of cognitive failure of private car drivers was 60,267. This value is included in the high category because it is in the range of 60-100. From the recapitulation table of CFQ scores of 30 respondents, as many as 15 respondents got scores in the range of 60-100 included in the category of high cognitive failure, as many as 13 respondents were included in the medium category with the range of CFQ score were 36-59, and 2 respondents were included in the low category because the CFQ score were in the range of 1-35.

Identification of factors causing cognitive failure in this study was carried out by grouping a total of 25 item values of the Cognitive Failure Questionnaire (CFQ) questions into 3 categories of cognitive failure.

Table 1.
Score of driver cognitive failure

No	Respondent	Age (years)	Total Score	Category
1	Driver 1	21	90	High
2	Driver 2	22	55	Medium
3	Driver 3	21	76	High
4	Driver 4	22	48	Medium
5	Driver 5	22	71	High
6	Driver 6	20	53	Medium
7	Driver 7	23	87	High
8	Driver 8	22	77	High
9	Driver 9	21	41	Medium
10	Driver 10	23	74	High
11	Driver 11	24	56	Medium
12	Driver 12	30	73	High
13	Driver 13	22	33	Low
14	Driver 14	25	49	Medium
15	Driver 15	53	39	Medium
16	Driver 16	36	92	High
17	Driver 17	25	55	Medium
18	Driver 18	26	78	High
19	Driver 19	22	52	Medium
20	Driver 20	28	73	High
21	Driver 21	28	57	Medium
22	Driver 22	35	85	High
23	Driver 23	33	79	High
24	Driver 24	23	42	Medium
25	Driver 25	20	72	High
26	Driver 26	22	91	High
27	Driver 27	31	65	High
28	Driver 28	19	35	Low
29	Driver 29	44	51	Medium
30	Driver 30	22	37	Medium

Table 2.
Dominant factors caused cognitive failure

Number	Respondent	Total Score	Classification of Cognitive Failure			Dominant Category
			Forgetfullnes	Distractability	False Triggering	
1	Driver 1	90	28	34	28	Distractibility
2	Driver 2	55	20	21	14	Distractibility
3	Driver 3	76	29	28	19	Forgetfulness
4	Driver 4	48	17	18	13	Distractibility
5	Driver 5	71	23	30	18	Distractibility
6	Driver 6	53	14	23	16	Distractibility
7	Driver 7	87	29	34	24	Distractability
8	Driver 8	77	30	26	21	Forgetfulness
9	Driver 9	41	14	11	16	False Triggering
10	Driver 10	74	23	24	27	False Triggering
11	Driver 11	56	26	17	13	Forgetfulness
12	Driver 12	73	29	25	19	Forgetfulness
13	Driver 13	33	10	18	5	Distractibility
14	Driver 14	49	17	19	13	Distractability
15	Driver 15	39	17	14	8	Forgetfulness
16	Driver 16	92	30	14	28	Distractibility
17	Driver 17	55	20	34	14	Distractibility
18	Driver 18	78	29	21	21	Forgetfulness
19	Driver 19	52	17	28	15	Distractibility
20	Driver 20	73	23	20	20	Distractibility
21	Driver 21	57	19	30	16	Distractibility
22	Driver 22	85	29	22	24	Distractibility
23	Driver 23	79	30	32	21	Forgetfulness
24	Driver 24	42	15	28	16	False Triggering
25	Driver 25	72	23	11	25	False Triggering
26	Driver 26	91	29	24	28	Forgetfulness
27	Driver 27	65	23	34	17	Distractibility
28	Driver 28	35	11	25	6	Distractibility
29	Driver 29	51	17	21	13	Distractibility
30	Driver 30	37	17	13	8	Forgetfulness
Total		1808	658	703	526	-

The categories are:

1. *Forgetfulness*, the tendency to move on from one that is remembered or planned, such as names, attentions, promises, and words. Rated from question items no: 1, 4, 5, 7, 16, 17, 20, and 22).
2. *Distractibility*, the distraction of the respondents' attention, especially in social situations or interactions with other people, such as forgetting or easily distracted their focus of attention. Rated from question numbers: 8, 9, 10, 11, 14, 15, 19, 21, and 25.
3. *False triggering*, the disruption of the process of a series of cognitive or motor actions. Rated from items no: 2, 3, 5, 6, 12, 18, 23, and 24.

According to the cognitive failure grouping described above, the identification of factors causing cognitive failure in drivers is presented in Table 2. Based on the information shown in the table, it is evident that distractibility was the dominant factor causing cognitive failure, followed by forgetfulness. A total of 17 people experienced cognitive driving failure due to distractibility, 9 people due to forgetfulness, and 4 people due to false triggering. Table 2 presents the dominant type of distraction for each respondent.

The difference test in this research aims to determine the effect of respondents' age on cognitive failure scores. The test was conducted by dividing respondents into two age categories: adolescents, aged 17–25 years, and adults, aged 26–45 years. Respondents outside these age groups were not included in the testing process. In this study, only one respondent was outside of these age groups.

The difference test used an independent sample t-test with a confidence level of 95%, using IBM SPSS Statistics V22 software. In terms of cognitive failure results by age group, the adolescent group had an average failure score of 59.7, while the adult group had a score of 72.3. The differences between the two groups were tested using an independent sample t-test. The test results showed no significant difference between the adolescent and adult age groups in terms of the rate of cognitive failure, with a p-value of 0.078. This means that the rates of cognitive failure between the two age groups were not significantly different.

3.3. Driving distractions

Observations of distractions experienced by drivers when they were driving were recorded in the check sheets. The check sheets presented the types of distractions while driving that driver commonly experience. Check sheets were used to find out the secondary tasks performed by drivers. The check sheets consist of 15 types of driving distraction which refer to several studies on driving disorders that have been conducted. According to Misokefalou [16], drivers in Attika toll way, Greece experiencing interference in the form of using mobile phone, set up the radio, talking to passengers, drinking, and others.

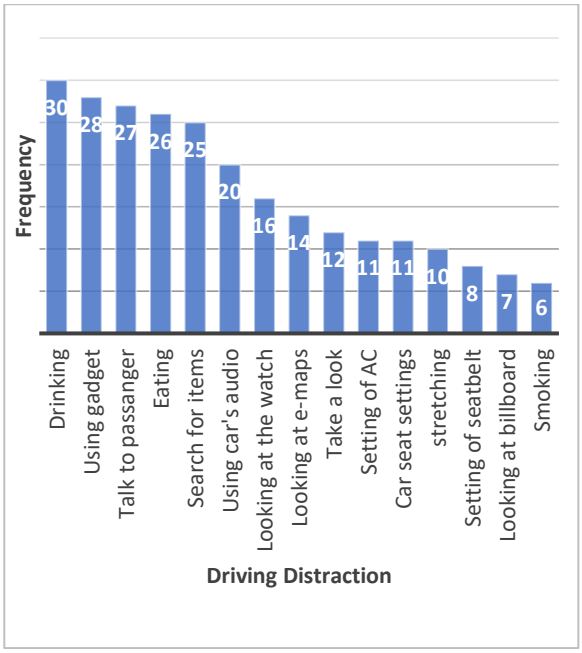

Figure 1. Driving distraction

During the observation, the researcher recorded the frequency of secondary tasks performed by the driver. Fig. 1 presents a diagram of the frequency of driving distractions for 30 respondents. The frequency of driving distractions was determined by summarizing the activities of each respondent based on the check sheets used during field observation. According to the information in Fig. 1, the diagram shows the secondary tasks most often performed by drivers while driving. Out of the 15 activities, the cumulative frequency of secondary tasks was 251. Each secondary task had a frequency ranging from 6 to 30 occurrences. During the observation, drinking had the highest frequency, observed 30 times, followed by operating gadgets (28 times), talking to passengers (27 times), eating (26 times), and looking for goods (25 times).

Driving distractions are grouped into two categories: internal factors and external factors. Internal factors are those that originate inside the vehicle and affect the driver's concentration, including passengers, objects around the driver, audiovisual elements in the vehicle, the driver's personal belongings, and the physical environment within the vehicle, such as temperature, sound, or video. External factors are those that come from outside the vehicle, such as advertisements along the road, noise on the road, or seeing other vehicles that do not interfere with the vehicle's lane, among others. Based on the table above, the five dominant driving distractions are all internal, including drinking, operating gadgets, talking to passengers, eating, and operating the head unit. The external factor recorded in this observation was viewing a billboard, which ranked 14th among the distractions experienced during driving.

3.4. The effect of age on driving distraction

The test of differences between two age groups in the level of distraction experienced during driving aims to determine the effect of respondents' age on driving distraction. The testing process was carried out using IBM SPSS Statistics V22 software with an independent sample t-test, to see how age affects driving distraction. The group of age observed in this study was adolescence with an age range between 18 – 25 years old and adulthood with an age range of 26 – 45 years old. In the difference test, one respondent's data wasn't included in the test because the age of the respondent was outside of the age category of the study. The average score of the frequency of driving distraction in the adolescent category was 9.8 and the average score of it in the adult category was 6.4.

The results of the independent sample t-test for two group of respondents based on their experience in driving distraction showed a two-way significance value of 0.003, it can be concluded that there is a significant difference in the level of driving distraction between them, where the adolescent group experiences higher driving distraction than that on adult group. The adolescent group experienced higher in driving distraction because this group tended to perform more secondary tasks than the adult age group. This study is in line with research conducted by the National Highway Traffic Safety Administration, U.S. (NHTSA) in 2021 that drivers in adolescent group, aged 16-24 years old experience in driving distraction more often than adults [18]. According to NHTSA study in 2022, adolescent drivers also use electronic devices more often than adult drivers [19], [20].

3.5. Identify the causative factors of driver cognitive failure

The driver's cognitive failure rate is at high to moderate levels, with the dominant failure on forgetfulness factor is often got distraction in social situations or interactions with others such as forgetting or easily distracted the focus of attention. The forms of cognitive failure in this group are 'You read something and find you haven't been thinking about it and must read it again', 'You fail to listen to people's names when you are meeting them', 'you can't quite remember something although it's on the tip of your tongue', You forget where you put something like a newspaper or a book and others. Tabel 3 presented the highest group of driving distraction based on this study. The second cognitive failure factor is *distractibility*. Include in this factor you find yourself suddenly wondering whether you've used a word correctly, 'not finding something to say', 'daydreaming when listening to something you fail to hear people speaking to you when youare doing something else', 'often distracted while doing something and moving attention to other activities', and others. A factor of cognitive failure that is rarely experienced by drivers is *false triggering*, examples of activities that fall into this category are accidentally 'throwing away needed items and storing items that are not needed', 'you fail to notice signposts on the road', Do you find you forget whether you've turned off a light or a fire or locked the door? 'You forget why you went from one part of the house to the other', and other.

Table 3.
The highest cognitive failure in driving

No.	Question	Score	Category
19	Do you daydream when you bought to be listening to something?	97	Distractibility
18	Do you find you accidentally throw away the thing you want and keep what you meant to throw away ?	88	False triggering
21	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	86	Distractibility
22	Do you find you can't quite remember something although it's "on the tip of your tongue"?	84	Forgetfulness
20	Do you find you forget people's names?	80	Forgetfulness
25	Do you find you can't think of anything to say?	79	Distractibility
14	Do you find yourself suddenly wondering whether you've used a word correctly?	78	Distractibility

Based on information from the Tabel 3, the highest cognitive failure in driving that done by respondents was item number 19 'often daydreaming when listening to something', with a total of 97 observation which include in the group of distractibility factor. In general, from 25 questions in CFQ, the highest total score is dominated by the distractibility factor.

Accidents can be caused by several factors, include of errors in recognition aspect, errors in decision making, acting errors and physical fatigue. Although these factors are different from each other, they have similarity factor which involves attentional and perception factors or recognition, memory and decision-making factors, and factors for acting [21]. Driving need cognitive abilities and driving skills, to be safe in driving, drivers must have good driving skills and good mental readiness. Cognitive factors of the driver play a very important role because cognitive aspects can analyze conditions along the way and analyze the consequences of an action taken during driving [22].

By comparing the cognitive failure rates of drivers in adolescent and adult age groups, there wasn't a significant difference between them. The factor of driving experience more than one year and already having a driving license makes the cognitive abilities of the two age groups no different. It is imperative for the industry to consistently enhance competition, effectively manage relationships across the supply chain, and continuously improve production quality. WKB is a company that manufactures precast concrete in various forms of electrical poles. An assessment of both the manufacturing process and the resulting goods is conducted to oversee and maintain production quality.

3.6. Distractions on drivers

Driving distraction is any activity that diverts attention from the main task of driving to other activities. When a driver is distracted, their attention is divided between two focuses: the primary task (driving) and the secondary task (other activities unrelated to driving). For example, when making a call on a mobile phone, the driver's cognitive resources are used to analyze both the driving situation (primary task) and the mobile phone conversation (secondary task).

Driver distraction refers to anything that disturbs the driver's attention while driving. Forms of distraction can be visual, auditory, cognitive, or other impairments. Common high distractions experienced by drivers include drinking, operating mobile phones, talking to passengers, eating, and searching for items. Distraction affects a driver's alertness in performing their task, which in turn impacts driving performance and driver awareness [11].

Distraction is any condition or activity that comes from outside the driver and hinders or weakens the driver's progress or purpose. Distractions during driving can be either internal or external. Internal distractions occur within the vehicle and include activities such as eating, smoking, talking, drowsiness, using the radio, and talking to passengers. External distractions come from outside the vehicle, such as looking at roadside advertisements or billboards. In this study, the dominant distractions experienced by drivers were internal distractions.

The difference in distraction levels between teenagers and adults shows that adolescents experience a higher level of driving distraction. The adolescent group tends to engage in more secondary tasks than the adult group. The adult group, being more mentally stable, is better able to control themselves and avoid secondary tasks while driving.

4. Conclusions

The rate of cognitive failure of private car drivers is at high to moderate levels, with the dominant factor is distractibility, which is a distract of driver's concentration that is influenced by an environment. When experiencing interference, the individual may uncontrollably move on to other activities. There was no difference in the rate of cognitive failure due to group of adolescent and adult age. But adolescent drivers experience higher driving distraction than adult drivers. Driving distraction experienced by many drivers are internal distraction with the highest activities are drinking, using mobile phones, and talking to passengers.

Declaration statement

Hasby al Baihaqi: **Data curation, documentation, analysis.** Lovely Lady: **Conceptualization, methodology, formal analysis, writing**.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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