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Abstract. To some people, back-in parking maneuver is a relatively hard thing to do. However, previous studies have proven that back-in parking is safer than head-in parking because when exiting the parking space (back-out) from head-in parking, the driver's field of view is more limited, thus increasing the chance of an accident. This study aims to determine the changes in the driver's viewing frequency on the rear-view mirror, maneuver duration, and degree of difficulty during back-in parking maneuvers. Data collection was obtained from 45 participants who tried to park their cars in a parking space with an angle of 30°, 45°, 60°, 90°, each with four different conditions of parking spaces. The driver's viewing frequency on each rear-view mirror (left, right and center) and maneuver duration were obtained from a dashcam and an external camera recording. The difficulty level for maneuvering was filed according to the driver's opinion during the experiment for each parking space condition. Based on the data analysis, it was proven that the existence of cars parked on either side of that parking space (obstacles), parking space line signs, and both simultaneously increase the driver's viewing frequency and maneuver duration when doing back-in parking maneuver, but at the same time, ease the parking maneuver, according to the driver.

1. Introduction

Some people find that back-in parking maneuver is a relatively hard thing to do. However, several previous studies have recommended and proven that back-in parking is safer than head-in parking. This is because in head-in parking, when exiting the parking space (back-out), the driver's field of view is more limited, thus increasing the chance of an accident [1]. This is proven by data that indicates 9% of pedestrian deaths in parking lots are a result of back up incidents [2]. Furthermore, the United States federal government estimates that around 15,000 people are injured, and 210 people are dead each year in backup crashes involving light vehicles, in which in most cases, many of these injured and dead are children younger than 5 years old [3]. Other data from the Not-in-Traffic Surveillance (NiTS) system, the Fatality Analysis Reporting System, and the National Automotive Sampling System (NASS) General Estimates System, states that an estimated 18,000 injuries and 292 fatalities occur each year due to backover crashes [4].

A lot of research papers have been published to aid and simplify parking maneuvers for cars. One of the experiments involved installing light displays on the C-Pillars to increase the awareness of drivers visually [5]. Furthermore, an experiment involving the use of a rearview camera and parking sensor technology, shows that drivers look rearward over their shoulders less frequently than participants without the technology [6]. Other published experiments involved the use of ultrasonic sensors and Arduino Uno-based MP3 Shield, which produces sound as a voice guide for drivers to park their vehicles [7].

Many studies have investigated driver glance behavior and found that glance behavior is a key indicator of drivers' underlying cognitive processes and can assist in evaluating driving performance and safety [8–10]. Although there are technologies that may aid the parking maneuver process, such as rearview cameras and parking sensors, the performance of these technologies has varied [11], and these technologies are still not mandatory for new cars in Indonesia. Therefore, most drivers rely more on their rearview mirrors during back-in parking maneuvers. However, the problem that often occurs while doing back-in parking maneuver, is that the driver cannot clearly see the position of parking space line-markings related to their car position without lowering the direction of their left and or right rearview mirrors. Especially, when no cars are parked on either side of the parking space.

In this research, the obstacles (cardboards, standing signboard, etc.), which functions as a substitute for cars parked on either side of the parking space, and the sign, were used to figure out how it changes the driver's viewing frequency, maneuver duration, and the difficulty level of the parking maneuver. Due to the COVID-19 pandemic during this experiment, only 56 Petra Christian University students were willing to be involved in this experiment. After initial checking of the video recording for the parking maneuver duration, only 45 participant's data were eligible for analysis. The data obtained from this experiment are the frequency of the driver's view to the rearview mirrors (left, right, and center), parking maneuver duration, and the driver's response to the difficulty level of parking maneuvers for each condition of parking space. This experiment uses four parking spaces with four variations in parking angles (30°, 45°, 60°, and 90°). The dimensions of each parking space are 2.3 m x 5 m [12]. The experiment was conducted four times for each parking space with variations in conditions of parking space (with and without obstacles and signs).

2. Literature Review

2.1. Variety of Parking Maneuvers

When entering a parking lot, the driver has several options of parking maneuvers to choose from to park their cars in the parking space. First, the driver can choose to do a head-in parking maneuver, and hence, when exiting the parking space, they will perform a back-out parking maneuver. Second, the driver can choose to do back-in parking first when entering the parking space and then exit the parking space by way of head-out parking maneuver [1].

2.2. Several factors that affect parking maneuvers

Several factors that affect the ease of parking maneuvers such as, the physical condition of the driver, weather conditions, the presence of parking attendants who help provide directions during parking maneuvers, and the last is the presence of other cars currently parked on the left and or right side of the parking space [13].

2.3. Driver's viewing frequency

In this study, the frequency refers to the driver's viewing to the left, right, and center rearview mirrors during back-in parking maneuver. The driver's view that is taken into account in this study is the eye view (when the eyeballs move to see the side mirrors or the center rearview mirrors) and the rotation of the neck facing the rearview mirrors [14,15]. Back-in parking will get the benefit from the presence of other cars on the left or right side of the parking space (obstacles) and/or signs to indicate the location of the parking space line as a reference to position car in the parking space, while in head-in parking maneuver, the driver does not require these aids.

3. Research method

All the 45 participants have a driver's license and have been driving for more than 6 months. The location of the experiment was carried out in the parking space of the Q building in Petra Christian University, Surabaya, Indonesia. The vehicles used in this study are owned by each participant and varies from small hatchbacks to big SUVs. The technologies that aid the parking maneuver of each vehicle, such as rearview camera and parking sensor, are turned off. The center console display is covered by a black cloth so that all participants have the same conditions, while also directing the drivers to use the rearview mirrors instead. The drivers are also not allowed to do direct glances or look rearward over their shoulders. The sound sensor in some cases is not turned off, as some cars do not have the feature to turn it off, and hence it was not investigated further in this study.

Before starting, participants were briefed about the sequence of the experiment. One dashcam was installed inside the car (Figure 1) and one camera was installed in the parking space (Figure 2). Inside the car, there is a participant and a surveyor. The surveyor will show the cue card to the dashcam when the vehicle starts to maneuver until it stops at each parking space. The car is declared parked in the parking space when the car tire hits the wheel stopper. Afterward, a surveyor will ask the participant about the level of difficulty in performing parking maneuvers in the parking space.

Figure 1. Dashcam position inside the car to record the driver's glances.

Figure 2. Camera position on the parking space.

This research has four variations of parking space angles, which are 30°, 45°, 60°, and 90° (Figure 3 to 6). For each angle variation, the parking space is further divided into four conditions: (1) the right and left sides of parking space are empty (E) (Figure 3), (2) obstacles are placed in the form of cardboards which functions as a substitute for a parked car at the left and right side of the parking space (O) (Figure 4), (3) signs are placed at the end of the parking space as a marker to end parking (S) (Figure 5), (4) parking space with both obstacles and signs (OS) (Figure 6). Relative to the driver's point of view, the parking space of angles 30° and 90° (Figure 3 and 6 respectively) are on the left side of the car, while parking space of angles 45° and 60° (Figure 4 and 5 respectively) are on the right side.

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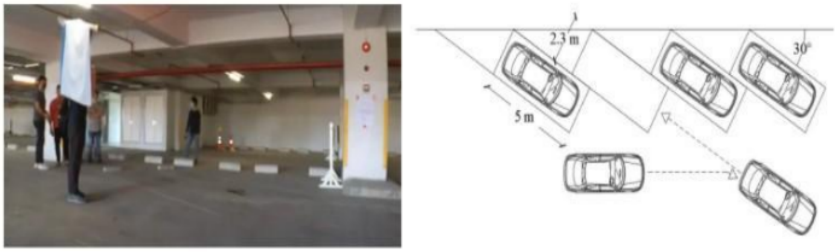

Figure 3. Illustration of parking space condition for 30° with the left and right sides of the parking space are empty (E).

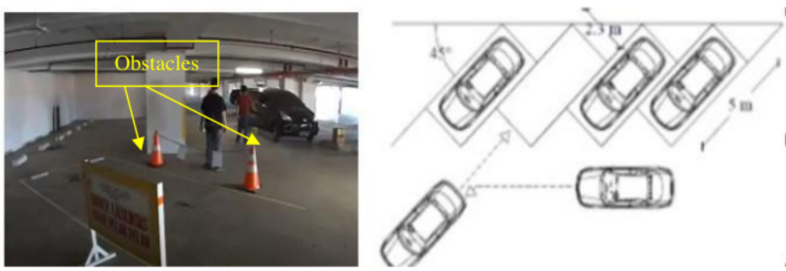

Figure 4. Illustration of parking space condition for 45° with obstacles (O) on both sides of the parking space.

Figure 5. Illustration of parking space condition for 60° with signs (S) at the end of the parking space line marking.

Figure 6. Illustration of parking space condition for 90° with both obstacles and signs (OS).

The recording results were evaluated after the experiment. Viewing frequency data are retrieved by counting the driver's glances at the left, right, and center rearview mirrors while doing a back-in maneuver using a dashcam. When the driver starts to maneuver, the driver's viewing direction starts to be calculated (looking to the left, right, and center rearview mirrors). This is calculated up to the point when the vehicle is parked in each parking space. The results from the dashcam recording and the outside camera will assist in data processing. Meanwhile, data for the duration of the parking maneuver is obtained from the dashcam and the external camera recordings, which starts from when the car moves backward until it stops in the parking space. For data on the difficulty level of the parking maneuvers, a form with a scale of 1-5 is used, where 1 and 2 are categorized as difficult, 3 as neutral, and 4 and 5 are easy.

4. Results and discussion

In this research, there are four angles of parking space (30°, 45°, 60°, and 90°), four conditions of parking space (E, O, S, OS), and three rearview mirrors (Left, Center, Right), and hence, 48 combinations are obtained. The Shapiro-Wilk normality test was carried out on the drivers' viewing frequency data to know if the data of the 48 parking space combinations are normally distributed. The test results show that the data tend to not be normally distributed. Because of this, the non-parametric Wilcoxon Signed-Ranks Test method was carried out to find out the difference of drivers' viewing frequency between the condition where the right and left sides of the parking space are empty (E) and the other conditions (obstacle/O, signs/S, and both simultaneously/OS), in which the results can be seen in Table 1.

Table 1. Ranks for each parking space condition.

Parking Space Angle	**Desc.**	**OS vs E LM**	**OS vs E CM**	**OS vs E RM**	**O vs E LM**	**O vs E CM**	**O vs E RM**	**S vs E LM**	**S vs E CM**	**S vs E RM**
		Number of Participants								
30°	NR	7	5	7	15	8	12	16	6	10
	PR	24	6	21	18	5	19	17	7	16
	T	14	34	17	12	32	14	12	32	19
45°	NR	3	10	3	4	11	5	14	9	14
	PR	34	7	33	33	2	31	17	3	13
	T	8	28	9	8	32	9	14	33	18
60°	NR	0	6	6	4	4	6	12	6	19
	PR	35	5	33	33	7	31	13	5	14
	T	10	34	6	8	34	8	20	34	12
90°	NR	6	10	7	9	8	14	10	7	10
	PR	27	11	33	24	10	20	24	7	22
	T	12	24	5	12	27	11	11	31	13

Description:

E	= The left and right sides of the parking space are empty
O	= Parking space with Obstacles
S	= Parking space with Signs
OS	= Parking space with both Obstacles and Signs
LM	= Left rearview Mirror
CM	= Center rearview Mirror
RM	= Right rearview Mirror
NR (Negative Ranks)	= The frequency of the driver's view on the E condition is higher than the driver's view with the installation of obstacles and/or signs (O, S, OS)
PR (Positive Ranks)	= The frequency of the driver's view on the E condition is lower than the driver's view with the installation of obstacles and/or signs (O, S, OS)

T (Ties) = The frequency of the driver's view on the E condition is the same with driver's view with the installation of obstacles and/or signs (O, S, OS)

Table 1 compares the ranks for each parking space condition (O, S, OS) against the Empty (E) parking space condition. For example, at angle 30° where OS Left is compared to E Left (OS Left - E Left), the value of 24 for Positive Ranks means that 24 participants turned their attention to the left rearview mirrors more with the Obstacle and Signs (OS) than in Empty (E) conditions.

For each condition (Negative Ranks, Positive Ranks, or Ties), the largest dominating value is taken to represent that condition. Then, in each condition, p-value is obtained from the Wilcoxon test to find out whether there is a significant difference between the two variables under study (Example: OR LM and E LM). The two test results carried out in the three conditions above are recapitulated in Table 2.

Table 2. Highest ranks for each parking space condition.

Parking Space Angle	**OS vs E LM**	**OS vs E CM**	**OS vs E RM**	**O vs E LM**	**O vs E CM**	**O vs E RM**	**S vs E LM**	**S vs E CM**	**S vs E RM**
30°	PR*	T	PR*	PR	T	PR	PR	T	T
45°	PR*	T	PR*	PR*	T*	PR*	PR	T	T
60°	PR*	T	PR*	PR*	T	PR*	T	T	NR
90°	PR*	T	PR*	PR*	T	PR	PR*	T	PR

* $p \leq 0.05$

From Table 2, the P-values show that there are 15 significant differences from a total of 36 conditions. These significant differences tend to occur more on the side rearview mirrors (left and right). In addition, most of the results are Positive Ranks (PR) for left and right rearview mirrors for all conditions (O, S, OS) compared to the Empty (E) condition. This might be caused by drivers who tend to be more careful to avoid colliding with the obstacles and/or signs. Another variable that is analyzed in this study is the duration of the back-in parking maneuver. The average maneuver duration of the 45 participants can be seen in Table 3.

Table 3. Average maneuver duration for each parking space condition.

Parking Space Angle	**Average Maneuver Duration (seconds)**			
	E	**O**	**S**	**OS**
30 °	28	29	29	33
45°	38	33	30	36
60°	31	32	28	33
90°	36	63	36	41

From the results shown in Table 3, it can be concluded that there is an increase in the duration of parking maneuvers in the type of parking space that is given obstacles (O), signs (S), and obstacles and signs (OS) simultaneously.

However, the increase in parking maneuver duration and driver's viewing frequency are not due to an increase in difficulty when the driver is doing the parking maneuver to park their car. Instead, the installation of obstacles, signs, or both obstacles and signs simultaneously ease the drivers to do the back-in parking maneuver as shown in Table 4.

Table 4. Difficulty level of back-in parking maneuver for each parking space condition.

Parking Space Angle	Difficulty Level	E	O	S	OS
30 °	Easy	73%	85%	87%	87%
	Neutral	25%	13%	11%	11%
	Difficult	2%	2%	2%	2%
45°	Easy	73%	84%	87%	87%
	Neutral	22%	16%	11%	13%
	Difficult	5%	0%	2%	0%
60°	Easy	69%	67%	73%	87%
	Neutral	20%	29%	20%	7%
	Difficult	11%	4%	7%	6%
90°	Easy	44%	78%	60%	87%
	Neutral	38%	18%	31%	9%
	Difficult	18%	4%	9%	4%

5. Conclusion

Based on the analysis, it was found that the driver's viewing frequency to both left and right rearview mirrors and maneuver duration when performing back-in parking maneuvers tend to increase for three parking space conditions, which are: cars are parked on either side of the parking space (obstacles), parking space line signs (signs), and with both obstacles and signs simultaneously, compared to parking space without obstacles and signs (empty). This might have been caused by an increase in the driver's awareness towards the presence of obstacles, which is to simulate the presence of cars parked on either side of the parking space, and signs in the parking space. However, the level of difficulty to do the back-in parking maneuver decreases for parking conditions with only obstacles, only signs, and both obstacles and signs, compared with if the right and left sides of parking space are empty. Nonetheless, due to the limited number of participants in this research, further research needs to be conducted to confirm how significant the presence of parked cars on each side of the parking space (obstacles) and parking space line signs, are in helping the drivers to ease them in performing back-in parking maneuvers.

References

[1] Findley D J, Nye T S, Lattimore E, Swain G, Bhat S K P and Foley B 2020 Safety effects of parking maneuvers *Transp. Res. Part F Traffic Psychol. Behav.* **69** 301–10
[2] NSC Parking Lot Injuries Often Result of Distraction
[3] NHTSA 2016 *Traffic Safety Facts 2014*
[4] Austin R 2008 *Fatalities and Injuries in Motor Vehicle*
[5] Hipp M, Heuten W, Löcken A and Boll S 2016 Ambient park assist: Supporting reverse parking maneuvers with ambient light Automotive UI 2016 - *8th Int. Conf. Automot. User Interfaces Interact. Veh. Appl. Adjun. Proc.* 45–50
[6] Kidd D G and McCartt A T 2016 Differences in glance behavior between drivers using a rearview camera, parking sensor system, both technologies, or no technology during low-speed parking maneuvers *Accid. Anal. Prev.* **87** 92–101
[7] Supriyono and Marjuki 2020 Ultrasonic sensor parking assistant with Arduino Uno *Int. J. Adv. Res. Eng. Technol*. **11** 26–33
[8] Green P 2015 Where do drivers look while driving (and for how long) *Hum. factors traffic Saf.* 77–110
[9] Liang Y, Lee J D and Yekhshatyan L 2012 How dangerous is looking away from the road? Algorithms predict crash risk from glance patterns in naturalistic driving *Hum. Factors* **54** 1104–16
[10] Victor T, Bärgman J, Boda C-N, Dozza M, Engström J, Flannagan C, Lee J D and Markkula G 2014 Analysis of Naturalistic Driving Study Data: Safer Glances, Driver Inattention, and Crash Risk *Anal. Nat. Driv. Study Data Safer Glances, Driv. Ina. Crash Risk*

[11] AAA 2015 FACT SHEET: Rear Cross Traffic Alert Systems
[12] Direktur Jenderal Perhubungan Darat 2012 *Pedoman Teknis Penyelenggaraan Fasilitas Parkir*
[13] Setiawan R 2008 Faktor-Faktor Yang Mempengaruhi Kemudahan Manuver Parkir (Studi Kasus Universitas Kristen Petra Surabaya) **2** 6–7
[14] Kidd D G, Reimer B, Dobres J and Mehler B 2018 Changes in driver glance behavior when using a system that automates steering to perform a low-speed parallel parking maneuver *Transp. Res. Part F Traffic Psychol. Behav.* **58** 629–39
[15] International Organization for Standardization 2002 *Road Vehicles: Measurement of Driver Visual Behaviour with Respect to Transport Information and Control Systems: part 1: Definitions and Parameters*. (Geneza, Switzerland)

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