ISSN: 2769-545X

Research Article

Advances in Machine Learning & Artificial Intelligence

Verification of rearward visibility using side mirrors of short-distance mobility vehicles (Electric wheelchair standards) WHILL

Koji Sakai*

Department of Human Relations, Faculty of Human Relations, Kyoto Koka Women's College, 38 Kadono-cho, Nishikyogoku, Ukyo-ku, Kyoto 615-0882, Japan

***Corresponding Author**
Koji Sakai, Department of Human Relations, Faculty of Human Relations, Kyoto Koka Women's College, Japan.

Submitted: 2024, Oct 10; **Accepted:** 2024, Nov 20; **Published:** 2024, Dec 03

Citation: Sakai, K. (2024). Verification of rearward visibility using side mirrors of short-distance mobility vehicles (Electric wheelchair standards) WHILL. *Adv Mach Lear Art Inte, 5*(4), 01-07.

Abstract
In a test drive experiment of the short-distance mobility device (electric wheelchair standard) WHILL, young test participants drove the vehicle both with and without side mirrors, and the evaluation data after the test drive under each condition was compared and analyzed. The results revealed that the presence of side mirrors makes driving more comfortable significantly in situations where checking behind is required. Many test participants checked behind them both with the side mirrors and with their eyes when parking. Test participants who drive cars on a daily basis tended to check the side mirrors frequently when driving forward, and used them effectively. Many test participants rated the side mirrors as expensive, but also expressed a desire to purchase them, and rated the mirror surface measuring 4.5 cm high x 11.5 cm wide was narrow in height.

Keywords: Short-Distance Mobility Vehicles, Whill, Side Mirror, Rear View, Test Drive

1. Introduction

1.1 Operability of Electric Wheelchairs

This study examines the effect of the presence or absence of side mirrors on the operability of the "WHILL" short-distance mobility (electric wheelchair standard) in test-driving experiments. The model of the WHILL is the handle-type WHILL Model S. This model is intended to be used like a bicycle, to travel to a destination, park in bicycle parking when arriving at the destination, and then dismount and travel on foot [1].

Electric wheelchairs are treated as pedestrians under the Road Traffic Act and can be driven on sidewalks. Electric wheelchairs are broadly divided into two types: self-propelled and assisted, and self-propelled wheelchairs come in standard-type and handle-type. The results of a real-world driving test of a handle-type electric wheelchair showed that both able- bodied adults and elderly people were penalized most frequently in three maneuvers: crossing a lateral incline, crossing a threshold, and crossing a ditch [2]. In a test drive experiment to evaluate the operating ability, a test course was run through the width of a door, and the results showed that the three participants took a long time to pass through the door (A), changed their direction and passed through the door but received a large amount of operating assistance in front of the door (B), and slowed down and adjusted their direction by themselves (C) [3]. The operating ability of the three participants was evaluated as C > B > A.

One of the social issues surrounding electric wheelchairs is the low number of electric wheelchair users both in Japan and overseas. There is a low awareness that daily use of electric wheelchairs is natural, and improving social understanding and acceptance is a challenge for the spread of electric wheelchairs. A questionnaire survey analyzed negative attitudes toward the use of electric wheelchairs, and found that electric wheelchair users were more likely to experience refusal to use electric wheelchairs at restaurants and negative attitudes from taxi, train, and bus staff than non-users [4].

1.2 Short-Distance Mobility "WHILL"

WHILL was developed to create a smart vehicle that everyone would want to ride. WHILL Corporation was founded in 2012 with the mission of "making travel fun and smart for everyone" with the aim of developing a more user-friendly and stylish vehicle. As of August 2024, two types of chair-type and one type of handle-type (WHILL Model S) are on sale [5]. WHILL is a vehicle that allows everyone to travel comfortably, including not only people with physical disabilities and people with weak legs and hips, but also able-bodied adults, regardless of age or gender. WHILL is ridden in everyday life at theme parks, outlets, parks, hotels, city halls, etc. [1].

WHILL's operability has been verified through test drive experiments and social experiments. As a result of a test drive experiment of WHILL on a public road with 10 able- bodied men and women, about half of the participants felt no anxiety about operating WHILL, but many of the participants felt anxiety about operating the vehicle diagonally in reverse [6]. WHILL's handle was easy to operate and the comfort during the test drive was also high. The impression evaluation of WHILL changed significantly from negative to positive before and after the test drive. In a test of an electric wheelchair operated autonomously in a hospital for patients with skeletal diseases, the patients showed high satisfaction and rode safely without any collisions [7]. In a social experiment of WHILL conducted in 2022 by Niigata City, the majority of the participants said that the operation was easy, accounting for 70% of the total [8]. On the other hand, there were some negative opinions, such as "there were some scary moments," which included concerns about operating errors and vibrations when going over braille blocks. In addition, many participants mentioned issues such as "the low line of sight and the size of the wheelchair, and being careful of other people's gazes," and some participants said that it was inconvenient to ride on slopes and narrow passages.

1.3 Checking the Rear with Side Mirrors

When an electric wheelchair is running on the sidewalk, pedestrians and bicycles are passing by. In addition, electric wheelchairs are sometimes parked in bicycle or motorcycle parking areas. Therefore, there are situations where it is necessary to check the rear, such as when changing lanes to avoid pedestrians, turning right or left, or reversing. In such cases, side mirrors are effective. Side mirrors are standard on cars and motorcycles, but as with bicycles, they are optional on electric wheelchairs. When an electric wheelchair does not have side mirrors, there are three ways to check behind, just like with bicycles: looking back at the rear, looking at the headlights of cars, or listening to the sound of the vehicle [9]. In WHILL's test ride experiment, many participants said that it would be ideal to be able to check behind using side mirrors [6].

In a study on rearview confirmation using side mirrors on electric wheelchairs, the maximum angle that the head made with respect to the front of the electric wheelchair was approximately 80 degrees when looking with the eyes, and approximately 20 degrees when the rearward image was displayed on a display [10]. The maximum angle that both shoulders made was approximately 20 degrees when looking with the eyes, and nearly 0 degrees when the rearward image was displayed on a display. From these results, it was interpreted that the angle at which the body is twisted when checking the rearward on a display is smaller, which is effective in reducing the burden on the neck and lower back.

In addition to electric wheelchairs, there have been empirical studies on rear checking for various types of mobility, such as bicycles and cars. The results of a bicycle simulator ride experiment showed that the time required to check left and right and rearward was significantly shorter with side mirrors than without them [9]. While there were favorable opinions on the use of side mirrors, there were also opinions such as anxiety when checking only the side mirrors and wanting to check with one's own eyes, and the side mirrors having a small visible area. In addition, an experiment using a camera monitor system replacing the side mirrors of a car verified the required field of view [11]. As a result, the waterside field of view of the camera monitor system, adjusted by the driver, was 41 to 45 degrees on average, which was wider than the horizontal field of view of 20 to 25 degrees for a conventional side mirror. There are age differences in the information processing ability for checking behind. In a study that measured eye movements while driving a car, young people looked relatively far ahead while also looking at the side mirrors and rearview mirror to understand the situation, whereas older people focused their attention on the closer ahead and paid less attention to the side mirrors and rearview mirror [12]. Older people tend to be slower in directing their attention to objects, and when making a decision, they sometimes rush to make the decision and move on to the next driving action without accurately understanding the situation around them.

In this study, we will verify the ease of checking behind with or without side mirrors by conducting a test drive experiment on the WHILL for young people, as shown in Figure 1. We will test drive the WHILL both with and without mirrors, and compare and analyze the evaluation data after each test drive.

(a) with side mirror

(b) without side mirrors

Figure 1: WHILL with (a) and without side mirrors (b)

2. Method

2.1 Experimental Period

The experiment was conducted in July and August 2024, with an average temperature of 33.8 degrees (SD: 1.17 degrees) and an average humidity of 66.5 % (SD: 7.26 %) on the experimental days, in a hot, sunny environment.

2.2 Experimental Participants

The participants were 11 students from Kyoto Koka Women's University, aged 20 to 51 years (average age 26.0 years), and all were female. The 11 participants walked in their daily lives, were healthy, and did not ride a wheelchair. Eight of the 11 participants had obtained a driver's license, and two of them drove a bicycle in their daily lives.

2.3 Experimental Equipment

The electric wheelchair used in this experiment was the WHILL Model S. Its features are as shown in the test drive experiment [6]. Figure 2 shows the side mirror installed on the WHILL Model S. The mirror was rectangular, and the size of the mirror surface was 4.5 cm high x 11.5 cm wide. The mirror was placed at the end of the steering wheel so that the rear information projected on the side mirror would not be blocked by the body of the participant who was test-driving the WHILL, resulting in a blind spot. In the mirror condition, the participant adjusted the mirror angle to make it easier to see before the test drive. The side mirror was placed on the steering wheel, and the horizontal angle of the mirror also moved when the steering wheel was moved.

Figure 2: Side mirror installed under mirror condition

2.4 Experimental Procedure

First, the experimenter explained how to operate the WHILL to the participants while they practiced the test drive. After that, the participants drove the WHILL on the designated route around the university. After that, they drove on the sidewalk of a public road in both the mirror condition and the no-mirror condition, and then conducted a questionnaire survey on operability. In the mirror condition, the experimenter did not instruct the participants to drive while looking at the mirror, and the participants were free to use the mirror while driving.

The test drive experiment route was the same as the test drive experiment, both on the university campus and on the sidewalk of a public road [6]. The sidewalks were flat with no slopes, and lightly crowded with people and bicycles. The test ride lasted about 30 minutes, and the questionnaire and interview survey lasted about 15 minutes, for a total experiment time of just under an hour. The participants were free to control the speed at which WHILL moved. To ensure the safety of the participants, an experimenter accompanied them while they were test-driving WHILL. The experimenter warned the participants as necessary to avoid colliding with pedestrians or bicycles. In addition, the experimenter was prepared to respond to any malfunctions caused by operating errors.

2.5 Experimental Design

The 11 participants participated in both the mirror condition and the no-mirror condition. The order of the mirror condition and the no-mirror condition was counterbalanced between the participants. Therefore, 6 of the 11 participants drove in the order of mirrored conditions, and non-mirrored conditions. The other 5 participants did in the order of the no-mirror condition and the mirror condition.

2.6 Questionnaire and Interview Survey

After test drives under both mirror and no-mirror conditions, participants were asked to rate the following items on a 5-point scale in a questionnaire survey: 1. Going straight, 2. Turning left and right, 3. Going forward diagonally, 4. Going backward diagonally, 5. Going backward, 6. Parking, 7. Turning around, 8. Ease of driving in general, 9. Getting used to the controls, 10. Comfort while driving, 11. Size of mirror (question 11 was only for the mirror condition).

After rating the results under both mirror and no-mirror conditions, participants were asked in a questionnaire survey to determine how high their operability and sense of security were with or without mirrors, and whether they would like to purchase a mirror. After the self- administered questionnaire survey, the experimenter conducted an interview survey on their impressions of the WHILL, areas for improvement, and where it would be good to have one.

2.7 Ethical Considerations

It was explained in writing that the information obtained in this study would not identify individuals, and that participation in the experiment was voluntary. After explaining that the risk of accidents in this test drive experiment was extremely low, it was explained in writing that in the event of a traffic accident or the like, the insurance to which all experiment participants had been subscribed would be applied. The experiments in this study were conducted with the approval of Kyoto Koka Women's University Research Ethics Committee (approval number 24-12).

3. Results

3.1 Questionnaire Survey

Table 1 shows the comparison of the average values between the no-mirror condition and the mirror condition, and the results of the t-test. The higher the rating, the stronger the negative feeling, such as stronger anxiety for questions 1 to 7, difficulty in driving for question 8, difficulty in getting used to question 9, and discomfort for question 10. The results of the t-test showed that the no-mirror condition caused significantly more anxiety than the mirror condition for "5. Reversing," "6. Parking," and "7. Turning around." In addition, there was a significant tendency at the 10% level for "2. Turning left and right," "4. Reversing diagonally," and "8. Ease of driving in general."

In the no-mirror condition, anxiety was stronger for "4. Reversing diagonally," "5. Reversing," "6. Parking," and "7. Turning around," while in the mirror condition, anxiety was strongest for "4. Reversing diagonally." This result was similar to the result in which anxiety was strongest for "4 [6]. Reversing diagonally" only in the no-mirror condition. On the other hand, anxiety about "1. Going straight" was low, "9. Getting used to the operation" was easy to get used to, and "10. Comfort when driving" was high.

No.	Questions	No mirror condition	Mirror condition	t-value	Significant probability
1	Going straight	1.9	1.5	1.79	
2	Turning left and right	2.6	1.9	1.90	
3	Moving forward diagonally	2.5	2.3	1.00	
4	Moving backward diagonally	3.2	2.7	1.84	†
5	Moving backward	3.3	2.2	2.96	*
6	Parking	3.3	2.1	3.36	**
7	Turning around	3.2	2.5	3.07	*
8	Ease of driving in general	2.2	1.6	2.21	†
9	Ease of gripping the steering wheel	1.5	1.4	0.56	
10	Comfort while driving	1.7	1.7	0.00	
**p<0.01 *p<0.05 †p<0.10					

Table 1: Average ratings for mirror and no mirror conditions and t-test results (n=11)

Table 2 is a frequency distribution table comparing the evaluation of operability and reassurance with and without mirrors. Five participants rated operability the same with and without mirrors, and six participants rated it higher with mirrors. One participant rated it the same with and without mirrors, one participant rated it higher without mirrors, and nine participants rated it higher with mirrors.

		Operability	Reassurance
More in no mirror condition	Very high	0	0
	High	0	0
	A little high	0	1
Same both in conditions		5	1
More in mirror condition	A little high	2	4
	High	3	4
	Very high	1	1

Table 2: A frequency distribution table comparing the ratings of operability and reassurance with and without mirrors

Table 3 is a frequency distribution table of evaluations of the size of the side mirrors. Eight out of 11 participants (72.7%) rated the mirrors as small. The size of the mirrors in this experiment was 4.5 cm high x 11.5 cm wide (in Section 2.3). From the results of the interviews, the majority of participants thought that the mirrors were small in height, not in width.

	Frequency
Large	1
A little large	0
Just right	2
A little small	6
Small	2

Table 3: A frequency distribution table of ratings for side mirror size

Table 4 is a frequency distribution table evaluating the price of the mirrors, 8,250 yen (tax included). Nine out of 11 participants (81.8%) rated the mirrors as expensive.

	Frequency
Expensive	4
A little expensive	5
Just right	1
A little cheap	1

Table 4: Frequency distribution table of ratings for mirror price evaluations

Table 5 shows the frequency distribution of the evaluation of the desire to purchase mirrors. Eight out of 11 participants (72.3%) answered that they would like to purchase mirrors.

	Frequency
Hope	8
No hope	3

Table 5: Frequency distribution table evaluating the desire to purchase mirrors

3.2 Interview Survey

As a result of the interview survey, the following opinions were obtained. The opinions of two of the 11 participants who were daily drivers are specially noted.

The presence of mirrors increased the amount of information to be processed. Sometimes, the amount of visual attention decreased because the attention was paid to looking at the mirror. Conversely, without mirrors, the consciousness of checking the actual scenery increased. I did not look at the mirror when moving forward. I was so busy checking the front when going straight that I hardly looked at the mirror. But I might look at the mirror when I become skilled at driving WHILL.

When I was driving, if there was someone walking behind me or I heard a sound from behind, I checked the mirror and felt reassured. When there were a lot of people on the road, I checked the rearview mirror. Regardless of the number of people passing by, I glanced at the mirror when necessary while driving (daily driver). It would be better if the mirror was a little larger and taller. The image I wanted to see was slightly different from the image reflected in the mirror. I couldn't fully trust the image in the mirror. Therefore, after looking at the mirror, I also checked with my eyes. It would be good if the mirror was difficult to adjust, and the depth could be adjusted. Also, when turning the steering wheel shallowly, I could see behind, but when turning deeply, it was difficult to see behind. When reversing in places such as bicycle parking spaces at convenience stores, I was able to check in the mirror and feel safe. When parking in a bicycle parking space, having a mirror makes it much easier to park. Being able to see the parking curb in the mirror made it easier to park (daily driver). When reversing, I looked at the mirror to check behind me, and also checked with my eyes. It was possible to check with my eyes without the mirror. It was difficult to get a sense of distance with just the mirror. When I was passing someone in front of the bus stop, I checked the mirror and was able to drive close to the wall (daily driver).

4. Discussion

Table 1 shows that the three items of reversing, parking, and turning were significant, and the three items of turning left and right, reversing diagonally, and general ease of driving tended to be significant, and the condition with mirrors was less anxious and easier to drive. These results indicate that the presence of side mirrors allows drivers to drive with confidence in situations where rearview confirmation is required. Table 2 also shows that the presence of side mirrors increases operability and reassurance, in a direct comparison between the presence and absence of mirrors.

In a study on rearview confirmation while riding, checking the rear view displayed on a power wheelchair requires less twisting of the neck and waist, and is effective in reducing physical strain [10].

In addition, in a bicycle simulator, the installation of side mirrors significantly reduced the time required to check left and right and behind [9]. The factors that increased operability and reassurance in this experiment are thought to be the reduction in physical strain and the efficiency of information processing due to rearview confirmation using side mirrors.

According to the results of the interview survey in Section 3.2, many participants checked the rear of the vehicle both in the side mirror and in their eyes when parking. They checked the rear of the vehicle in the mirror, and then visually. This result was consistent with the findings of a bicycle simulator in which participants were favorable to the use of side mirrors, but were uneasy about checking only the side mirrors and wanted to check the rear of the vehicle with their own eyes [9]. By checking the rear information to a certain extent in the side mirror, the range of rear information that needs to be checked visually is limited, so the angle of the body to be twisted is narrowed and the physical burden may be reduced.

The method of checking the side mirror when moving forward varied from person to person. Some participants were too busy processing information to check the front and did not pay attention to the side mirror, while others looked at the side mirror as needed to check the rear. Two participants who drive a car in their daily life frequently checked the side mirror when moving forward and tended to use it effectively. For example, one of the daily drivers was able to drive close to the side of the sidewalk wall by checking the side mirror (in Section 3.2). The nine participants in this experiment, who do not drive in their daily life, had no experience using side mirrors to check the rear. By getting used to riding a WHILL equipped with side mirrors, the effectiveness of using the mirrors when moving forward may increase.

The mirror surface of the side mirror in this experiment was 4.5 cm high x 11.5 cm wide, and the mirror surface area was 51.8 cm2. 72.7% of the participants rated the mirror as small in size and narrow in height (in Table 3). Some participants said that the image they wanted to check was slightly different from the image reflected in the mirror, and that they did not fully trust the image in the mirror and checked it with their eyes after looking in the mirror (in Section 3.2). This result is thought to be partly due to the small size of the side mirror in this experiment. The distance between the driver and the side mirror is not significantly different for electric wheelchairs compared to motorcycles. Motorcycle inspections require the mirror surface area to be 69 cm2 or more [13]. Of course, motorcycles run on roads and have higher speed limits, so it is thought that they need to quickly check a wider range of rear information than a WHILL. However, it is also possible that drivers are accustomed to the size of side mirrors on cars and motorcycles. By increasing the height of the side mirrors in this experiment, it is expected that rear confirmation using the mirror and visual inspection will become easier, processing speed will be faster, and a sense of security will increase.

Side mirrors are optional for electric wheelchairs, just like bicycles. When an electric wheelchair does not have side mirrors, there are three ways to check behind the wheel: visual inspection, the lights of a car or other vehicle, or the sound of the vehicle moving [9]. However, it is difficult to see the lights of a bicycle or other vehicle during the day, and the sound of a bicycle or other vehicle moving is drowned out by the sound of cars moving on the road, making it difficult to hear. While 81.8% of the participants in the experiment rated the price of the side mirrors as high (in Table 4), the rate of those who wanted to purchase a mirror at this price was high (72.3%) (in Table 5). In other words, they judged the side mirrors to be an option that was worth the price. The effectiveness of side mirrors in terms of operability and safety has been shown [9,10], and this was verified in this experiment. In the UK, Class 3 electric wheelchairs that can be used off-side pavements are required to have a maximum speed of 8 mph (approximately 13 km/h) or less and to have mirrors that allow rear visibility. From a safety perspective, it may be a good idea to provide side mirrors on electric wheelchairs as standard, rather than as an option, and only offer them to select customers [14].

5. Future Considerations

The following two points are to be considered in the future.
The first is to verify the operability of the device for elderly people. The author believes that one of the target groups for WHILL is people who live in the following living environments:

- Unable to drive a car due to license surrender,
- No one nearby who can drive to and from the house,
- Physical problems make it difficult to ride a bicycle,
- No public transportation in the area, or the bus stop or station is far from the house,
- Need to go out every week to the supermarket or hospital, which is about the last mile (about 1.6 km) from the house. People who live in living environments with these elements are mainly elderly people. In the future, when physical function declines, the most preferred means of transportation was to ask family members and use public transportation, followed by a handle-type electric wheelchair (30%) [15]. The participants in this experiment were young, with an average age of 26.0 years (in Section 2.2). Compared to younger people, elderly people look less at the side mirrors and rearview mirrors when driving a car [12]. A future topic for consideration will be a comparative verification of WHILL's operability and how to check rearward in the side mirrors between older and younger people.

The second is the verification of WHILL's operability on highly congested sidewalks. In this study, test drives were conducted on uncrowded sidewalks, and pedestrians and cyclists traveling in the same and opposite directions avoided WHILL's passage when WHILL was being driven. However, there are many situations in daily life where travel is highly congested, such as sidewalks in urban areas, busy tourist spots, and exploring theme parks. When travelling on highly congested sidewalks, it is expected that the driver of WHILL will need to check rearward in the side mirrors and change lanes while travelling. A future topic for consideration will be a comparative verification of WHILL's operability at different levels of congestion.

Ethical Compliance

This study was conducted using a WHILL donated to our university by Kyoto Daihatsu Sales Co., Ltd.

Acknowledgements

Kyoto Daihatsu Sales Co., Ltd. and WHILL Co., Ltd. provided various advice. I would like to express our deepest gratitude.

References

1. Horiide Shino. (2023). Utilizing personal mobility for the last mile of transportation for the elderly. *Rehabilitation Engineering , 38* (1), 18-22.
2. Asami, M., & Hirose, H. (2019). Elucidation of the effect of cognitive decline on the driving skills of a handle-type electric wheelchair. *Research Report Collection: Traffic Safety, Elderly Welfare, 25*, 37-39.
3. Murakami, T., Yasuda, T. (2012). Studies on electrically powered wheelchairs adjusting to operation abilities of users : 6th report : An attempt to evaluate the operation abilities of users. *JSME annual Conference on Robotics and Mechatronics*, 1-4.
4. Maruoka, T., Miyano, H., & Kamoji, S. (2022). Acceptance of electric wheelchairs in public spaces. *Rehabilitation Engineering , 37* (3), 146-153.
5. WHILL Co., Ltd.
6. Sakai, K., & Yasuda, M. (2024). Verification of the Operability of Short-Distance Mobility Vehicles (Electric Wheelchair) WHILL Through Test Drive Experiments. *Psychology, 14*(4), 121-131.
7. Takahashi, H., Suzuki, K., Nishino, T., Shibao, Y., Noguchi, H., Kanamori, A., ... & Yamazaki, M. (2024). Safety and feasibility of in-hospital autonomous transportation using a driverless mobility for patients with musculoskeletal disorders: preliminary clinical study to achieve mobility as a service in medical care. *BMC musculoskeletal disorders, 25*(1), 352.
8. Niigata City. (2022). Short-distance Mobility WHILL Social Experiment.
9. Onooka, H., Murano, R., Tomono, T., Iwaasa, T., & Kato, M. (2022). The effect of side mirrors on rear safety checks while cycling. *Ergonomics*, 58(Supplement), 1B3-03.
10. Watanuki, K., Shirasawa, T., Wakabayashi, T. (2006). Evaluation of physical burden for electric wheelchair users : In the case of run with level difference and rear confirmation. The JSME Symposium on Welfare Engineering, 35-38.
11. Satoru Kubota, Hayato Kikuta, Tomoaki Ryu, & Hiroki Kitajima. (2021). The required field of view and its implementation feasibility for a camera monitor system replacing automobile side mirrors. *Journal of the Institute of Image Information and Television Engineers , 75* (2), 319-324.
12. Fukuda, R. (2009). Visual information reception and driving behavior of elderly drivers. *Human Engineering , 45* (3), 183-188.
13. Motor-Fan Bikes If it's too small, you get 1 violation point.
14. Ministry of Land, Infrastructure, Transport and Tourism: Survey results on the use of electric wheelchairs overseas.
15. Ajimi, A. (2023). Recognition that general citizen living in hill and mountainous have for electrically powered scooters. Japanese Journal of Traffic Psychology, 39(1), 1-8.