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Comparison of Design and Operability Evaluations Between Two Electric Wheelchair Models

Koji Sakai, Tomoko Tonami, Hiroshi Kanaji
Kyoto Koka University, Kyoto, Japan

In this study, a comparative test-ride experiment involving 17 university students was conducted using the WHILL Model S (WHILL, Inc.) and the e-SNEAKER (Daihatsu Motor Co., Ltd.). Participants evaluated the design before the test ride, and assessed factors such as operability, ride comfort, and a sense of security afterward; follow-up interviews were also conducted. The results revealed differing trends between the pre-ride design evaluation and the post-ride operability assessment, with no significant correlation found between initial impressions and overall satisfaction. While the WHILL received high marks for seating comfort and general comfort, the e-SNEAKER was highly rated for minimal vibration and a sense of security when traversing steps. Furthermore, the sense of security was the strongest factor influencing overall satisfaction. These findings suggest that selecting an electric wheelchair requires a comprehensive evaluation based on actual test-ride experiences, rather than relying solely on catalogs or visual appearance. This study proposes a user-centered comparative evaluation method that integrates pre-ride design assessments with post-ride operability evaluations, thereby providing valuable insights for the selection of electric wheelchairs.

Keywords: electric wheelchair, WHILL Model S, e-SNEAKER, design evaluation, operability, perceived safety

Introduction

In recent years, with the aging population and the increasing number of elderly people with declining physical functions, demand for electric wheelchairs has expanded not only in the medical and welfare fields but also as mobility aids for daily life. According to Global Market Insights (GMI), the global electric wheelchair market is expected to continue growing, and safety and convenience are predicted to improve further through advancements in battery technology, AI (artificial intelligence) and IoT (internet of things)-based driving assistance functions, and weight reduction and increased functionality. Furthermore, the importance of electric wheelchairs as mobility aids for daily life is increasing against the backdrop of the promotion of home healthcare and community-based integrated care. Currently, major manufacturers such as Permobil, Ottobock, MEYRA, Sunrise Medical, Invacare, and Pride Mobility Products are leading the global market, and in Japan, companies such as WHILL, Yamaha Motor, and Suzuki are developing and selling a variety of electric wheelchairs.

Koji Sakai, Ph.D., Professor, Faculty of Career Development, Kyoto Koka University 38 Kadono-cho Nishikyogoku, Ukyo-ku, Kyoto, Japan.
Tomoko Tonami, Ph.D., Associate Professor, Faculty of Health Science, Kyoto Koka University 38 Kadono-cho Nishikyogoku, Ukyo-ku, Kyoto, Japan.
Hiroshi Kanaji, Ph.D., Professor, Faculty of Career Development, Kyoto Koka University 38 Kadono-cho Nishikyogoku, Ukyo-ku, Kyoto, Japan.

Previous research on electric wheelchairs has reported numerous comparisons of operating methods and machine performance. Asakawa, Yoshidome, and Nishihara (2007) compared joystick-type, push-button-type, and voice-controlled types and showed that joystick-type wheelchairs offered the best operability. Furthermore, Rentschler (2002) compared five types of electric wheelchairs based on ANSI/RESNA standards and reported that there were significant differences in safety and performance such as stability, braking performance, and obstacle-climbing ability among the machines, and that standardized performance evaluation is necessary for selecting a machine suitable for the user. Pellegrini et al. (2010) compared three types of electric wheelchairs and revealed differences between machines in indoor and outdoor driving performance and satisfaction evaluation using QUEST, pointing out the importance of evaluation that combines driving tests and user evaluations.

On the other hand, in recent years, research focusing on evaluation from the user's perspective has also been progressing. Layer, Levy, and Nelson (2010) showed that in evaluating electric wheelchairs, it is necessary to evaluate not only the user's attributes and lifestyle, but also the operability and stability indoors and outdoors separately. Furthermore, Kataishi (2023) pointed out the importance of a comprehensive suitability evaluation that includes not only the user's physical and cognitive functions, but also the living environment and road environment. In addition, Asada and Otsuyama (2022) measured the vibration acceleration during operation for self-propelled handle-type electric wheelchairs and power-assisted wheelchairs and compared the ride comfort levels based on ISO2631-1. The results showed that ride comfort is influenced by the vehicle structure, road surface conditions, and the operator's operating characteristics, and that ride comfort evaluation is important from the perspective of improving quality of life (QOL) and supporting outings. Asada and Otsuyama (2019) and Koya et al. (2023) have reported that the vehicle structure and road surface conditions affect ride comfort and vibration characteristics, demonstrating the importance of comfort evaluation.

The authors have previously reported changes in impressions and operability before and after test rides of the WHILL (Sakai & Yasuda, 2024), improvements in safety due to the installation of side mirrors (Sakai, 2024), and the impact of sidewalk width on operating burden and psychological safety (Sakai, Tonami, & Kanaji, 2026). These studies have shown that a comprehensive evaluation of electric wheelchairs is important, including not only the performance of the machine itself, but also the usage environment and the psychological evaluation of the user. However, most previous studies have focused on comparing operating methods, evaluating performance, or user evaluations of a single device. There are very few studies that compare the design evaluation before a test ride and the operability, sense of security, and ride comfort after a test ride of handlebar-type electric wheelchairs from different manufacturers and examine the relationship between the visual impression and the actual user experience.

Therefore, this study aimed to clarify the influence of machine characteristics on user evaluations by comparing pre-test design evaluations and post-test operation evaluations of the WHILL Model S from WHILL Corporation and the e-SNEAKER from Daihatsu Motor Co., Ltd. This study aims to complement previous research that focused on objective machine performance comparisons and provide useful insights for selecting electric wheelchairs through subjective user evaluations.

Method

Experiment Period

The experiment was conducted from May to June 2026. The average temperature on the experiment days was 26.1°C (SD = 3.0), and the average humidity was 52.6% (SD = 10.6). Both conditions were sunny and cloudy, and there was no rain.

Experiment Participants

The experiment involved 17 students from our university (5 males and 12 females). Their ages ranged from 18 to 63 years (average 21.5 years) (including working students), and all were able to walk independently in their daily lives and did not regularly use electric wheelchairs. Three participants had prior experience riding electric wheelchairs, while 14 did not.

Laboratory Equipment

The electric wheelchairs used for comparison were the WHILL Model S manufactured by WHILL Corporation and the e-SNEAKER manufactured by Daihatsu Motor Co., Ltd. Both are handlebar-type electric wheelchairs, with a maximum speed of 6 km/h, a maximum step clearance of 7.5 cm, and a maximum road gradient of 10°. However, their specifications, such as body dimensions, seat height, and tire diameter, differ. The main specifications of both models are shown in Table 1, and their external appearance and control sections are shown in Figures 1a and 1b.

Experimental Environment

The test ride experiment was conducted on a course set up on public sidewalks within and around the university campus. The test ride course was the same as that used in the study by Sakai et al. (2026) and included both wide and narrow sidewalks. The total distance of the test ride course was 565 m, and the time taken was approximately 9 minutes and 48 seconds per aircraft.

Evaluation Items

Prior to the test ride, participants were shown only the exterior of each aircraft and asked to complete a design evaluation questionnaire. The questionnaire consisted of 15 items across two scales: a “design scale” and a “usability scale”, and was evaluated on a five-point scale (Table 2).

After the test ride, participants were asked to complete a test ride evaluation questionnaire consisting of 16 items, including ride comfort, operability, sense of security, and overall evaluation for each aircraft (Table 3). In addition, a direct comparative evaluation of the design and post-test ride was conducted, along with an open-ended interview survey.

Experimental Procedure

The experiment was conducted using the following procedure:

(1) After observing the two aircraft, the experiment participants first answered a design evaluation questionnaire about one aircraft and then answered the same questionnaire about the other aircraft. Subsequently, a design evaluation was conducted comparing the two aircraft directly.

(2) After the experimenter explained the basic operation of one of the aircraft, the participants practiced operating it thoroughly on a practice course on the university campus. After the practice, they drove at their own speed on a test course that included public sidewalks around the university. To ensure safety, the experimenter always walked behind the participants and gave verbal instructions to ensure safety as needed. After the test ride, the participants answered a test ride evaluation questionnaire.

(3) The other aircraft was also tested and evaluated using the same procedure.

(4) A direct comparison of the design and post-flight evaluation of both aircraft was conducted, followed by semi-structured interviews regarding the aircraft’s characteristics and areas for improvement.

Furthermore, to eliminate order effects, the design evaluation, test drive order, and comparison order were counterbalanced among participants.

Statistical Analysis

For design evaluation and test drive evaluation, the mean and standard deviation of each item were calculated. Prior to analysis, the distribution of scores for each scale was confirmed. A paired t-test was used to compare WHILL Model S and e-SNEAKER, correlation analysis was performed to examine the relationship between design evaluation and test drive evaluation, and multiple regression analysis was performed to analyze the factors contributing to overall satisfaction in the test drive evaluation. The significance level was set at 5%. SPSS was used for statistical analysis. In addition, free-response comments were categorized into similar content using content analysis.

Ethical Considerations

Participants were informed, both in writing and verbally, of the research objectives, that their participation was voluntary, and that their personal information would be anonymized. Their consent was obtained. Furthermore, it was explained that this test drive experiment was a low-risk study, and that in the event of an accident, the insurance policy covering all participants would apply. This research was conducted with the approval of the Kyoto Koka University Research Ethics Review Committee (Approval Number 25-1).

Table 1

Comparison of Two Aircraft (WHILL, e-SNEAKER)

	WHILL	e-SNEAKER
Body size	Overall length: 1,182 mm Overall width: 557 mm Overall height: 915 mm	Total length: 1,130 mm Overall width: 645 mm Overall height: 985 mm
Main unit weight	67 kg	64 kg
Load capacity	100 kg	100 kg
Tire diameter	Front wheel 265 mm Rear wheel 265 mm	Front wheel 340 mm Rear wheel 290 mm
Seat size	Seat width 43 cm x depth 43 cm	Seat width 42 cm x depth 40 cm
Seat height	55 cm in this experiment (Adjustable in 3 stages)	63 cm in this experiment (Adjustable in 3 stages)
Maximum speed	6 km/h	6 km/h
Overcoming steps	Maximum 7.5 cm	Maximum 7.5 cm
Width of trench	up to 10 cm	up to 10 cm
Road gradient	up to 10 degrees	up to 10 degrees
Suitable height	130-150 cm	140-185 cm

(a) WHILL (b) e-SNEAKER

Figure 1a. Overall view of the aircraft, seat, and tires (image courtesy of (a) WHILL and (b) Daihatsu).

(a) WHILL (b) e-SNEAKER

Figure 1b. Handle, accelerator, and speed control section of two aircraft (image courtesy of (a) WHILL and (b) Daihatsu).

Result

Design Evaluation

Table 2 shows the results of the design evaluation of the two devices. The evaluation consisted of two scales: the "Design Scale" and the "Usability Scale". In terms of design, the e-SNEAKER ($M = 3.88$) scored significantly higher than the WHILL ($M = 3.12$) in "2. Has a high-class feel" ($p < 0.05$). The e-SNEAKER also tended to score higher in "1. Has a stylish design" ($p < 0.10$). On the other hand, WHILL scored significantly higher in "11. Seems easy to operate" ($p < 0.01$) and "12. Seems easy to use in public" ($p < 0.05$) and tended to score higher in "10. Seems safe to use" ($p < 0.10$). Furthermore, both the Design Scale (Cronbach's $\alpha = 0.804$) and the Usability Scale (Cronbach's $\alpha = 0.747$) showed sufficient internal consistency.

Table 2

Results of Design Evaluation of Two Aircraft (WHILL, e-SNEAKER)

	WHILL		e-SNEAKER			
	Average	SD	Average	SD	Cohen' d	t-test
(1) Design quality (alpha coefficient = 0.804)						
1. The design is stylish.	3.65	1.11	4.29	0.69	-0.490	p < 0.10
2. It has a luxurious feel.	3.12	0.86	3.88	0.86	-0.637	p < 0.05
3. It is futuristic.	4.12	0.99	4.18	0.73	-0.051	n.s.
4. Refined.	4.24	0.75	4.12	0.60	0.127	n.s.
5. Approachable.	4.12	1.11	3.88	1.05	0.169	n.s.
6. Good first impression.	4.47	0.80	4.29	1.05	0.132	n.s.
(2) Utilization acceptance (alpha coefficient = 0.747)						
7. I would like to ride it.	4.53	0.72	4.35	0.93	0.137	n.s.
8. I would like to use it on a daily basis.	4.24	0.97	3.94	1.03	0.254	n.s.
9. I feel that going out would be fun.	3.94	0.97	4.38	0.62	-0.424	n.s.
10. Seems like it can be used with peace of mind.	4.59	0.51	4.24	0.75	0.449	p < 0.10
11. Seems easy to use.	4.35	0.93	3.82	0.88	0.738	p < 0.01
12. Seems easy to use in front of others.	4.41	1.06	4.18	1.01	0.538	p < 0.05
13. It doesn't look like an electric wheelchair.	3.88	1.36	3.88	1.11	0	n.s.
14. It doesn't seem like it would be embarrassing to ride.	3.88	1.32	4.06	1.03	-0.124	n.s.
(3) Overall evaluation						
15. Overall attractive.	4.18	0.81	4.41	0.62	-0.216	n.s.

Test Drive Review

Table 3 shows the results of the test ride evaluation of the two vehicles. In terms of operability, the e-SNEAKER scored significantly higher than the WHILL in "1. Less vibration" ($p < 0.001$) and "2. Less impact from bumps" ($p < 0.01$). On the other hand, WHILL scored significantly higher in "3. Comfortable seating" (p <

0.01) and “4. Less tiring even when riding for long periods” ($p < 0.05$). In addition, the e-SNEAKER scored significantly higher in “12. Less anxiety on bumps” ($p < 0.01$) and “14. Overall sense of security” ($p < 0.05$) and tended to score higher in “13. Less anxiety on inclines” ($p < 0.10$). The operability scale (Cronbach’s $\alpha = 0.705$) and the sense of security scale (Cronbach’s $\alpha = 0.809$) showed sufficient internal consistency.

Table 3

Results of Test Ride Evaluations of Two Aircraft (WHILL, e-SNEAKER)

	WHILL		e-SNEAKER			
	Average	SD	Average	SD	Cohen’ d	t-test
(1) Operability (α coefficient = 0.705)						
1. Less vibration	3.00	1.58	4.53	0.62	-0.989	p < 0.001
2. Less impact from bumps and uneven surfaces	3.00	1.54	4.41	0.62	-0.850	p < 0.01
3. Comfortable to sit on	4.94	0.24	3.71	1.26	0.950	p < 0.01
4. Less tiring even when riding for long periods of time	4.59	0.87	3.65	1.37	0.562	p < 0.05
5. Stable driving	4.12	1.05	4.47	0.62	-0.317	n.s.
6. Forward operation	4.47	0.62	4.12	0.86	0.354	n.s.
7. Easy to adjust speed	4.29	1.26	4.06	1.09	0.127	n.s.
8. Easy to steer	4.24	1.09	4.53	0.62	-0.210	n.s.
9. Easy to maneuver in tight spaces	4.06	0.97	4.41	1.00	-0.289	n.s.
10. Easy to operate in confined spaces	3.82	1.19	4.12	1.11	-0.174	n.s.
(2) Sense of security (alpha coefficient = 0.809)						
11. Safe even when near pedestrians	3.88	1.17	4.35	0.70	-0.354	n.s.
12. Less anxiety due to uneven surfaces	3.00	1.27	4.24	0.75	-0.771	p < 0.01
13. Less anxiety due to the slope	3.47	1.18	4.06	0.97	-0.429	p < 0.10
14. Overall, there is a sense of security.	3.94	1.03	4.59	0.62	-0.530	p < 0.05
(3) Overall evaluation						
15. Overall satisfaction	4.29	0.77	4.47	0.51	-0.243	n.s.

Relationship Between Design Evaluation and Test Drive Evaluation

Using 34 data points from WHILL and e-SNEAKER, Pearson’s product-moment correlation coefficient was calculated to examine the relationship between the design evaluation “15. Overall attractive” and the test drive evaluation “15. Overall satisfaction”. The results showed no significant correlation between the two ($r = 0.076$, n.s.). In other words, the first impression before the test drive was not directly related to the overall satisfaction after the test drive.

Factors Influencing Overall Satisfaction in Test Drive Evaluations

Table 4 shows the results of a multiple regression analysis with overall satisfaction in the test drive evaluation as the dependent variable. The explanatory variables included “design appeal” and “usability” from the design evaluation, and “operability” and “sense of security” from the test drive evaluation, entered using the forced entry method. The multiple regression model was statistically significant ($F(4,29) = 8.14$, $p < 0.001$), with an adjusted R^2 of 0.464. In the standardized partial regression coefficients, only “sense of security” showed a significant positive influence ($\beta = 0.490$, $p < 0.05$). On the other hand, “design appeal”, “usability”, and “operability” did not show a significant influence. The adjusted R^2 was 0.464, indicating a model with moderate explanatory power.

Table 4

Results of Multiple Regression Analysis With Overall Satisfaction Level in Test Drive Evaluations as the Dependent Variable

Explanatory variables	Standardized coefficient	VIF	t-value	Significance probability
Design	-0.100	1.733	-0.595	n.s.
Usability	0.036	1.698	0.217	n.s.
Operability	0.309	2.08 0	1.681	n.s.
A sense of security	0.490	1.949	2.751	$p < 0.05$

Interview Survey

Table 5 shows the results of the interview survey. For WHILL, the most frequently cited issues were “good seating comfort and cushioning”, “easy speed adjustment with the dial”, and “strong vibration, making it easy to feel uneven road surfaces”, each with 10 responses. Additionally, “the chair height is just right” and “the screen is difficult to see” each received five responses.

On the other hand, for the e-SNEAKER, the most common complaint was “low vibration and stable” (11 responses), followed by “the seat is too high” (10 responses) and “arms and wrists get tired from holding the accelerator” (9 responses). Additionally, “feels secure even on uneven surfaces and slopes” and “the digital screen is easy to see” each received five responses.

Table 5

Results of Interviews Regarding Two Aircraft

WHILL	
Interview content	Frequency
Comfortable to sit on and has good cushioning.	10
Speed can be easily adjusted using the dial.	10
The vibrations are strong and you can easily feel the unevenness of the road surface.	10
The chair height is just right.	5
The screen (speed/battery) is difficult to see.	5
Lever operation is less tiring.	4
I felt there was a possibility of sudden acceleration or misoperation.	4
There is ample legroom.	3
It felt fast-paced and scary.	2
e-SNEAKER	
Interview content	Frequency
Low vibration and stable.	11
The chair is high.	10
Holding the accelerator for so long tires your arms and wrists.	9
It provides a sense of security even on uneven surfaces and slopes.	5
The digital screen is easy to see.	5
The button-type speed control is easy to understand.	4
The screen is difficult to see in the sunlight.	4
Easy to maneuver in tight spaces.	3
It gives the impression of coming to a sudden stop.	3
Display and warning functions contribute to peace of mind.	2

Comparison of Test Drive Evaluations and Interview Surveys

Table 6 shows a comparison of the combined results of test ride evaluations and interview surveys. WHILL was praised for its “comfortable seating” and “ease of lever operation”, but many users also commented on "high vibration" and "difficulty seeing the screen". In contrast, the e-SNEAKER received high marks for safety and stability, with users noting "stable ride with minimal vibration" and "a sense of security even on bumps and inclines". However, some users pointed out issues such as "high seating position" and "fatigue due to constantly holding the accelerator". Regarding speed adjustment, users preferred the dial-type control for WHILL and the button-type control for e- SNEAKER, highlighting the distinct characteristics of each device. Overall, WHILL was highly rated by users for its comfort, while e-SNEAKER was highly rated for its sense of security and stability.

Table 6

Comparison Based on Test Drive Evaluations and Interview Results

Category	WHILL	e-SNEAKER
Seating comfort	◎ Good cushioning and seating comfort	△ The seat is high and narrow
Driving performance	△ High vibration	◎ Low vibration and stable
Operability	〇 Less fatigue when holding the lever	△ It's easy to get tired from holding the accelerator
Speed adjustment	○ Easy to adjust with a dial	○ Easy to understand with button controls
Screen display	△ Difficult to see	△ Difficult to see due to sunlight
Comprehensive evaluation	Highly rated for its comfort	Highly valued for its sense of security and stability

Discussion

Discrepancy Between Pre-test Drive and Post-test Drive Design Evaluations

This study revealed different evaluation trends between design evaluations before the test drive and operability evaluations after the test drive. Furthermore, no significant correlation was found between the overall design evaluation and overall satisfaction after the test drive, indicating that the first impression from the appearance does not necessarily determine actual user satisfaction.

While many conventional electric wheelchair studies have compared operability and safety performance, few have focused on changes in impressions before and after test rides. Rentschler (2002) compared five types of electric wheelchairs based on ANSI/RESNA standards and reported that even within the same electric wheelchair standard, there were significant differences in stability, braking performance, and obstacle-climbing ability. Furthermore, Pellegrini et al. (2010) combined indoor and outdoor driving tests with QUEST for three electric wheelchair models and found differences in operability and satisfaction among the machines, highlighting the importance of using both driving tests and subjective evaluations.

This study is also unique in that it compares design evaluations and test ride evaluations with the same participants. Before the test ride, WHILL was rated as "easy to operate" and "seems safe to use", but after the test ride, its evaluation regarding vibration decreased. Conversely, e-SNEAKER was not only praised for its premium feel and design, but also highly rated for its low vibration and sense of security during the actual test ride. This indicates that users' impressions based on appearance are modified after test riding the product.

Therefore, when selecting an electric wheelchair, it is extremely important to evaluate its actual operability and ride comfort through a test ride experience, rather than judging solely from catalogs or appearance.

Differences in the Characteristics of the WHILL and e-SNEAKER

This study revealed that WHILL and e-SNEAKER have distinct characteristics. WHILL received significantly higher scores for "comfort" and "less fatigue even after long rides", and many users commented on its "high cushioning" and "less fatigue from lever operation" during interviews. On the other hand, e-SNEAKER received significantly higher scores for “low vibration”, “less impact from bumps”, and “a sense of security”, with many users praising its riding stability.

Asada and Ohtsuyama (2019) reported that the vehicle structure and road surface conditions greatly affect ride comfort and stated that tire structure and cushioning performance in particular influence comfort. Furthermore, Koya et al. (2023) have shown that the vibration response of a handle-type electric wheelchair is affected not only by road surface conditions but also by the vehicle structure.

In this study, it is possible that the e-SNEAKER’s large front wheel diameter and body structure, which contribute to its superior shock absorption from the road surface, led to its positive evaluations of “less vibration” and “feeling safe even over bumps”. In addition, the difference in the control input method (lever type vs. accelerator type) may have influenced upper limb strain and the feeling of operation. The interview survey (Table 5) also supported these results, with opinions such as “lever operation is less tiring” for WHILL and “holding the accelerator for so long is tiring” for e-SNEAKER. On the other hand, it is presumed that the WHILL’s lower seat height and larger seat size contributed to its high evaluation of body support and seating stability.

In short, this study suggests that the ride comfort and sense of security experienced by users are not simply due to differences between manufacturers, but rather are the result of a complex interplay of multiple design elements, including tire diameter, seat height, cushioning, and operating methods.

Key Factors That Determine Overall Satisfaction With a test Drive

In the multiple regression analysis, only “sense of security” had a significant impact on overall satisfaction. On the other hand, design, usability, and operability were not significant explanatory variables.

Layer et al. (2010) have shown that the future utility of electric wheelchairs can be explained not only by current satisfaction but also by safety, independence, and lifestyle. Furthermore, Kataishi (2023) stated that the selection of electric wheelchairs requires a comprehensive suitability assessment that includes not only physical function but also road and housing environments.

In this study, a sense of security was identified as the most important explanatory variable, suggesting that users may value a “device that allows them to go out with peace of mind” more highly than a “device that is easy to operate”. Situations such as passing pedestrians, steps, and slopes are frequently encountered in daily use, and it is thought that the psychological sense of security in these situations greatly influences overall satisfaction. Pellegrini et al. (2010) also reported that evaluations of safety and ease of use in QUEST are related to user satisfaction, which is consistent with the results of this study. The authors’ previous research has reported that psychological tension and operational burden increase on narrow sidewalks. The results of this study support the findings of previous research that not only device performance but also suitability to the usage environment influences user satisfaction.

Practical Implications of This Study

The results of this study offer several practical suggestions for the selection and dissemination of electric wheelchairs. First, when users choose a wheelchair, it is important not to judge solely based on catalogs or appearance, but to test riding it and experience its operability, ride comfort, and sense of security before deciding. Second, it is desirable for medical and welfare professionals and sales companies to support the selection of wheelchairs that consider not only the user’s physical function but also the daily usage environment, such as the living environment, sidewalk width, steps, and slopes. Furthermore, it is expected that manufacturers will be able to design wheelchairs that balance comfort and safety by reflecting the characteristics and areas for improvement of each wheelchair revealed in this study into product development. In the future, as the number of electric wheelchair users is expected to increase further with the aging population, accumulating comparative evaluation data that incorporates subjective evaluations from users in addition to objective performance evaluations is expected to support the selection of wheelchairs that are suitable for each individual user, as well as contribute to promoting the dissemination of electric wheelchairs and improving the quality of life (QOL).

The evaluation method proposed in this study, which combines “design evaluation before test ride” and “operability evaluation after test ride”, can not only be used as a user-centered evaluation method for electric wheelchairs, but also has the potential to be applied in the future to the development of evaluation criteria and test ride programs for personal mobility in general. In the future, it will be necessary to further enhance the validity of the evaluation method proposed in this study by conducting further verification with elderly people and actual electric wheelchair users.

Proposal for Suitable Environments for the Two Aircraft

Table 7 compares the suitable environments for home use based on the results of this study. The two devices have different recommended user profiles, housing environments, road environments, and purposes of use, and it is desirable to choose according to the user’s living environment. The WHILL Model S was evaluated for its seating comfort, comfort during long-term use, and ease of lever operation, making it suitable for use on relatively flat sidewalks with sufficient width or in residential areas with good pavement, for purposes such as long walks, shopping, and going to parks. On the other hand, the e-SNEAKER was highly evaluated for its low vibration and sense of security when traveling oversteps and inclines, making it suitable for use on residential streets with slopes, steps, uneven sidewalks, or living environments with steps.

Figure 2 is a conceptual diagram that organizes the contents of Table 7 along two axes: the usage environment and the values that users prioritize. WHILL is positioned in the quadrant of “flat roads × emphasis on comfort”, and e-SNEAKER is positioned in the quadrant of “roads with many slopes and steps × emphasis on safety”, conceptually summarizing the characteristics of user evaluations obtained in this study.

Kataishi (2023) points out: In selecting an electric wheelchair, it is important to comprehensively evaluate not only the user’s physical condition but also its compatibility with the living environment and road environment. The compatible environmental model proposed in this study has the potential to be used by medical and welfare professionals in selecting the equipment, in test ride support at sales sites, and as a design guideline in future product development.

Table 7

Comparison of Suitable Environments for Home Use (Proposal)

Item	WHILL Model S	e-SNEAKER
User characteristics	Users who prioritize prolonged outings or maintaining a seated position	Users who prioritize a sense of security and stability
Housing environment	Barrier-free housing, housing with sufficient turning space in the entrance and interior	Houses with steps or slopes at the entrance or when going outside.
Road environment	Flat, well-paved sidewalks and residential roads	Residential roads including steps, slopes, and uneven surfaces
Geographical environment	Relatively flat areas such as urban areas and residential areas	Hilly residential areas and mountainous regions, and other areas with uneven terrain
Recommended use	Walking, shopping, and long outings	Outings include hospital visits, short-distance travel, and walking uphill
Values that we value	Comfort/maintenance of sitting position	Sense of security and driving stability

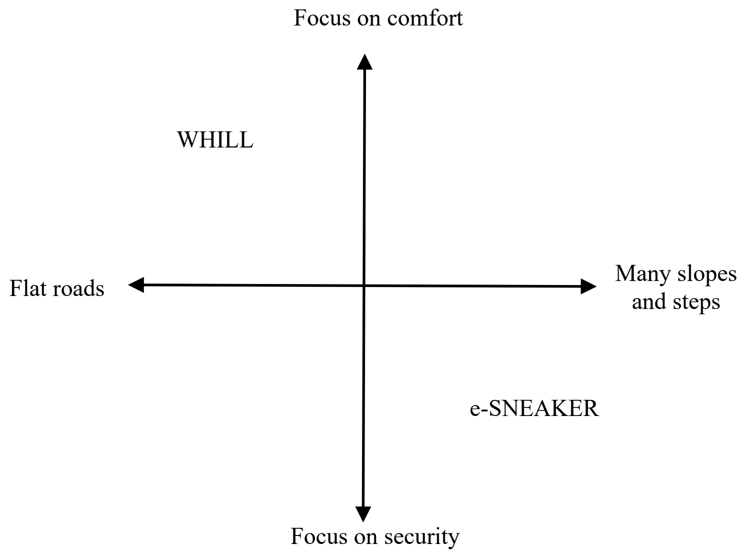

Figure 2. Road environment (horizontal) × User-centric (vertical) matrix for electric wheelchairs.

Limitations of This Study

This study has several limitations. Firstly, the sample size is small, consisting of only 17 healthy university students, and the initial trial ride does not adequately reflect the learning effect. Furthermore, the subjects are not actual electric wheelchair users or elderly individuals. Secondly, the trial ride time was short, and evaluations of long-term use are not reflected. Thirdly, evaluations were not conducted in an indoor environment, and the differences between indoor and outdoor environments pointed out by Layer et al. (2010) were not sufficiently examined. In the future, it is necessary to conduct long-term loan studies targeting the elderly and people with disabilities, and to evaluate use in real-life situations, including sidewalk and residential environments. In addition, it is expected that evaluation methods will be developed that integrate objective indicators such as travel speed, turning radius, travel trajectory, and vibration acceleration in addition to subjective evaluations.

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