Measuring User Experience of Using Battery Swapping Station

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Abstract. This study aims to understand the factors that influence the acceptance of battery swap station (BSS) for electric scooters and the intention of using the BSS in the light of the user experience. This study is an initial stage; therefore, an experiment was conducted with a sample of 28 participants who had no experienced the service from selected BSS of this study - Gostation and filled out user experience evaluation questionnaire for eliciting their emotions and usage intention. The results showed that the average operation time was approximately 32.05 s. All participants agreed with the Gostation may provide them with a convenient charging service. Results also revealed that positive correlations were noted between usage intention and positive emotions, such as the emotions of pleasant surprise, fascination, and desire.

Keywords: Battery swapping station · User experience · Positive emotions · Usage intention

1 Introduction

The world is in the face of an energy shortage, environmental pollution, and global warming [1]. Decreasing CO_2 emissions is viewed as an important policy around the world [2]. Recently, the development of electric vehicles (EVs) has become more popular due to their contribution of alleviating the global energy crisis and reducing emissions [3]. Taiwanese government is dedicated to promoting an eco-environmental protection policy for improving the air quality and public health. One of the aims of the policy is to increase the penetration level of electric two wheelers (E2Ws). The widespread adoption of E2W may bring potential social and economic benefits, such as reducing the usage of fossil fuels and greenhouse gas emissions, as well as environmental benefits. The development of EVs relies on the charging patterns and available charging infrastructure, such as charging piles, charging stations, and battery swap stations (BSSs). The BSS, as one promising charging infrastructure, can provide great convenience to EV customers without considering the all-electric range limit while the BSS is available. The BSS services may let E2W owners avoid long recharge times by simply changing to a fully charged battery in a self-service process that takes only a few minutes. Such battery swapping infrastructure for E2Ws is an innovative service that provides much convenience to E2W riders. The purpose of this study is to

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understand the factors that influence the acceptance of BSS and the intention of using the BSS in the light of user experience.

2 Literature Reviews

2.1 Battery Swapping Station

Electric vehicles (EVs) have received increasing attention because of their high-energy efficiency, low carbon emissions, fuel independency, and environmental friendliness. Road vehicles using fossil fuels in internal combustion engines emits tailpipe pollutants such as coarse particulate matter (PM10), nitrogen oxides (NOx), and volatile organic compounds (VOCs), which are harmful to human health. In addition, road traffic is responsible for a significant and growing share of global anthropogenic emissions of CO2: Decreasing CO2 emission is viewed as an important policy around the world [2]. Many countries are ramping up their effort to push for the adoption of advanced electric drive vehicles in the market. In order to improve the air quality and public health, the Taiwanese government is dedicated to promoting an eco-environmental protection policy. One of the aims of the policy is to increase the penetration level of electric two wheelers (E2Ws). In Taiwan, E2Ws include electric scooters (e-scooters), small-scale e-scooters, electric bikes (e-bikes), and electric-assisted bicycles. However, the majority of customers are still buying traditional vehicles. The EV market growth is hampered by many factors, including poor battery performance, high cost, long battery-charging time, low oil prices, and consumer expectations. "Range anxiety," which is the fear of being stranded in an EV because of insufficient battery performance and accessible charging infrastructure, kept consumers away from EVs [4].

In Taiwan, limited driving range is the major problem that keeps consumers away from E2Ws. Other problems, including inconvenient charging, long charging time, short lifetime, and an expensive purchase price, bring more challenges to battery usage and maintenance. The major ways to charge batteries for E2W owners living in New Taipei city are by plugging the E2Ws into a plug at the owner's home or workplace, or by rapid charging stations at a specialized service center (only a few stations). The development of EVs relies on the charging patterns and available charging infrastructure, such as charging piles, charging stations, and BSS [5]. Unfortunately, current battery technology does not allow for charging in less than half an hour. Hence, charging stations analogous to gas stations, where refueling can be completed in a few minutes, do not currently seem possible [6]. BSS is one of the solutions to address these limitations [6–9]. The concept of exchangeable battery service was first proposed as early as 1896 in order to overcome the limited operating range of electric cars and trucks [10]. An alternative to common charging modes is the deployment of BSSs, which swap a customer's discharged battery with a fully charged one of the same type. If the batteries can be swapped in and out of the EV's, a discharged battery can be replaced with a fully charged one very rapidly. Such swapping stations would require that batteries be easily accessible on the vehicle, and replaceable by an automated process [6]. Furthermore, such stations would require standardization of batteries and interfaces, thus allowing only a few different kinds of batteries for use. As a result, the

BSSs can reduce the customers' concerns about long charging times or having enough stored energy to finish a trip.

2.2 User Experience (UX)

User experience (UX) is the person's experience at the moment experienced [11] and associated with a wide variety of meanings [12], ranging from traditional usability to beauty, hedonic, affective or experiential aspects of technology use. Specifically, UX is a consequence of a user's internal state, the characteristics of the designed product/service/system, and the context/environment within which the interaction occurs. It is subjective and holistic. It has both utilitarian and emotional aspects, which change over time [13]. This creates innumerable design and experience opportunities [14]. In other words, an experience and experience are distinguishable. An experience has a beginning and end, [and] inspires behavioural and emotional change. Experience as a constant stream of self-talk that happens when we interact with products [12]. In human-product interaction, UX is a consequence of the presentation, functionality, system performance, interactive behaviour, and assistive capabilities of the interactive system [15].

Hassenzahl [16] defined the UX as a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service. The International Organization of Standards (ISO) defines user experience as all aspects of the user's experience when interacting with the product, service, environment or facility [15]. Hassenzahl [17] assume that people perceive interactive products along two different dimensions. Pragmatic quality calls for a focus on the product – its utility and usability in relation to potential tasks. In contrast, Hedonic quality calls for a focus on the Self, i.e., the question of why does someone own and use a particular product. Specifically, pragmatic quality is more like the term "usefulness". In the field of ergonomics, the usefulness refers to how well a system achieves a desired goal, and is divided into two subcategories: utility and usability [18]. Utility is the question of whether that functionality in principle can do what is needed; usability is the question of how well users can use the functionality of a system [19]. The two concepts of usability and utility are highly interrelated. With regard to the definition of usability, the International Organization of Standards (ISO) [20] defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. The pragmatic user goals include acceptable perceived experience of use (pragmatic aspects including efficiency), acceptable perceived results of use (including effectiveness), and acceptable perceived consequences of use (including safety). With regard to the hedonic quality, Jordan [21] takes a hedonistic perspective by proposing that pleasure with products is the sum of socio-pleasure, ideopleasure, physiopleasure and psychopleasure. Hassenzahl [17] further identifies stimulation (i.e. personal growth, an increase of knowledge and skills), identification (i.e. self-expression, interaction with relevant others), and evocation (i.e. self-maintenance, memories) as hedonic goals. UX needs to be concerned with satisfying both user pragmatic and hedonic goals related to the experience and outcomes of interaction [22]. UX (satisfaction) is the sum of pragmatic and hedonic quality [17].

3 Methods

This study forms investigation into user experience evaluation based on experimental and survey studies for evaluating user emotions before and after using the BSS. The materials of the study are described as below,

1. Gogoro e-scooter and its BSS service, i.e. Gostation, has been selected.
2. Providing a Gogoro e-scooter, which has 2 batteries.
3. The selected Gostation for this study was located near Fuchu MRT(Mass Rapid Transit) Station, Banqiao District, New Taipei City. It was expected to recruit experimental participants easily and provide them to have a real battery swapping experience.
4. An experimental record form was developed to record each participant's operation time and errors during each run for researchers. The operation time is that the total time participant spent in action was recorded from the start-up of taking one battery inside of the Gogoro e-scooter to the end of inserting 2^{nd} fully-charged battery into Gogoro e-scooter.
5. Pre-experimental subjective rating for user experience evaluation contained the following three sections—(1) personal information: three items designed to collect socio-demographic data on age (20–29, 30–39, 40–49, 50–59, and ≥ 60), education (elementary, junior high, high school (senior), college, master's degree, and other), and occupation (student, industrial, commercial, service industry, teacher, and other); (2) product perception: 6 pairs of contrasting emotions designed to elicit participant's perceived emotions form impressions of Gostation by an eleven-point scale (e.g., satisfaction-neutral-dissatisfaction). The emotional evaluation was adapting PrEmo [23]; (3) usage intention: one item designed to collect his/her intention of using Gostation by an eleven-point scale (willing-neutral-unwilling).
6. Post-experimental subjective rating for user experience evaluation contained the following three sections—(1) product perception: 6 pairs of contrasting emotions designed to elicit of user's perceived emotions after complete 3 experimental runs by an eleven-point scale (i.e., satisfaction-neutral-dissatisfaction); (2) usage intention: one item designed to collect his/her intention of using Gostation after complete 3 experimental runs by an eleven-point scale (willing-neutral-unwilling).

This study is a small scale preliminary study. It was conducted over two month period between January and February 2017. The study recruited people who have never used the Gostation to participate in the experiment. All of the participants have to fill out a pre-experimental subjective rating, after researcher introduced the experimental procedure. And then, they have to complete the operation procedure of swapping 2 batteries for an e-scooter with 3 runs. During the term of swapping batteries for each participants, researcher record each participant's operation time and errors. During the experiment, participant's behavior was video-taped as well. After participant compete the 3 experimental runs, participant has to fill out the post-experimental subjective rating.

4 Results

For the 28 participants who completed the experiment and two experimental subjective ratings, summarized data are shown in Table 1.

Table 1. Demographic information of the participants (N = 28)

Items		Frequency (n) & Sequence				
		1	2	3	4	5
Age	Item	20–29	30–39	40–49	50–59	≥ 60
	Total	17	3	2	2	4
	%	(60.7%)	(10.7%)	(7.1%)	(7.1%)	(14.3%)
Education	Item	College	Senior	≥ Master	Junior	
	Total	19	4	3	2	
	%	(67.9%)	(14.3%)	(8.7%)	(7.1%)	
Occupation	Item	Student	Industrial	Service Industry	Commercial	Other
	Total	10	1	5	4	8
	%	(35.7%)	(3.6%)	(15.7%)	(14.3%)	(28.6%)

4.1 Descriptive Statistics

The average operation time to complete swapping batteries for the experimental participants was 32.05 s (σ = 10.94), amongst the average opersation time of first time to complete swapping batteries at Gostation ($\bar{X}$ = 34.72 s, σ = 13.19), the second time to use the Gostation ($\bar{X}$ = 30.48 s, σ = 9.07), and the third time using the Gosation ($\bar{X}$ = 29.89 s, σ = 11.30), summarized data are shown in Table 2. No error was made by the participants. Participants (N = 28) rated 6 pairs of emotions based on their perceived emotions and usage intention for using Gostation before and after experiment, data are shown in Table 3.

Table 2. Operation time of each experimental run and each operating procedure

Operating procedure	Average operation time					
	Run 1		Run 2		Run 3	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
a. Remove 1st battery from e-scooter and insert it into Gostation	6.17	3.32	4.40	2.07	3.92	2.00
b. Remove 2nd battery from e-scooter and insert it into Gostation	6.72	5.14	5.29	3.50	6.02	5.99
c. Information process and providing 2 fully-charged batteries	10.29	2.03	10.25	1.80	10.45	1.59
d. Remove 1st battery from Gostation and insert it into e-scooter	7.53	3.77	6.07	3.68	5.28	2.44
e. Remove 2nd battery from Gostation and insert it into e-scooter	5.06	3.60	4.47	2.99	4.22	2.48
Total operation time	34.72	13.19	30.48	9.07	29.89	11.30

Table 3. Participants' perceived emotions and usage intention before and after experiment

Items	Before experiment		After experiment	
	$\bar{X}$	σ	$\bar{X}$	σ
Satisfaction	7.64	2.18	7.21	2.49
Desire	7.39	1.85	6.96	2.56
Admiration	7.64	2.36	7.54	2.29
Pleasant surprise	7.11	1.99	7.43	2.04
Amusement	7.64	2.36	7.54	2.29
Fascination	7.71	1.979	7.43	2.33
Usage intention	7.00	1.91	7.14	2.66

4.2 ANOVA

A repeated measure of ANOVA results revealed that the operation time of removing 1^{st} battery from e-scooter and inserting it into Gostation between experimental runs [$F(2, 81) = 6.143$, $p = 0.003 < 0.01$] and the operation time of remove 1st battery from Gostation and insert it into e-scooter between experimental runs [$F(2, 81) = 3.231$, $p = 0.045 < 0.05$] were significant. The multiple comparison of the operation time of removing 1st battery from e-scooter and inserting it into Gostation indicated that run 1 ($\bar{X} = 6.17$ s, $\sigma = 3.32$) and run 2 ($\bar{X} = 4.40$ s, $\sigma = 2.07$) ($p = 0.028 < 0.05$) and run 1 and run 3 ($\bar{X} = 3.92$ s, $\sigma = 2.00$) ($p = 0.004 < 0.01$) were significantly different. Regarding the operating procedure of remove 1st battery from Gostation and insert it into e-scooter, the operation time between run 1 ($\bar{X} = 7.53$ s, $\sigma = 3.77$) and run 3 ($\bar{X} = 5.28$ s, $\sigma = 2.44$) was significantly different. The operation time of each experimental run decreased gradually (see Figs. 1 and 2).

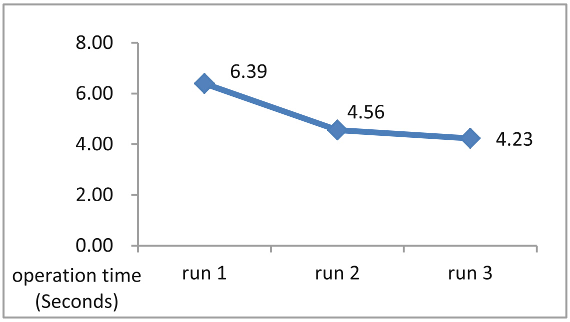

Fig. 1. Comparison of operation time of removing 1 st battery from e-scooter and inserting it into Gostation between experimental runs

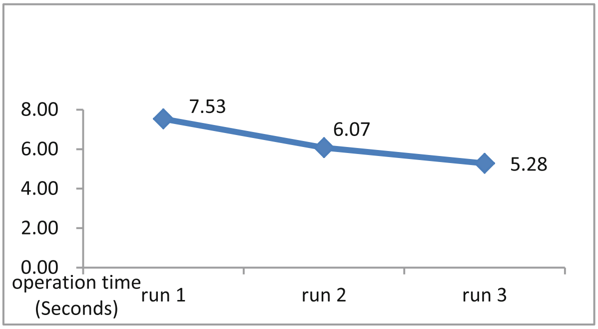

Fig. 2. Comparison of operation time of removing 1st battery from Gostation and inserting it into e-scooter between experimental runs

4.3 t Test

The Paired-Sample T test results indicated that there were no significant differences between the percieved emotions of before experiment and after experiment and between the Gosatation usage intention of before experiment and after experiment.

4.4 Regression Analysis

The regression analysis results revealed that the usage intention before the experiment between 6 positive emotions [F (6, 27) = 6.587, p = 0.001 < 0.01] and the usage intention after using 3 times Gostaion between 6 positive emotions [F (6, 27) = 24.473, p = 0.000 < 0.01] were significant. Also, the coefficient of determination (R^2) showed that the multiple regression equation built based on the data of post-experimental subjective rating (R2 = 0.875) is better than the multiple regression equation built based on the data of pre-experimental subjective rating (R2 = 0.653). The multiple regression is shown by the following.

$$y = -0.264 + 0.583x_1 + 0.523x_2 + 0.558x_3$$

Where:
Y = Usage intention
x_1 = Pleasant surprise
x_2 = Fascination
x_3 = Desire

5 Discussion

The average operation time for e-scooter riders to accomplish swapping batteries by using the Gostation was approximately 32.05 s. We are 95% confident that the operation time is between 28.55 s and 35.55 s. The results did not show a significant learning effect for using the Gostation. Results revealed that user response time of removing 1st battery either from e-scooter or from Gostation were decreased gradually. In other words, Gostation may provide user to accomplish swapping batteries within very short time.

With regard to the participant's perceived emotions, all of them tend to have positive emotions on the Gostation either their impressions of it or their use experience. During the experimental period, many people were unwilling to become our participant. Therefore, the participants of this study were more willing to open their mind to new stuffs or curious about the Gosatation. It may be an important influencing factor to their emotions. This may be an issue to investigate the relation between first impressions of product and intention of trial using product.

With regard to the usage intention, results revealed that the emotions of pleasant surprise, fascination, and desire are important influencing factors of Gostation usage intention. The service of battery swapping station is very special for the people of Taiwan. The appearance of the Gostation presents its innovation and technology. However, price is the main reason not to learn more about the product and service for the scooter-based commuters. In addition, most of the participants were surprised at battery weight, especially for the first time he/she moving it. A lithium-ion battery of this study is approximately 9.8 kg. One participant was caught his hand by Gostasion at the beginning of the procedure because of the heavy battery.

According to the results of this study, the sample size for the following experiment was estimated by the formula $\left[n \geq \left(\frac{Z\sigma}{E}\right)^2\right]$. It was determined that the following experiment will need to sample at least 52 randomly selected participants. With this sample the following experiment will be 95% confident that the sample mean will be within 3 s of the population of Gostation usage.

6 Conclusion

In this study, an experiment and a survey of user experience evaluation were conducted to find participant's operation performance of using the Gostation and elicit their emotions and usage intention. All participants agreed with the Gostation may provide them with a convenient charging service. Results also revealed that positive correlations were noted between usage intention and positive emotions, especially for the emotions of pleasant surprise, fascination, and desire. This preliminary study provides a user experience evaluation and suggestions to the future researches.

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