

# Electroencephalogram as a Validation Method in Usability Testing

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**Abstract** - Usability testing is a recommended main testing method to evaluate the usability or ease of use of a software. However, this approach can induce bias. Usability testing with survey method using questionnaire instruments and interview has a risk of generating lack of objectivity from the participants because the facilitator can influence the evaluation results. The evaluation process is not optimal and the biases that arise from usability testing can affect the success or failure of a software in the market. A method for validating usability testing results needs to be studied to ensure whether the test results obtained are valid and unbiased. Electroencephalogram (EEG) is one of the tool that can be used to validate usability testing. This study aims to conduct usability testing of the three most popular e-marketplace applications in Indonesia. From the results it can be seen that usability testing using user-based testing gives a fairly good result in term of accuracy. Usability testing using EEG gives lower results than user-based testing. Nevertheless, we cannot rule out EEG as a usability testing method in the future.

**Keywords:** E-marketplace, electroencephalogram, usability testing, user experience questionnaire, validation

## I. INTRODUCTION

Electronic marketplace (e-marketplace) is a virtual location where sellers and buyers interact online to make buying and selling transactions [1]-[2]. Even though the majority of buying and selling in Indonesia is dominated by conventional types of businesses, e-marketplaces remain an attractive and easy location for buying and selling transactions [3]. In the first quarter of 2022, it is known that there are 38 e-marketplaces in Indonesia with the top 3 positions held by: Tokopedia, Shopee, and Bukalapak [4]-[5]. Based on a survey conducted by reference [6], it is known that there are several factors that influence the popularity of e-marketplace platforms in Indonesia, such as: reputation, price, product choice, service, promos, ease of use of applications, and so on.

Usability testing is a test that is recommended as the main test to evaluate the usability or ease of use of a

software [7]. Usability testing is generally carried out using a user-based testing approach where participants will test the interface design by following a series of scenarios that have been prepared and continue to fill out questionnaires or interviews with the facilitator [8] and [9]. However, this approach can introduce bias. Testing usability with the survey method using questionnaire instruments and interview methods has a risk resulting in a lack of objectivity from the participants because the facilitator can influence the evaluation results [7] and [10]. Reference [11] adds that instruments such as questionnaires have limitations, such as questions that are ambiguous and social pressure which results in participants not giving objective answers. The evaluation process is not maximal and the bias that arises from usability testing can certainly affect the success or failure of a software in the market. A method for validating usability test results needs to be studied to ensure whether the test results obtained are valid and unbiased.

Electroencephalogram (EEG) is a tool that can be used to validate usability testing. EEG is a tool used to detect changes in brain waves with the help of electrodes to capture the frequencies generated by the brain [12]. Reference [13] defines EEG as a graph that represents the difference in voltage between 2 different points on the brain over time. EEG is able to capture the frequency of brain waves. The frequency shows the emotional state that a person feels [14].

This study aims to test the usability of the 4 most popular e-marketplace applications in Indonesia. A number of respondents who are users of e-marketplace applications will be involved in usability testing using user-based testing and EEG. The researcher then validated the results of user-based testing by analyzing and comparing the results of the usability testing with the EEG results conducted on the respondents.

The testing approach involving EEG is expected to provide usability testing results that are free from bias. Thus being able to provide test results that are in accordance with reality to help assess quality and determine the success of a product in the market.

## II. METHOD

Usability is one of the factors that affect software quality. The increasing adoption of mobile devices in various fields poses challenges in terms of usability as well as the need for specific standardization of software products for mobile devices [15]. Usability shows the level of ease of use of an interface and to find out whether the interface design is successful in meeting the needs of use [7] and [16]. Reference [16] states that usability testing is used to determine 5 variables, namely: learnability, memorability, error, satisfaction.

Usability testing is an important thing in terms of the User Interface/User Experience (UI/UX) of a software because it can determine the success of the UI/UX of a software to improve the quality of life of everyday users [17]. In usability testing, a facilitator will ask participants to carry out several activities related to the appearance of the software interface. The facilitator will observe participant behaviour and ask for input regarding the appearance of the software interface being tested [18].

Reference [10] conducted research on the use of EEG in usability testing. From the research conducted, it is known that testing methods that depend on instruments such as questionnaires or respondent behaviour have limitations, such as: ambiguous questions or social pressure so that participants cannot provide objective answers. This might be overcome by using methods that can analyze the participants' emotions. Reference [19] states that there are several methods that can be used to analyze emotions in the usability testing process, such as: Emotion Intelligence, Eye Tracking, EEG, Galvanic Skin Response, Facial Coding.

EEG can be used to record electrical impulses generated by brain activity [20]. Human brain consists of millions of neuron cells that emit electrical impulses [21]. EEG can be used to make a diagnosis by monitoring changes in brain wave frequency with the help of electrodes [22]. The electrodes will analyze the electrical impulses generated by the brain and then send the results to a computer. In general there are 5 categories of brain wave frequencies as can be seen in Table I [23]-[24].

TABLE I  
EEG BRAINWAVES FREQUENCY

No	Waveform	Frequency Range	Emotion
1	Gamma	30 Hz s/d 100+ Hz	Concentrating
2	Beta	12 Hz s/d 30 Hz	Thinking
3	Alpha	7,5 Hz s/d 12 Hz	Calm
4	Theta	4 Hz s/d 7,5 Hz	Sleepy
5	Delta	1 Hz s/d 4 Hz	Deep sleep

Reference [25] argues that EEG provides a reliable indicator that reflects spontaneous activity of the brain. This spontaneous activity shows what a person actually experiences emotionally and in real-time. This makes EEG results difficult to manipulate emotionally which can lead to bias. However, EEG can also provide inaccurate results. There are several factors that can affect EEG results, such as: heart rate, breathing, muscle movement, sugar levels in the body, and so on [22].

Fig. 1 shows the research design that will be used. The author starts from determine the requirement analysis, such as research objects, population and sample, research variables, test instruments, and test scenarios. This study uses research objects of 3 popular e-marketplaces in Indonesia, namely: Tokopedia, Shopee, and Bukalapak [5]. The population of respondents in this study were students of class 2019, E class, Informatics Department of Universitas Ahmad Dahlan. The Slovin formula used to calculate the sample size and the inclusion criteria technique will be used as a sample selection technique because the author needs to involve respondents who are in accordance with research needs, namely individuals who are accustomed to using e-marketplace applications in accordance with the research object under study. With this technique it is hoped that data obtained will be more accurate and representative [26].

The next stage is experiment. Experiment took place in a controlled room to minimize distraction and carried out using 2 methods, namely: user-based testing and EEG. Respondents will be given a period to prepared emotionally and calming down then following a series of test scenarios that have been prepared by wearing an EEG device. This study will use the NeuroSky MindWave EEG tool as shown in Fig. 2. The user-based test is carried out using direct interview and questionnaire instrument which will be filled out by respondents after trying to carry out a number of test scenarios on e-marketplace applications that have been selected as research objects. The testing process will also be documented in the form of a video that can be used as supporting material in the next stage.

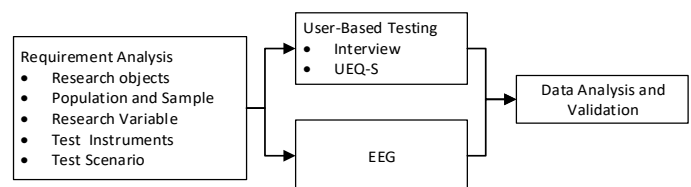


Fig. 1 Research design



**Fig. 2 Neurosky mindwave**

In the next stage, data analysis of usability testing results will be carried out. Researchers use a quantitative approach to perform data analysis from usability testing. The results of the user-based testing method will then be compared with the EEG results to validate the usability testing results followed by drawing conclusions from the research conducted.

### III. RESULT AND DISCUSSION

#### A. Population and Sample

The population in this study were Informatics students batch 19, E class, Universitas Ahmad Dahlan. The study sample size was calculated using the Slovin formula. Based on the calculation of the Slovin formula, the sample size used is 30 respondents consist of 15 male respondents and 15 female respondents. Random sampling technique and inclusion criteria were used as a sample selection technique because the research team selected respondents randomly while still paying attention to the respondent criteria according to research needs, namely individuals who are accustomed to using e-marketplace applications in accordance with the research object under study. With this technique the data collected obtained will be more accurate and representative.

#### B. Experiment and Data Collection

The experiment process is carried out in a controlled environment. A controlled environment will ensure that respondents feel calm, comfortable and free from distractions that could affect the data obtained. The testing process was carried out at Research Laboratory Universitas Ahmad Dahlan as shown in Fig. 3.



**Fig. 3 Experiment process**

The testing was carried out using the usability testing method using interview, UEQ-S and EEG. Interview used to find out which e-marketplace applications the respondents liked. The UEQ-S instrument used to assess the usability scale which will become data for further analysis. EEG used to see the user's brain wave response when using an e-marketplace application. In this experiment, respondents will be asked to follow a scenario to complete a task in order to achieve a desired goal, then proceed with the interview and testing process using the UEQ-S instrument.

Table II shows the scenarios carried out by respondents when using the e-marketplace application. Respondents was given 20 seconds before carrying out scenarios related to things that are commonly done by someone when using the e-marketplace. With this, research team hoped that the respondent will feel calm and comfortable so that the EEG recording results will be more accurate. Scenarios are arranged in such a way by taking into account the activities that are generally carried out by someone when shopping through e-marketplaces.

**TABEL II  
TEST SCENARIO**

No	Activities
1	Respondents calm down for 20 seconds by taking deep breaths and closing their eyes
2	Enter the e-marketplace website
3	Search for items with the keyword "tas punggung pria"
4	Filter by location of sellers with domiciles in DKI Jakarta or Jakarta
5	Sort items by most reviewed or best selling
6	Choose 1 item that has the most reviews or best selling
7	Choose an item with any color of the item then add it to the shopping cart

### C. Interview Results

The research team asked questions directly to the respondents after the respondents completed a series of scenarios that had to be carried out. This interview aims to find out which e-marketplaces respondents like the most in terms of interface appearance and user experience. Table III shows the respondents' preference marketplace according to its graphic user interface and user experience based on interviews conducted with 30 respondents. Based on Table III, it can be seen that the preferences of respondents related to the user interface and user experience are varies as follows: 1 respondent prefer Bukalapak, 15 respondents prefer Tokopedia, and 14 respondents prefer Shopee.

### D. UEQ-S Results

The initial step in the UEQ-S testing after the questionnaire filling process is to prepare the test results data which is entered into the UEQ-S data analysis tools file based on an excel file. UEQ-S uses a quantitative approach with a rating scale of 1 to 7. After obtaining the questionnaire data, the next step is transforming the data in such a way that each positive dimension question of the data will be reduced by 4, and each negative dimension question 4 will be reduced by data so that the most positive value will be +3 and the most negative value will be -3. After obtaining the transformation data, the data can be processed to find the average value of each respondent for each e-marketplace application. The UEQ-S instrument used measures 2 variables, namely pragmatic quality and hedonic quality. Pragmatic qualities are oriented towards the goals of application use, such as: efficiency and ease of use. Meanwhile, hedonic quality is not oriented towards the purpose of using the application, such as: the latest technology being used and feelings when using the application.

Table IV shows a comparison of the average UEQ-S scores between the Bukalapak, Tokopedia, and Shopee applications. The process of analyzing the results of the UEQ-S is carried out by comparing the average value of respondents for each e-commerce application. The greater the average value indicates that the respondents gave a positive response to the e-marketplace application. Conversely, the smaller the average value, the more negative the respondent's response to the e-marketplace application. Based on the tests carried out, it can be seen that the majority of respondents gave a positive response to the Tokopedia and Shopee applications.

TABEL III  
INTERVIEW RESULTS

Preference E-marketplace			
Respondent	Bukalapak	Tokopedia	Shopee
5		1, 4, 8, 9, 10, 11, 13, 18, 20, 23, 25, 26, 27, 28, 30	2, 3, 6, 7, 12, 14, 15, 16, 17, 19, 21, 22, 24, 29

TABEL IV  
UEQ-S RESULT COMPARISON

Respondent	Average		
	Bukalapak	Tokopedia	Shopee
1	0.88	1.5	0.75
2	1.25	2	2
3	-0.5	-0.63	2.38
4	-0.13	1.75	0
5	0	2	1.38
6	-0.5	1	-2.13
7	2	1.5	2.75
8	0.25	0.88	1.5
9	-0.13	1.13	1.25
10	0	1.25	1.5
11	1.25	1.25	2
12	-2.25	-0.88	1.75
13	2.25	3	2.25
14	0.88	1.13	1.88
15	0.5	-0.88	1.63
16	0.88	0.63	1.38
17	1.25	-0.75	0.5
18	1.13	1.13	1.13
19	0.13	0.63	1
20	-0.38	2	-2.63
21	-1.13	-0.13	2
22	-0.5	2	2.63
23	0.88	2.13	2.5
24	-1.38	0.25	2.38
25	0.38	0.88	0.63
26	2	3	2.75
27	1.25	1.25	2.25
28	1.25	1.38	-1.75
29	1.13	-0.13	0.63
30	0.88	1.75	1.63

### E. EEG Results

Fig. 4 to Fig. 6 show the results of the EEG recording of one respondent using the Neurosky Mindwave tool and the EEG Meditation application. The data collected are alpha, beta, and theta waves, starting from 21st to 60th second. As previously stated, the 20th data from the first second is not used because it is a calming period for respondents before starting to do the test. This data is then processed further to determine the emotional state of the respondents based on alpha, beta, and theta waves when working on the scenario following task for 3 e-

marketplace. A higher alpha number indicates that a person is conscious. A higher beta number indicates that a person is in a state of thinking, nervous and anxious [27]. Conversely, if the theta number is higher it indicates that a person is in a comfortable condition [7]. The red line shows Bukalapak, the green line shows Tokopedia which is the respondent's preference, and the orange line shows Shopee.

Fig. 4 shows the results of the alpha power analysis of one of the respondents. Alpha strength indicates a person's level of awareness and focus. The higher the alpha number indicates the person is focused and has emotional stability. Based on Fig. 4, it can be seen that the respondent's preference e-marketplace has a fairly high number, but it is below the respondent's non-preferred e-marketplace. Fig. 5 shows the results of the beta power analysis. According to the beta strength

figure, the respondent's preference e-marketplace has beta strength below other e-marketplaces. Beta strength indicates a nervous and anxious state of mind. The smaller the beta number indicates that the person feels calm. Fig. 6 shows the results of the theta power analysis. Again, the red line shows Bukalapak, the green line shows Tokopedia which is the respondent's preference, and the orange line shows Shopee. According to the theta power figures, respondents' preference e-marketplaces have higher theta power than non-preferred e-marketplaces. This is in accordance with the previous explanation that the higher the theta power, the more comfortable a person feels. Table V shows the results of the respondents' average EEG records which will then be compared with the results of direct interviews and the results of usability testing using the UEQ-S.

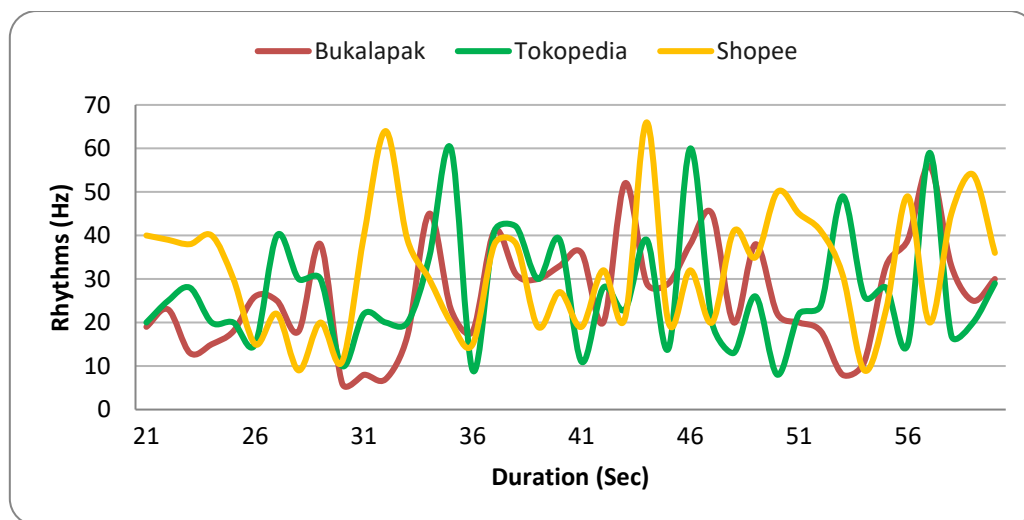


Fig. 4 Alpha result

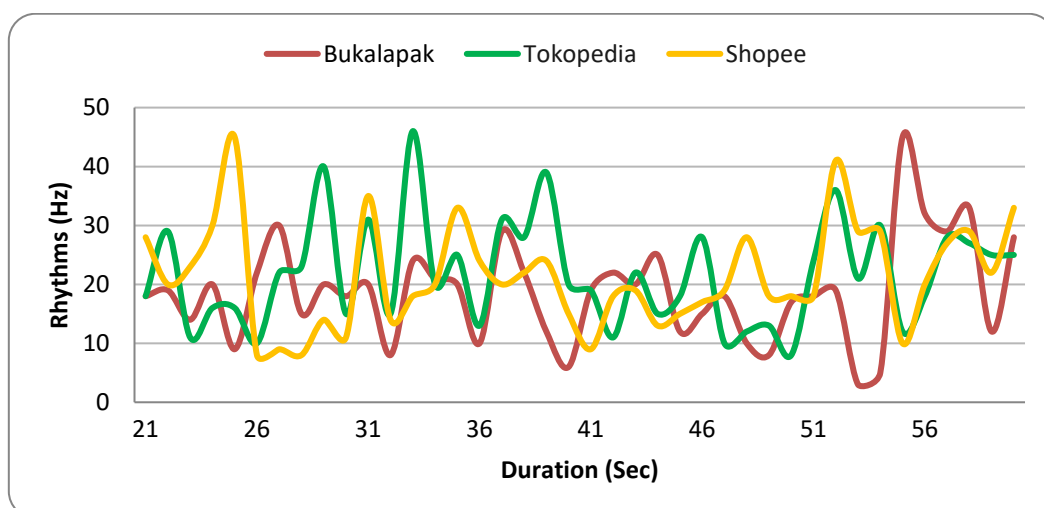


Fig. 5 Beta result

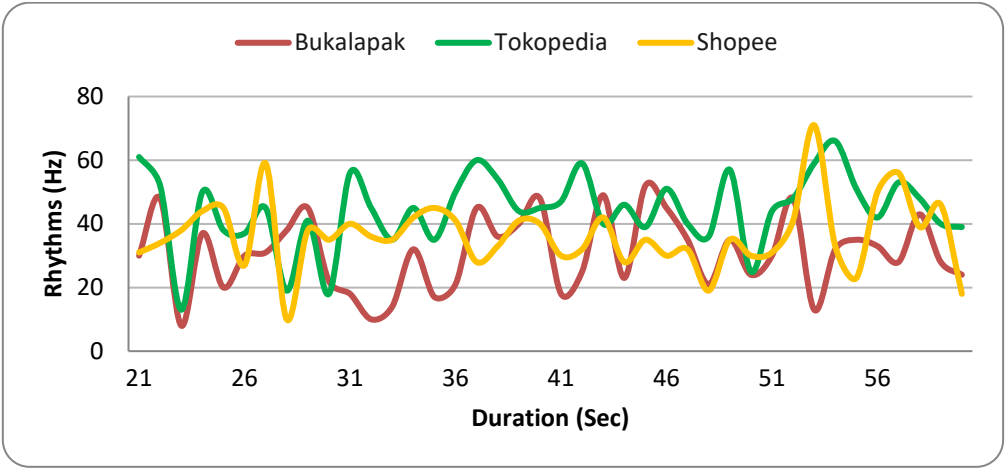


Fig. 6 Theta result

TABEL V  
EEG AVERAGE RHYTHM

Res	Alpha			Beta			Theta		
	Bukalapak	Tokopedia	Shopee	Bukalapak	Tokopedia	Shopee	Bukalapak	Tokopedia	Shopee
1	19	20	21	27	27	32	37	38	37
2	17	20	23	20	23	26	36	37	41
3	22	20	22	36	43	36	39	38	38
4	19	20	20	31	35	38	36	38	35
5	27	26	28	29	30	30	39	43	42
6	20	24	25	22	34	33	38	45	48
7	20	24	28	19	24	24	35	47	44
8	18	19	17	23	22	19	38	36	38
9	21	23	21	28	28	24	39	41	39
10	22	21	25	25	25	31	41	40	43
11	17	18	19	24	23	27	34	32	37
12	20	16	15	19	14	14	37	33	31
13	22	22	22	24	23	30	35	41	41
14	18	16	16	22	17	17	37	37	37
15	24	23	25	28	27	29	42	45	45
16	16	16	16	23	21	24	31	33	31
17	20	23	20	21	29	21	37	44	39
18	28	20	15	16	12	9	36	36	35
19	19	23	19	16	27	23	41	44	39
20	18	15	24	18	15	14	40	37	36
21	22	22	18	16	13	15	38	41	43
22	15	20	17	34	39	29	32	35	34
23	26	25	27	21	22	23	44	49	43
24	17	17	18	15	15	18	33	33	34
25	28	29	27	26	27	27	43	44	39
26	25	17	25	27	18	26	41	33	45
27	25	21	18	33	31	27	41	37	34
28	17	13	22	23	23	26	32	38	38
29	16	19	19	18	19	20	31	37	38
30	18	25	23	17	28	22	35	44	40

F. Results Comparison

Table VI shows a comparison of data from in-person interviews, UEQ-S results, and EEG recording results.

UEQ-S results give average value that becomes main indication to determine respondents’ preference for e-marketplace applications. The greater the average value

indicates that the respondents gave a positive response to related e-marketplace application. Alpha and Theta are taken based on the highest average rhythm value. While Beta is taken based on the lowest average rhythm value. Based on the table it can be seen that the interview results and UEQ-S results have a similarity of 66.67%. This shows that usability testing has subjective potential and gives results that are not in accordance with what respondents actually feel [7] and [10]. This can be influenced by feelings of pressure when following the testing process, respondents' confusion about the questionnaire instrument, or dishonesty in filling out the questionnaire instrument [11].

The results of the interviews and EEG recordings have varied comparisons. Alpha waves have a similarity

of 43.34%, beta waves have a similarity of 33.34%, and theta waves have a similarity of 53.34% compared to the interview results. Comparison of the results of the UEQ-S with the results of the EEG recordings gave results that were not much different. Alpha waves have a similarity of 43.34%, beta waves have a similarity of 40%, and theta waves have a similarity of 50% with the UEQ-S results. The low percentage of similarities in EEG recording results can be influenced by various things, such as discomfort due to wearing an EEG device on the head or uncontrolled environmental conditions that could affect the recording results. Nevertheless, EEG has the potential to be used as a usability testing method to complement and validate the results of user-based testing such as questionnaire or interview.

TABEL VI  
RESULTS COMPARISON

Respondent	Interview	UEQ-S	Alpha	Beta	Theta
1	Tokopedia	Tokopedia	Shopee	Bukalapak/ Tokopedia	Tokopedia
2	Shopee	Shopee	Shopee	Bukalapak	Shopee
3	Shopee	Shopee	Bukalapak/ Shopee	Bukalapak/ Shopee	Bukalapak
4	Tokopedia	Tokopedia	Tokopedia/ Shopee	Bukalapak	Tokopedia
5	Bukalapak	Tokopedia	Shopee	Bukalapak	Tokopedia
6	Shopee	Tokopedia	Shopee	Bukalapak	Shopee
7	Shopee	Shopee	Shopee	Bukalapak	Tokopedia
8	Tokopedia	Shopee	Tokopedia	Shopee	Bukalapak/ Shopee
9	Tokopedia	Shopee	Tokopedia	Shopee	Tokopedia
10	Tokopedia	Shopee	Shopee	Bukalapak/ Tokopedia	Shopee
11	Tokopedia	Tokopedia	Shopee	Tokopedia	Shopee
12	Shopee	Shopee	Bukalapak	Tokopedia	Bukalapak
13	Tokopedia	Tokopedia	Bukalapak/ Tokopedia/ Shopee	Tokopedia	Tokopedia/Shopee
14	Shopee	Shopee	Bukalapak	Tokopedia	Bukalapak/ Tokopedia/ Shopee
15	Shopee	Shopee	Shopee	Tokopedia	Tokopedia/ Shopee
16	Shopee	Shopee	Bukalapak/ Tokopedia/ Shopee	Tokopedia	Tokopedia
17	Shopee	Bukalapak	Tokopedia	Bukalapak/ Shopee	Tokopedia
18	Tokopedia	Tokopedia	Bukalapak	Shopee	Bukalapak/ Tokopedia
19	Shopee	Tokopedia	Tokopedia	Bukalapak	Tokopedia
20	Tokopedia	Tokopedia	Shopee	Shopee	Bukalapak
21	Shopee	Shopee	Bukalapak/ Tokopedia	Tokopedia	Shopee
22	Shopee	Shopee	Tokopedia	Shopee	Tokopedia
23	Tokopedia	Shopee	Shopee	Bukalapak	Tokopedia
24	Shopee	Shopee	Shopee	Bukalapak/ Tokopedia	Shopee
25	Tokopedia	Tokopedia	Tokopedia	Bukalapak	Tokopedia
26	Tokopedia	Tokopedia	Bukalapak/ Shopee	Tokopedia	Shopee
27	Tokopedia	Shopee	Bukalapak	Shopee	Bukalapak
28	Tokopedia	Tokopedia	Shopee	Bukalapak/ Tokopedia	Tokopedia/ Shopee
29	Shopee	Bukalapak	Tokopedia/ Shopee	Bukalapak	Shopee
30	Tokopedia	Tokopedia	Tokopedia	Bukalapak	Tokopedia

#### IV. CONCLUSION

The purpose of usability testing is to find out whether the interface design meets its usability, needs, and the problems it addresses. Usability testing is recommended to be the main method of usability evaluation. Usability testing can be done easily using a questionnaire instrument and can be used to conclude results or interface design problems. However, sometimes it is subjective so that it does not give results in accordance with what the respondent really feels. To overcome this problem, the research team tried to use EEG as an evaluation tool for usability 3 e-marketplace testing results. Based on the results it can be seen that the interview and UEQ-S have a similarity of 66.67%. This shows that usability testing has subjective potential and gives results that are not in accordance with what respondents actually feel. While the results of the interviews and EEG recordings have varied comparisons. Nonetheless, we cannot rule out EEG as a usability testing method in the future.

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