Establishing new methods for evaluating emotions associated with "WOW UX" through psychophysiological reactions

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1 Introduction

1.1 Background

These days, huge manufacturing companies tend to use an emotional expression "WOW" in their promotions and campaigns, such as Toyota's "WHAT WOWS YOU" project[1] and Sony's "The WOW Factory" project [2]. These companies are trying to provide "WOW" experiences through interactions with their products, that indicates companies are eager to understand how to design "WOW" experiences with their products. At first, the word "WOW" is believed to be originated in Scots in the early 16th century, and has been defined on several dictionaries. A widespread definition of WOW (from Oxford Dictionary) is "(Exclamation) Expressing astonishment or admiration.".[3] Even though WOW experience is becoming more important for designing products, there has not yet been any research focusing on "WOW" experiences, especially how to objectively evaluate "WOW" experiences gained by interactions with products.

On the other hand, the concept of user experience (UX) has been getting popular in the field of product design process. Before having the concept of UX, "usability" was the most important factor to consider when people designed and evaluated products. According to ISO 9241-11: 1998 [4], usability was defined as "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", while Dubey and Rana's experimental research[5] suggests that learnability, satisfaction, flexibility, efficiency, effectiveness, and memorability have big impacts on usability. In contrast to the importance of usability in the product design process, Carroll and Thomas [6] suggested that the notions of "easy to use" and "fun" were not understood well, and often confused. Usability basically focuses on ease of use, but does not fully account for fun and satisfaction. With these backgrounds, the concept of UX started to acquire popularity, because user experience (UX) is "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" and "User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use." according to ISO 9241-210:2010.[7]. Therefore, UX can consider not only ease of use, but also users' emotion, such as fun. And many researchers confirm the importance of UX in the design process.[8]

By combining the concept of WOW and the notion of UX, we came to conclude that the manufacturing companies were trying to create products or service which can provide UX which can cause "WOW" experience through interactions with the products - we call it "WOW UX" in this study. In order to enable designers to effectively make products that can generate WOW UX, it is helpful to understand contexts and emotions associated to WOW UX and to have objective evaluation methods for emotions of WOW UX.[9]

Furthermore, it is indicated that since commodities have been becoming more and more mature these days, products should be differentiated from other products in the same category in order to satisfy users and sell products well[10]. Also, there is a possibility that being able to provide WOW UX can differentiate the products from one another. Therefore, researching about WOW UX should bring a benefit to both users and those companies.

1.2 Related literature and studies

Even though product designers have to deal with what kind of emotions users would have from the interactions with the products, methods for objectively evaluating the emotions associated with UX are not yet well established. In this section, we are going to talk about its related studies.

1.2.1 WOW experience and user experience (UX)

As stated above, there are not many researches existed about WOW experiences or WOW UX. Desmet, Porcelijn, and Dijk conducted a research focusing on an approach to design for a wow-experience.[11] This study is aiming to " explore how a wow experience can be conceptualized and how one can design products that elicit such an experience." Even though it provides valuable insights, such as "design for wow can result in products that people are not only excited about to see - but also exited about to use and to own; independent of the inevitable future products that surpass its wow-impact with the newest up-to-the-minute excitement features.", this study focused only on the product design of tell phones, and also used subjective rating methods from participants to measure the scale of WOW. Therefore, the product designers would still like to know how to objectively evaluate WOW UX and how to apply the evaluation on not only tell phones but also other products.

In addition, there is also a research about quantitative evaluation of UX aiming to apply it for design process of home appliance.[12] Although this study successfully established a method to predictably and quantitatively evaluate the UX in the design process, this study did not focus on WOW UX, and also did not use psychophysiological (objective) indexes.

For the product design process, Kano model suggested about "WOW factor" of products.[13] Kano model is a theory about of the relationship between product functionality and satisfaction. It classifies customer preferences into five categories listed below.

Must-be quality This quality is the requirement that customers expect to have. Therefore, when it is well done, users would stay neutral, and when it is not, they would be dissatisfied.

One-dimensional quality This quality generates satisfaction when fulfilled, and dissatisfaction when not fulfilled.

Attractive quality This generates satisfaction when achieved, but does not cause dissatisfaction even when not achieved.

Indifferent quality This quality does not have an influence on users' satisfaction

Reverse quality This quality refers to a high functionality resulting in dissatisfaction.

The relationship among these qualities with axes of functionality and satisfaction is shown in figure 1.

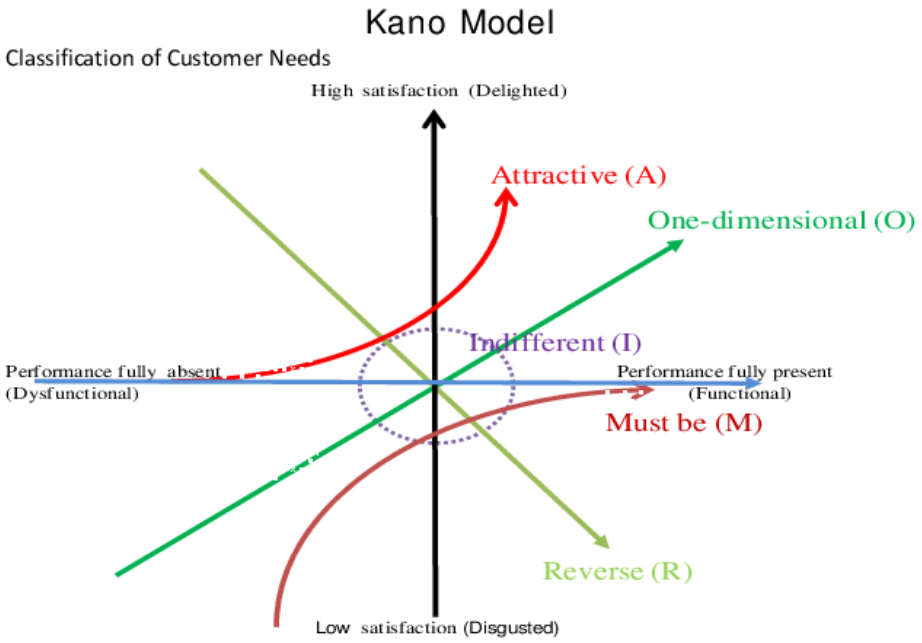

Figure 1: Functionality and satisfaction (Kano model) [14]

Also, the research also suggests that attractive quality can act as the WOW factors and trigger WOW experience through interactions with the products. Therefore, Kano model is providing a good clue to think of how to enable products to provide WOW UX to users.

1.2.2 Psychophysiological evaluation of emotions associated with UX

Even though there has not yet been a study about the relationship between WOW UX and psychophysiological reactions, some preceding researches have focused on psychophysiological emotional reactions associated with UX. Meiselman's review of current emotional state research in product development indicates "the study of emotions within sensory and consumer research has grown rapidly during the past ten years".[15] However, it also says "The situation in product oriented emotion measurement is quite different; although the field has existed for some time now, there is still no standard method or multiple methods for emotion measurement.", and most of them heavily rely on subjective questionnaire answers. Therefore, it is needed to establish standard evaluation methods to objectively measure emotions associated with UX.

As an example research related to this field, Li, Xu and Feng utilized physiological signals for inferring users' emotion, and tried to establish "a Group-Based IRS (Individual Response Specificity) model to improve performance of physiological-based emotion recognition by taking user's IRS into account."[16] This research also attempted to recognize human emotions through experiments on psychophysiological reaction. Therefore, seeing the similarity in our goals, we utilized their method for our experiments as well. For example, they measured users electrocardiogram (ECG), galvanic skin

response (GSR or EDA) and photoplethysmography (PPG), and so we also measured ECG, EDA, and PPG in our experiments. However, this study was focusing only on major apparent emotions, such as neutral, sadness, fear and pleasure. Therefore, it is still needed to have an evaluation method for measuring WOW UX.

Another related study is about measuring human attachment to products through an ergonomic experimental approach.[17] This research revealed the human reactions of attachment toward products, by conducting psychophysiological reaction experiments such as measuring hemoglobin changes in the frontal lobe, and electrodermal activity, electrocardiogram. As this study focuses on a specific emotion associated with UX through psychophysiological reaction experiments, this successfully helped companies to build products that can enhance feeling of attachment. Thus our study about WOW UX also would be beneficial for these companies. Also, another study focused on evaluating visual impression of products through psychophysiological reactions.[18] This research attempted to figure out the relationship between objective indexes of psychophysiological reactions and subjective indexes of answers on questionnaires. Seeing this study, our study also decided to try to understand the relationship between their subjective view point about WOW UX and the objective indexes of psychophysiological reactions.

In summary, there are some preceding studies about WOW UX and evaluation of emotions associated with UX, but there has not been any study about revealing and evaluating WOW UX, even though it would bring a huge profit to technology companies. Therefore, this study would have an impact in this field, as well as would be a consequence of the preceding studies.

1.3 Concept

As stated above, manufacturing companies tend to try to generate products and services which can provide WOW UX these days. However, there has not been any research revealing and evaluating WOW UX, and thus WOW UX would become very vague so that product/service designers would have difficult time for thinking of how to enable products to provide WOW UX and how to objectively evaluate emotions associated with these experiences.

Thus, at first, this study is aiming to reveal contextual information and surrounding emotions associated with WOW UX first so as to understand what WOW UX (WOW experience in general) is. Then, by conducting psychophysiological reaction experiments, we tried to find out what kind of human emotional reactions people have with WOW UX.

1.4 Purpose

The ultimate goal for this study is to help out the manufacturing industry (including product designers) to understand contextual information and human emotions associated with WOW UX. Therefore, this study is designed to reveal contextual factors (including emotions) surrounding WOW experiences through text mining on social media, and then figure out human reactions toward WOW UX through experiments on psychophysiological reactions where experiment participants were given simulated WOW UX in videos. Based on the results, the final goal is to establish new methods for objectively evaluating emotions associated with WOW UX.

1.5 Research direction

As written in the related literature and studies section, we started with researching about preceding studies about this topic, such as how to evaluate emotions in ergonomics experiments. Next, as explained a little above, we conducted text mining on Twitter to reveal contextual information and human emotions associated with WOW experience in order to understand what WOW experience is. Then, we moved on experiments on psychophysiological reaction to find out the relationship between emotions of WOW UX and its human reaction by showing simulated WOW UX in videos. These experiments were designed based on the results of text mining. Finally, from the experiment results, we tried to establish evaluation methods for emotions associated with WOW UX. The research direction is simply shown in figure 2.

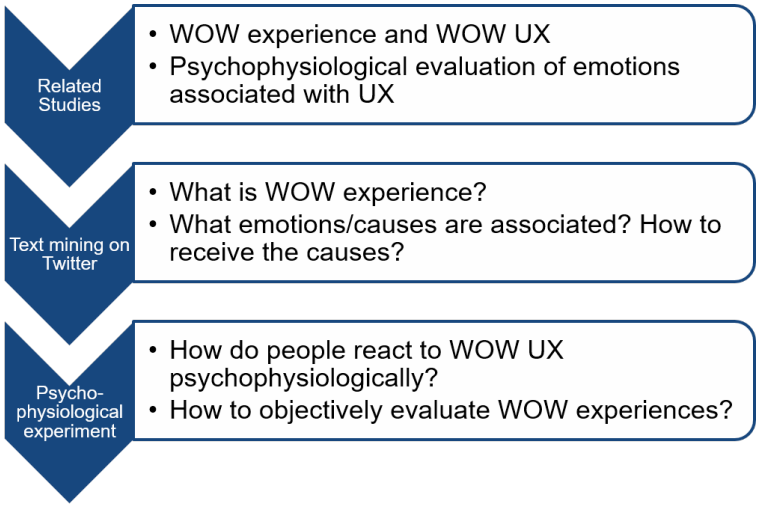

Figure 2: Research direction

2 Analyses of contextual factors associated with WOW experiences

2.1 Purpose and abstract

The word "WOW" is believed to be originated in Scots in the early 16th century, and has been defined on several dictionaries. Some widespread definitions of WOW (from Oxford Dictionary) are listed below.[3]

- (Exclamation) Expressing astonishment or admiration.
- (Noun) A sensational success.
- (Verb) Impress and excite (someone) greatly.

However, meaning of words, especially exclamations is always a subject to change, and people use the word in different ways in the real world. Since the final goal of this study is to evaluate WOW UX, it is necessary to clarify how people actually use "WOW" in daily life. Thus, the first step of this study aimed to reveal empirical meaning of WOW through text mining on Twitter. Furthermore, the text mining also aimed to find out the contextual information surrounding the usage of WOW.

The text mining started with creating categories of three contextual factors surrounding WOW experiences, that are described below;

- Cause of WOW experiences
- Recipient of the cause (e.g. five senses)
- Emotion associated with the experience

Chapter 2.3 elaborates each of them and its categories. With these categories, this chapter revealed the contextual factors of WOW experiences, and visualized data with fishbone diagram. In addition, we also tried to find out contexts about WOW experiences in a specific situation - chapter 2.3.2 talks about factors of WOW experiences related to driving a car. By using these two types of text mining, we summarized about the contextual information about WOW experiences. The knowledge gained in this chapter was utilized in the psychological reaction experiments for evaluating WOW experiences later in this paper.

2.2 Text mining on Twitter

2.2.1 Effectiveness of Twitter for text mining of WOW experiences

The reason why we decided to conduct text mining on Twitter is that the dictionary definition of WOW indicates WOW usually expresses short term emotion, and Twitter provides places for microblogging where people casually talk about users' emotions and feelings, while people talk about more serious topics on Facebook and about more stylish

things on Instagram. In other words, people are honestly and quickly tweeting about their emotions and feelings on Twitter, as shown in the picture below. (Figure 3)

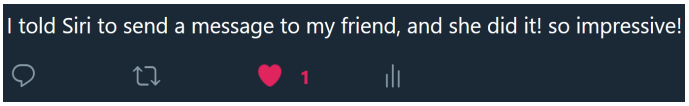

Figure 3: Example of a tweet expressing an emotion

In fact, a recent study has identified Twitter as a microblogging service for online word of mouth branding[28], which indicates users can easily and honestly discuss their daily life. Furthermore, another study shows the potential of Twitter for data collection for opinion mining and sentiment analysis.[29] For these reasons, Twitter is recognized as a platform where users casually discuss their feelings in their daily setting.

Since this study wants to reveal contextual information of WOW experiences in daily life, we concluded Twitter was one of the most suitable social media to conduct text mining on.

2.2.2 Data from Twitter

For this text mining, at first, we randomly collected tweets including "WOW" by searching with "WOW" on Twitter. Even though WOW is used in many languages, this study focuses on how people say WOW in English spoken environment. Since this text mining aims to reveal contextual factors associated with WOW experiences, we disregarded tweets which we were not able to understand the contexts surrounding the tweets and tried to collect ones which could provide information about the contexts and emotions. Even though we utilized information given from the pictures attached with the tweets when available, we did not use any information from users' profiles, date/location of the tweets, among others. In addition, although a lot of WOW tweets were talking about something negative, only positive tweets were retrieved, because this study is designed to understand WOW UX in order to help generate positive WOW UX. Some examples are shown below. The third tweet is declined, because it includes a negative content. Also, the fourth one does not provide enough information to see the contexts and emotions.

- (accepted) wow it' s 1am and i' m drinking wine from the bottle and watching bobs burgers in bed this is it. i have peaked.
- (accepted) Wow I just had the best driving home w the windows down blasting music sesh I'm shock
- (declined) Wow how' d they let that go? Browns get an unsportsmanlike conduct paper for calling a player on other team an idiot.
- (declined) DUDE ITS LATE WHERE I AM AND IM JUST WOW

Moreover, we collected tweets with two different search phrases listed below. In order to understand general WOW experiences, we began with analyses of tweets which include

WOW and meet the requirements described above. Then, we moved on a specific situation - driving a car - of WOW experiences to understand how text mining on Twitter can reveal contexts of WOW experience gained by interactions with products. It has a possibility to help designers produce products that can generate more WOW experiences.
The two search phrases are listed below:

- "WOW"
- "WOW" & "driving"

We analyzed and visualized data from each search phrase in different ways, which will be discussed in the later sections.

2.3 Extracting contextual factors associated with WOW experiences

2.3.1 Factors related to WOW experiences in general cases

This section talks about the result of analyses of tweets which includes WOW. In other words, it tries to reveal factors related to WOW experiences in general cases, and not specific cases. As we reviewed hundreds of Tweets including WOW, it is concluded that there are three factors contributing to WOW experiences describing in the figure 4, and these happen in this order. : cause of WOW experiences, recipient of the cause, and emotion caused by the cause.

Figure 4: Factors of WOW experience

Next, we created categories for each factor (cause/recipient/emotion). The only final version of the categories is listed below, but we iterated the process of generating categories several times by reviewing tweets.

Causes of WOW experience

1. Unusual tangible things (e.g. sensitivity of touch screen of smartphones)
2. New facts or something you did not know
3. Your own irregular actions (e.g. driving at midnight)
4. Artificial surrounding environment (e.g. background music)
5. Natural surrounding environment

6. Beauty of something
7. Appearance of someone
8. Funny things
9. Length of time / accumulation of something (e.g. anniversary, birthday)
10. Coincidence / Something lucky
11. Inside emotions (from your feeling)
12. Interaction/Communication/Relationship with others
13. Future event

Category 1. "Unusual tangible things" can be confusing, as most of the other categories include unusual contents. Thus, when tweets talk about unusual tangible things and do not fit into the other categories, these are defined in the category 1.

Recipients of the causes

The first version of categories for the recipients was only five senses, but WOW is sometime caused by emotion itself, and so we added emotion. Moreover, the data indicated receiving/recalling information also caused WOW, but this way of receiving information should be defined in "sight" or others, because there should be a difference between seeing products and absorbing information by reading books for example. Therefore we added receiving information and recalling information. Lastly, the category feeling of body is added, since feeling of tired or getting sunburned is different from all the other categories.

1. Sight
2. Taste
3. Smell
4. Touch
5. Sound
6. Receiving information
7. Emotion
8. Recalling/remembering information
9. Feeling of body

Emotions associated with the experience

1. Surprised
2. Feel good/comfortable
3. Enjoyed
4. Feel beauty
5. Feel cuteness / handsomeness
6. Feel funny
7. Feel uniqueness of length of time / accumulation of something (e.g. celebrating 1000th tweets)
8. Feel lucky
9. Grateful
10. Missing someone / something
11. Proud of someone / Something
12. Like / Love it
13. Excited about future events

With these categories, **248 tweets** including WOW were categorized on each of the factors, as shown in the figure 5 below, but the numbering is not necessarily same with the numbering of the categories listed above.

Numbe	Tweets	Sour	Recipier	Emotic
7	WOW in the morning I will be on my way to Illinois for boot camp.. I'm excited to start a new chapter, but can't wait to see my loved ones💖	21	7	21
8	I just followed the most beautiful man ever wow	7	1	7
9	I jst thought of the funniest tweet but rn fr isn't the right time, wow I love myself	8	7	8

Figure 5: Example of categorization of tweets on Excel

Table 1 inserted below shows the frequency of each emotion associated with WOW experiences, and therefore can indicate strength of the connection between each emotion and WOW experiences.

Table 1: Frequency of each of the emotion

Name of emotion	Frequency (%)
Surprised	19.36
Feel good/comfortable	6.86
Enjoyed	4.03
Feel beauty	9.68
Feel cuteness / handsomeness	8.07
Feel funny	5.24
Feel uniqueness of length of time / accumulation of something	9.27
Feel lucky	4.03
Grateful	6.05
Missing someone / something	2.02
Proud of someone / something	6.86
Like / Love it	12.10
Excited about future events	6.45

To visualize the data shown in table 1, we used fishbone diagram. The fishbone diagrams explain the result of the categorization. The figure 6 is intended to show emotions associated with WOW experiences, and also width of the arrows indicates strength of the connection between the emotion and WOW by calculating the frequency. For example, the emotion category 1 "surprised" is associated with WOW most frequently, and so has a wider arrow.

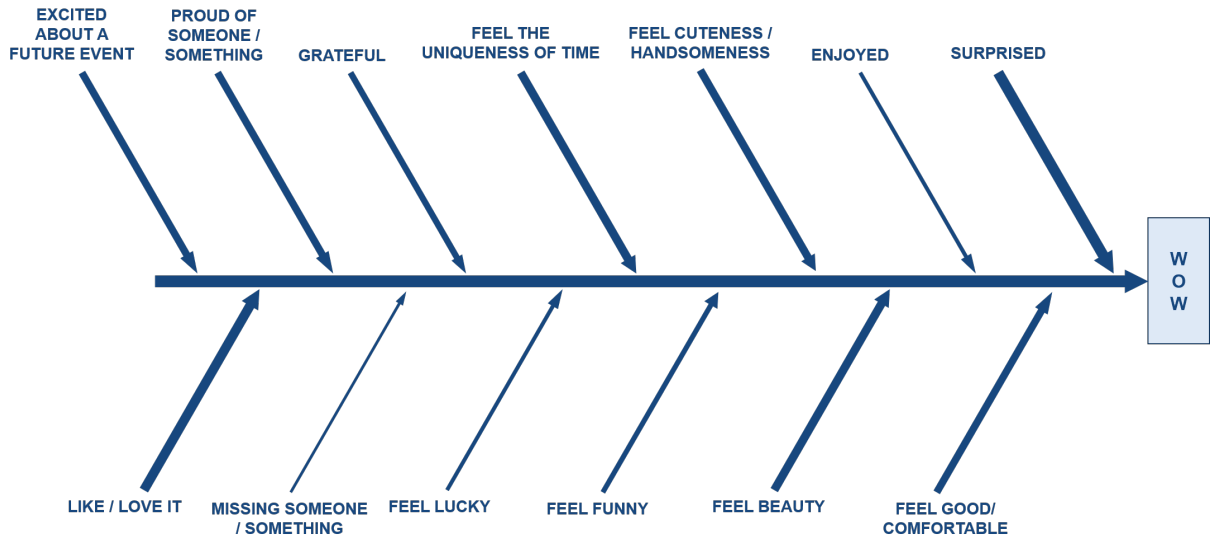

Figure 6: Fishbone diagram about emotions associated with WOW

Figure 6 is helpful to understand types of WOW experiences, and it suggests the emotions "surprised", "feel good / comfortable" "feel beauty", "feel cuteness /

handsomeness", "feel uniqueness of length of time / accumulation of something", "proud of someone / something" and "like / love it" are strongly related to WOW experiences. Next, we created another type of diagrams to indicates how each emotion of WOW experience is caused - what are causes of the WOW experience, and how people receive the causes. Only diagrams focused on the seven major emotions are shown below. The width of the arrows indicate the frequency as well.

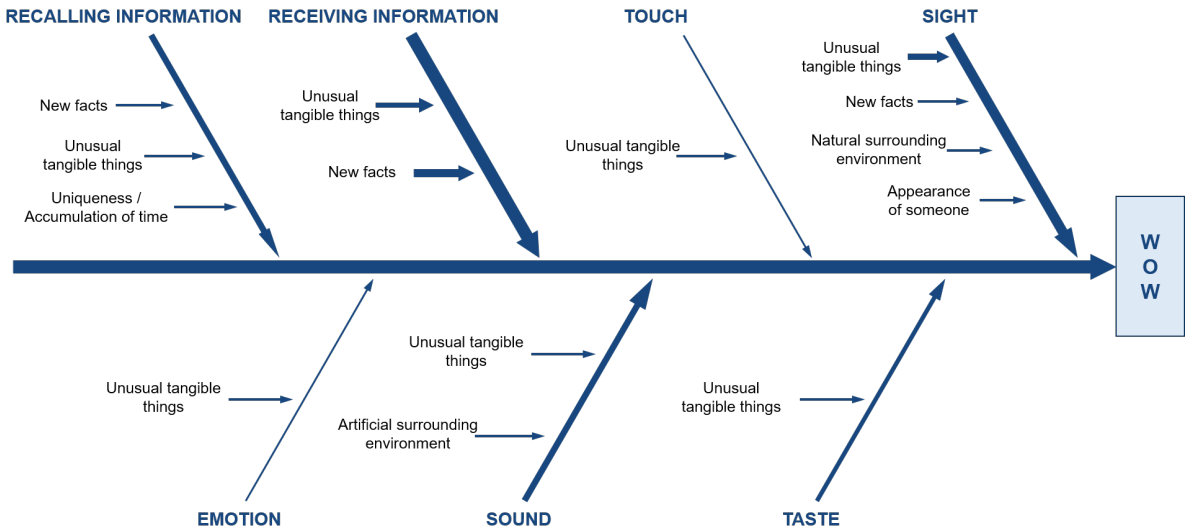

Figure 7: Fishbone diagram about factors associated with "surprised"

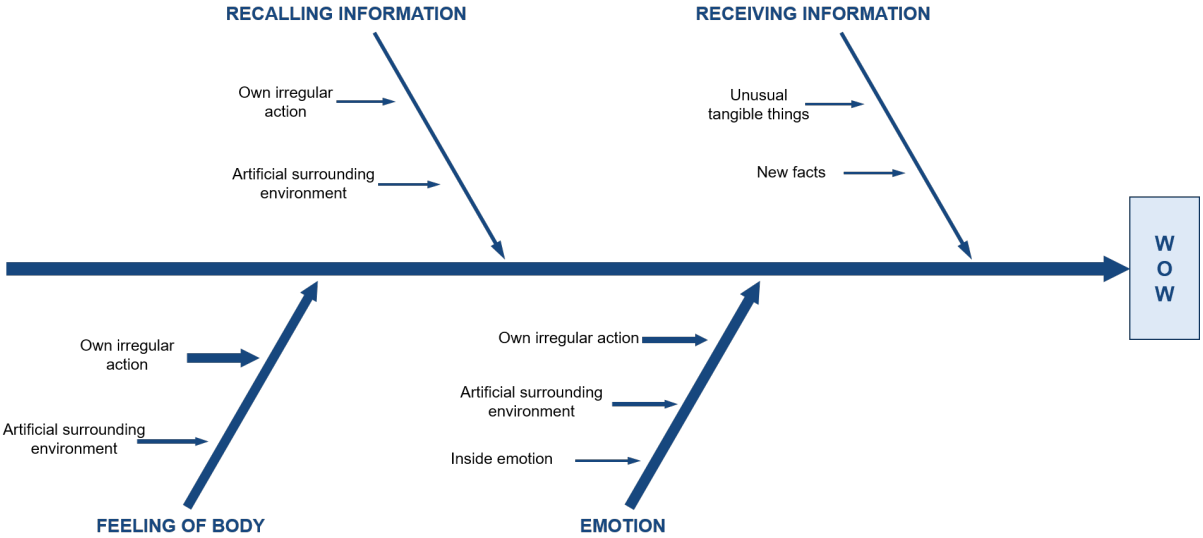

Figure 8: Fishbone diagram about factors associated with "feel good / comfortable"

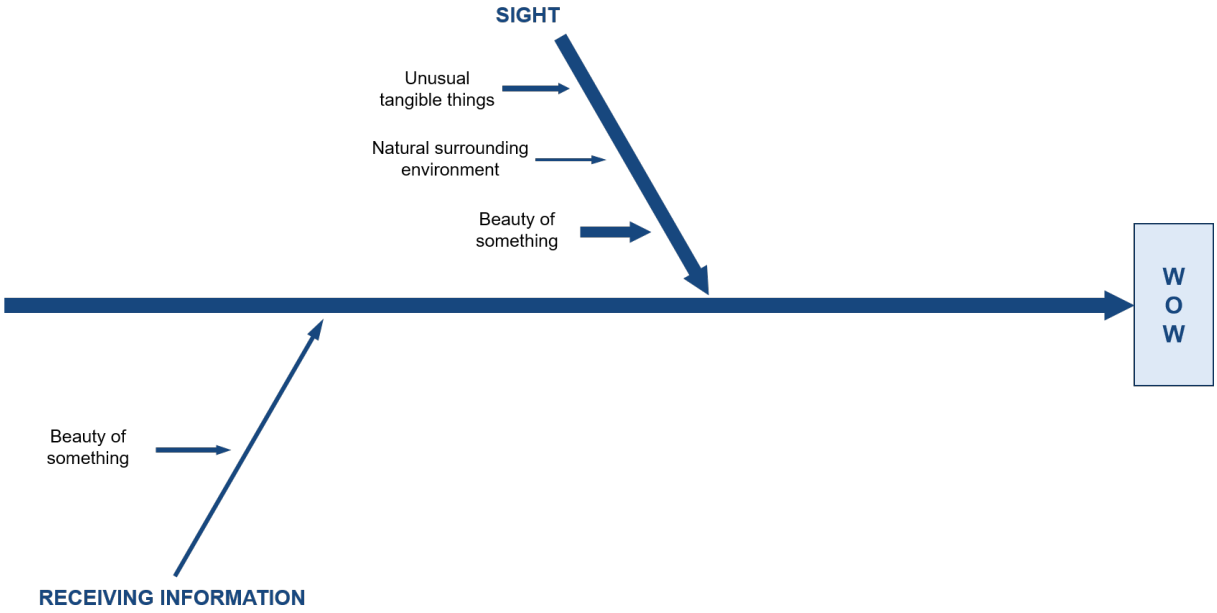

Figure 9: Fishbone diagram about factors associated with "feel beauty"

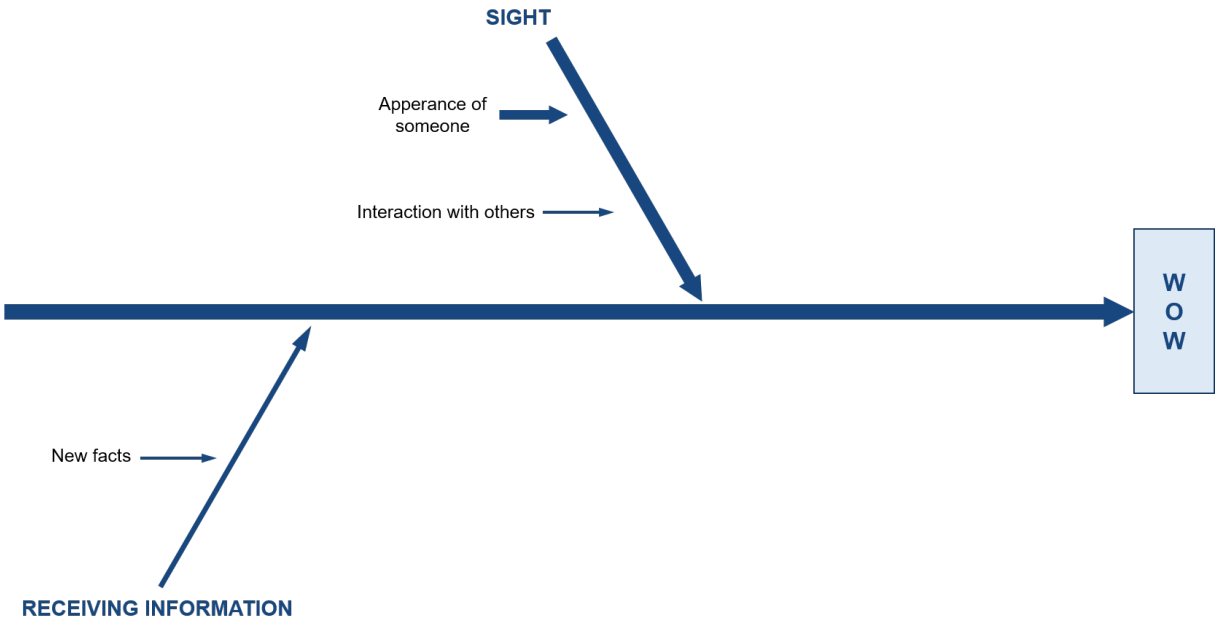

Figure 10: Fishbone diagram about factors associated with "feel cuteness / handsomeness"

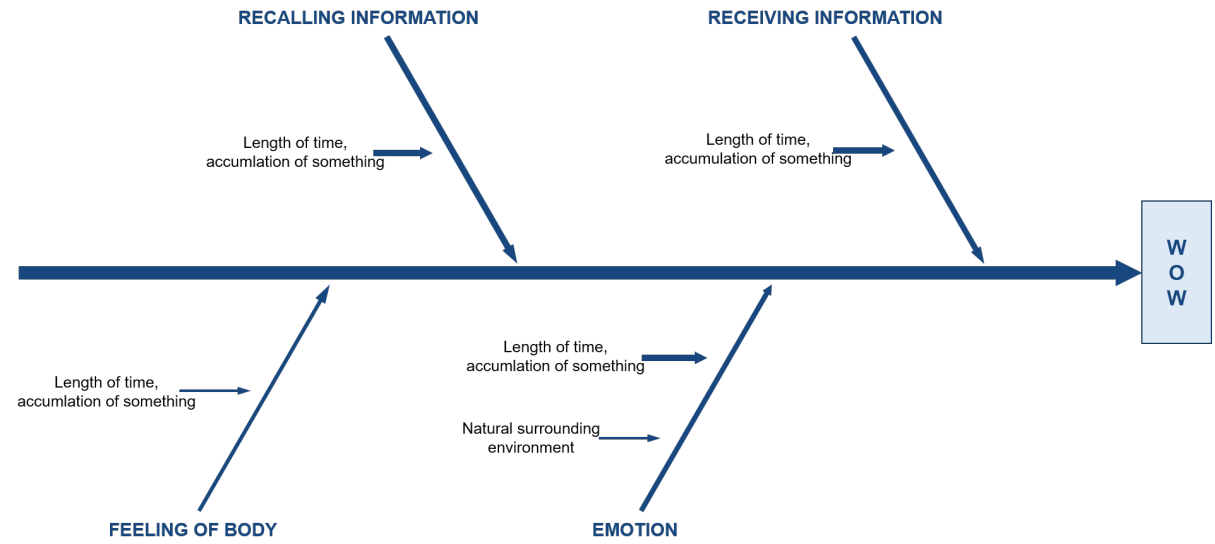

Figure 11: Fishbone diagram about factors associated with "feel uniqueness of length of time / accumulation of something"

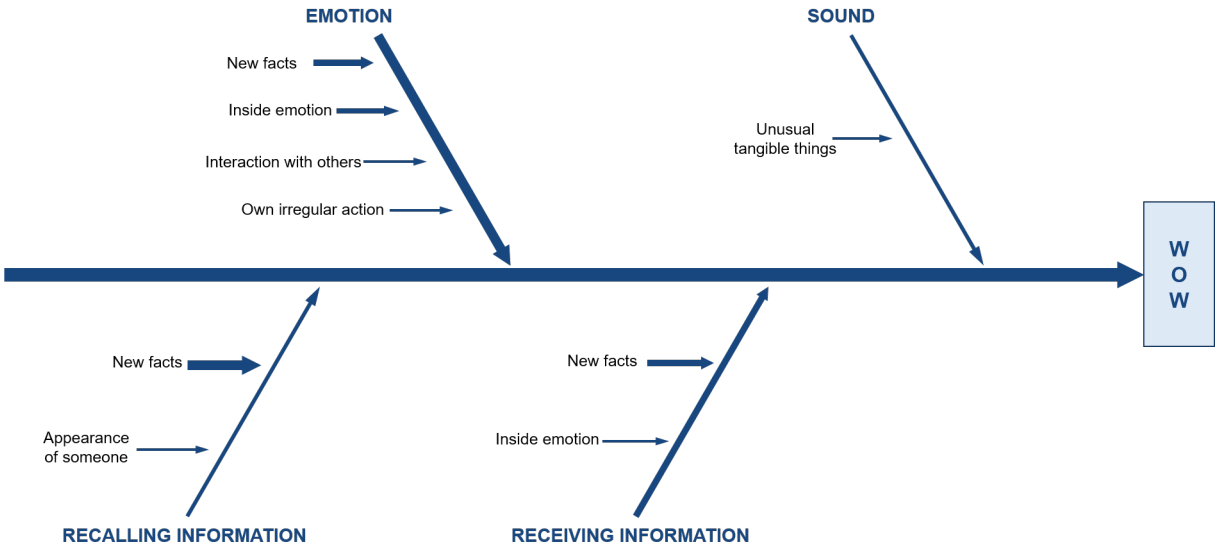

Figure 12: Fishbone diagram about factors associated with "proud of someone / something"

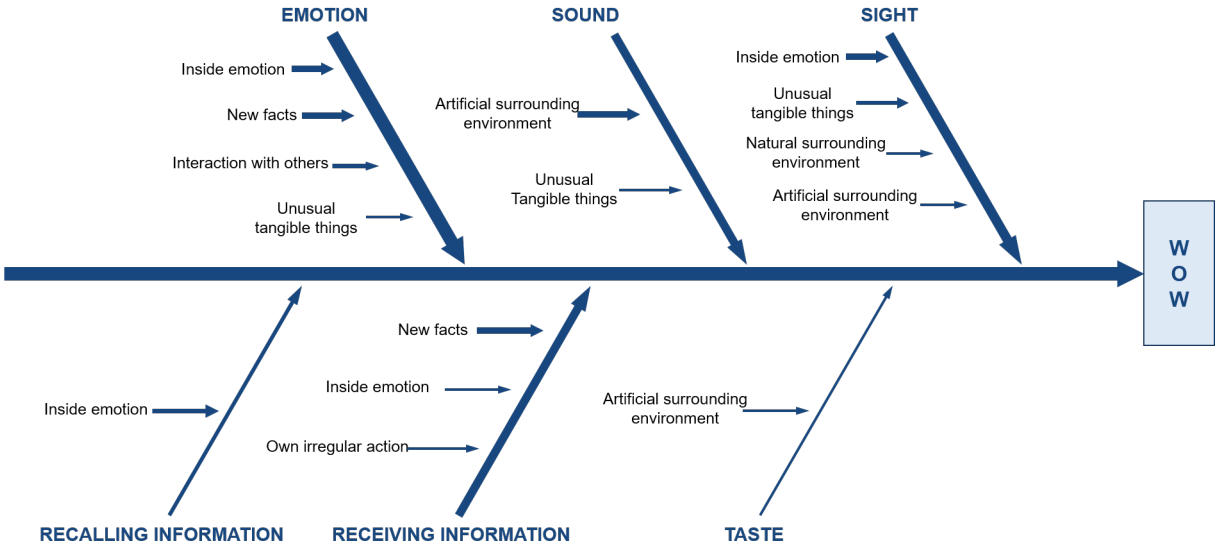

Figure 13: Fishbone diagram about factors associated with "like / love it"

These diagrams listed above could reveal the three factors - cause, recipient, and emotions - and how these are related to each other with WOW experiences in general cases.

2.3.2 Factors related to WOW experiences in a specific case (focused on situation of driving a car)

Since this study is designed to establish evaluation methods of WOW UX, it is also needed to reveal contextual factors surrounding WOW UX when people use products. As Toyota focuses on WOW experiences from interactions with automobiles through its own campaign "WHAT WOWS YOU"[1], this text mining is going to focus on WOW UX surrounding driving situations. To begin with, we collected **329 tweets** that include "WOW" and "driving" and that convey enough information about contextual factors surrounding driving experiences. Some examples of the tweets are listed below;

- Ok we're driving in A Nissan Cube and it's literally a square but wow so spacious
- Absolutely nothing beats driving around the backroads of west chester by yourself at 1am listening to country music wow
- Wow driving through Cocoa Beach brings back so many memories

Then, contextual information was retrieved from the data of these tweets and visualized in tables and as graphs.

Table 2: Frequency of all emotions associated with driving situation

Emotions	excited	enjoyed	like it	relaxed	surprised	grateful
How many times	44	39	48	22	57	6
	feel funny	proud	confident	recall memories	feel beauty	SUM
	34	8	1	12	41	312

Table 2 shows what kinds of emotions are associated with driving WOW experiences with what frequency (how many times each of the emotions is associated in data of the tweets). (Some minor emotions are excluded here, and therefore the sum of table 2 and the number of tweets collected is not matched.) Emotions "surprised", "like it", "excited", "feel beauty", "enjoyed" and "feel funny" are appeared with the highest frequency in this order. In comparison with table 1, there are some similarities and differences as listed below.

- (similarity) Emotions of "surprised", "like it", and "feel beauty" appear with high frequency.
- (similarity) Emotions of "grateful" and "proud of someone/something" are associated with both general WOW experiences and WOW driving experiences but these emotions appear with low frequency.
- (difference) WOW driving experiences are not associated with "feel uniqueness of time" and "excited about future event", and therefore it can be expected that general WOW experiences are related with time, while WOW driving experiences are not.

In addition, it is also revealed that the emotions associated with driving WOW experiences depend on whom driving with. According to this table, the emotions of "feel funny" and "feel beauty" are caused more often when being with friends. Moreover, the emotions of "like it" and "enjoyed" are frequently caused when being with family.

With whom	excited	enjoyed	like it	relaxed	surprised	grateful	funny	proud	confident	memories	feel beauty	SUM
friend	3	4	1	0	5	0	10	0	0	1	6	30
boy / girl friend	3	0	1	0	1	1	1	0	0	0	3	11
family	1	5	4	2	4	1	7	1	0	1	2	28
alone	36	29	41	18	46	2	16	7	1	10	29	251

Figure 14: Differences of frequency of the emotions by who to drive with.

Next, the pie charts show the contextual factors surrounding WOW driving experiences.

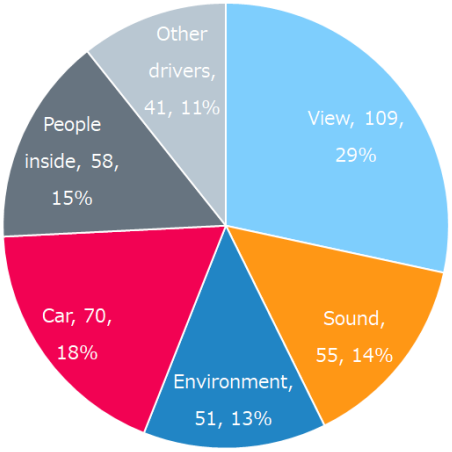

Figure 15: Causes of WOW driving experiences

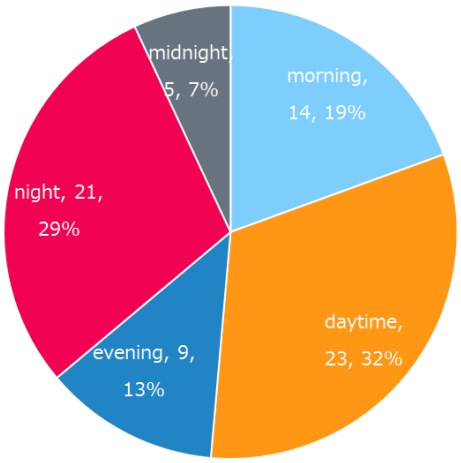

Figure 16: When to feel WOW in a day

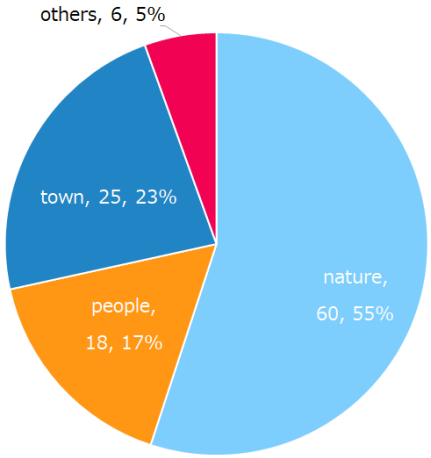

Figure 17: Categories of "view"

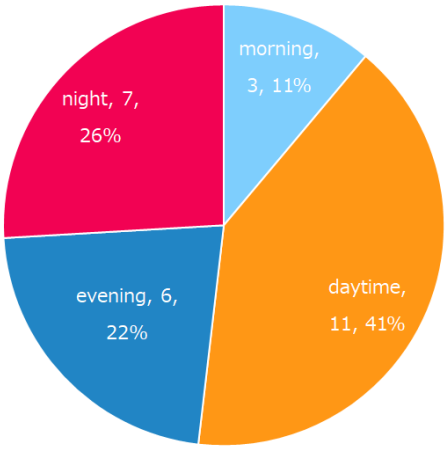

Figure 18: When nature causes WOW in a day

These pie charts shown above indicate contextual information about WOW driving experiences. Figure 15 shows what causes WOW driving experiences, and it is revealed that "view", "sound", and surrounding "environment" frequently cause WOW in driving experiences. Also, Figure 16 shows when to have WOW driving experiences in one day. Figure 17 shows categories of the views and their frequencies, and nature often stimulates human sight while driving. Then, by combining these data, figure 2.3.2 shows when in a day the nature causes WOW driving experiences. From these data, technology designers can understand what contexts can provide WOW driving experiences and therefore how technology related to automobiles can help generate the experiences.

2.4 Summary of contextual factors surrounding WOW experiences

The text mining of the general WOW experiences revealed what are the causes, how people receive the causes, and what kind of emotions are associated with WOW experiences, and also how these three factors are related to each other. Moreover, the text mining on a specific situation (driving a car) showed what contexts often cause WOW driving experiences, and there is a possibility that its outcome enables technology designers to have deeper understanding about how they should design products to provide the contexts that can generate WOW experiences.

3 Psychophysiological reaction experiments for evaluating emotions associated with WOW UX

3.1 Purpose and abstract of experiments

First of all, this study is designed to establish new methods for objectively evaluating emotions associated with "WOW" user experiences through psychophysiological reactions. Therefore we conducted psychophysiological reaction experiments where participants are given simulated WOW UX in order to measure human reactions. Then, the participants were asked to subjectively evaluate their experience in the experiments. Finally, by figuring out the relationship between the objective psychophysiological reactions and the subjective evaluations, this experiment is designed to reveal the psychophysiological reactions to WOW UX.

More specifically, the participants watched ten of 20-seconds-long videos that are showing user experiences gained by interactions with products, during which we measured their Hemoglobin change and arterial oxygen saturation in brain, electrodermal activity(EDA), photoplethysmography(PPG), and electrocardiography(ECG). After each of the videos, they answered a questionnaire asking how much WOW they felt (WOW score), what kinds of emotions were associated, and what the causes of WOW were. Also, before each of the videos, they were required to close their eyes for one minute so as to normalize their psychophysiological indexes.

3.2 Experiment methods

3.2.1 Experiment design

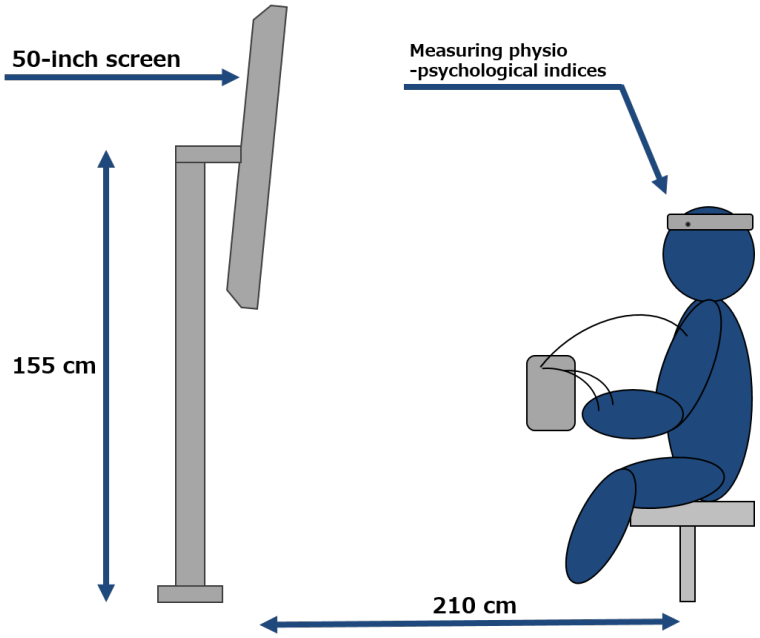

Figure 19: Experiment design

The experiments were conducted in a quiet room in which only one participant at a time was present, together with the two persons responsible for the technical supervision. The participants sat 2.1 m away from a 50-inch video screen that is located at 1.55m high, while one supervisor sat directly to the right of the participant and the other one was remotely positioned, controlling the video feed, as shown in the figure 19. Several sensor units were attached to a test person to measure various physiological indexes. (that are elaborated in the later chapter "Items to measure") After the sensors were installed and calibrated, the procedure of the experiment was explained to the participant.

3.2.2 Procedure of experiments

Once the explanations about the procedure and the ethical considerations, we started the experiments. During the experiment, the participant was presented with a total of 10 videos. The videos are each 20 seconds long and feature products from well-known brands as well as unrenowned producers. After each video, the participant was asked to answer a questionnaire (elaborated in the later chapter "experiment tasks of its participants") and rate the WOW-score of the video on laptop which was handed over by the supervisor sitting close by. After handing back the laptop, each attendant was asked to close both eyes and rest for a minute, to let the physiological indexes normalize again. During the whole experiment, the participants were not affected by any acoustic stimulus, the videos were muted entirely. This setup was able to ensure entirely visual influence on the test person. The whole procedure of the experiment took 50 minutes at most including the explanation of the experiments and attaching measurement machines on the participants.

3.2.3 Experiment tasks of its participants

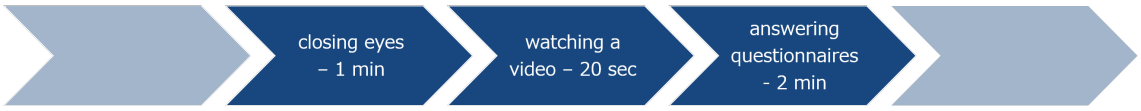

Figure 20: Experiment routine

As explained in the chapter "procedure of experiments", the participants were given three tasks described in the figure 20, and the routine consisted of these three tasks was repeated 10 times for each participant.

1. Closing eyes and rest(1 minute) : The participants were asked to close their eyes and rest for 60 seconds before watching each video to normalize their psychophysiological indexes and collect data during closing eyes for the later data analysis. A picture about this task is inserted below.

2. Watching a video (20 seconds) : The participants were asked to watch one video at one time on the screen. They are also told not to move their body so as to collect more accurate data of their psychophysiological indexes and to focus on the video.

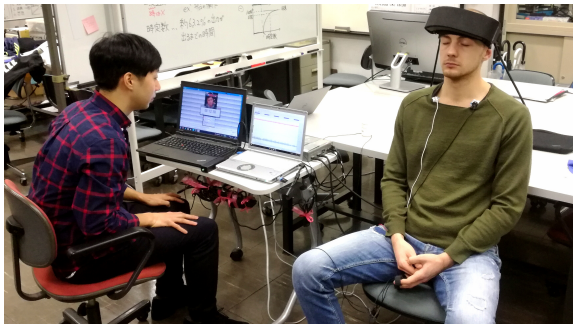

Figure 21: Closing eyes and resting

Figure 22: Watching a video

3. Answering questionnaires (1 to 2 minutes) : After the video finishes, the participants answered three questions on a laptop which was handed over by a supervisor, as shown in the figure 23. The participants took around 90 seconds on average to complete all the questions. All the questions are inserted below as figures (figure 24∼26). For the questions about emotions and causes, they are allowed to check three boxes at most, and required to check one box at least.

Figure 23: Answering questionnaires

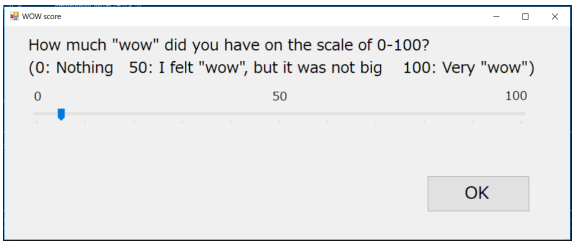

Figure 24: Question about WOW score

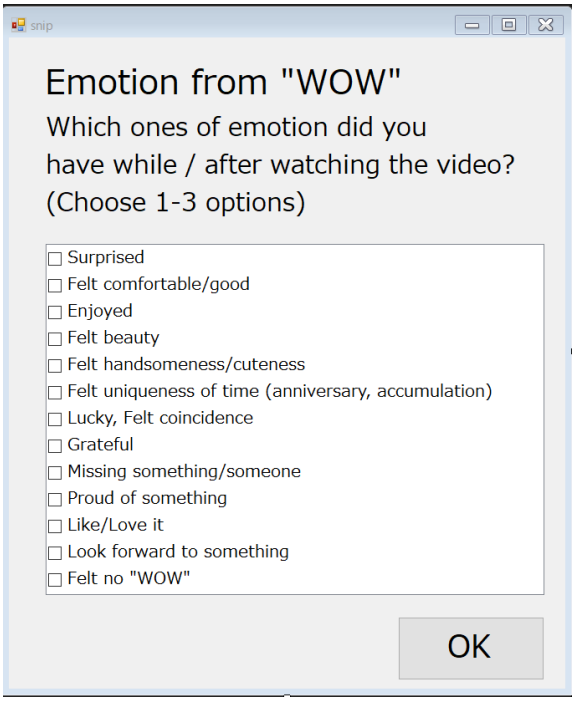

Figure 25: Question about emotions

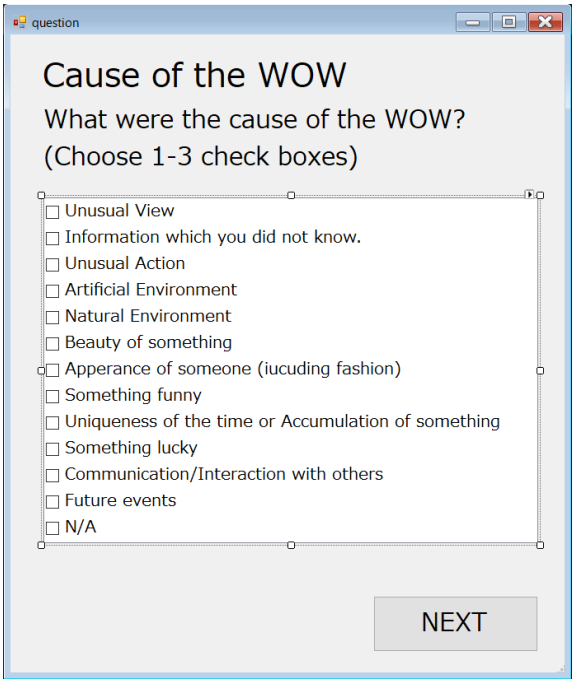

Figure 26: Question about cause of the emotions

3.2.4 Experiment participants

14 students of which 12 were males and 2 females participated in the experiments. The youngest participant was 21 years old and the most senior 26 years old (22.8 ± 1.4 years old). Since the expression “wow” is not commonly used in Japanese, only participants with a solid English speaking level were asked to partake. This led to a total of 7 involved nationalities in this experiment. There were no professional athletes participating in the experiments, since their physiological indexes can react different to external arousal.

3.2.5 Samples of experiments

30 videos featuring UX gained by interactions with products are prepared, and we tried to collect videos that are as various as possible in order to see the difference in psychophysiological reactions with different videos. 10 videos are randomly picked up for each of the participants. Screenshots of some of the videos are inserted below;

Figure 27: Samples of videos

3.2.6 Items to measure

During the experiments, we measured their hemoglobin change and arterial oxygen saturation in brain(HR), electrodermal activity(EDA), photoplethysmography(PPG), and electrocardiography(ECG). A research [9] indicates HR variability(standard deviation) can be a good indicator for recognizing human emotions, and therefore we decided to measure PPG and ECG.

Hemoglobin change and arterial oxygen saturation in brain (HC)

In recent years, many research which clarifies functions of each part of the brain have been conducted. These aspects of application in brain science is developed by noninvasive functional brain imaging techniques such as fMRI (functional magnetic resonance imaging: functional MRI) and NIRS (Near-infrared spectroscopy).

NIRS is a technique which measures subsequence change in density of Deoxy-Hb and Oxy-Hb included in blood by analyzing near-infrared light penetrated through repetitive refraction and irradiated to head area using high permeability of near-infrared light against organisms.

Though time resolution of NIRS is superb, as it is 0.1 second, the spatial resolution is still a few centimeters, and expected to be improved. The characteristic of NIRS is noninvasive, in other words, without restricting the body, it can result in the almost same measure as usual.

The development of the noninvasive functional brain imaging techniques has disclosed that the frontal lobe does not only play a main role to process rational information, but also emotion and emotional expression. Especially, area from frontal lobe to prefrontal cortex except motor cortex is anatomically defined as cerebral cortex received fiber projection from medial dorsal nucleus. (Brodmann area, BA8, 9, 10, 11, 12, 13, 44, 45, 46) [19](as shown in figure 28, figure 29)

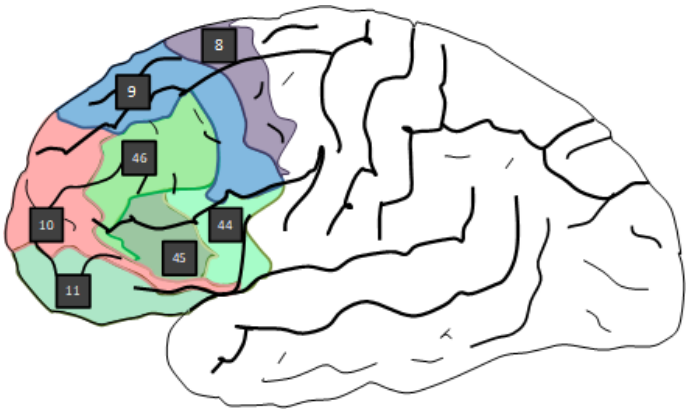

Figure 28: Broadmann area (outside surface)

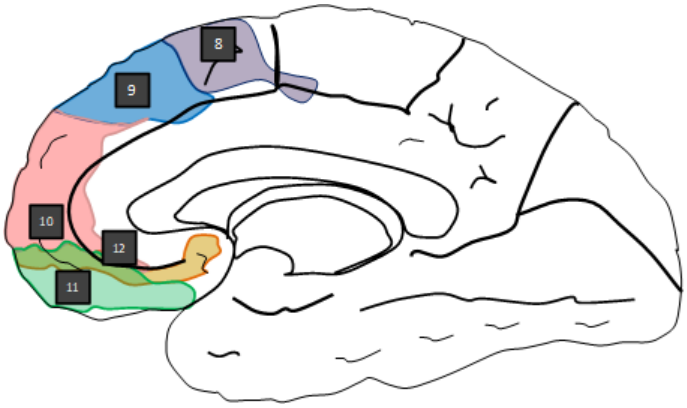

Figure 29: Broadmann area (inner surface)

Moreover, the prefrontal cortex in front of the prefrontal area is divided into four parts:(1) the dorsolateral prefrontal cortex (DLPFC), (2) the medial prefrontal cortex (MPFC), (3) the ventrolateral prefrontal cortex (VLPFC), and (4) the orbitofrontal cortex (OFC), which is related to the highest order cerebral function.[20] The location information is shown in figure 30.

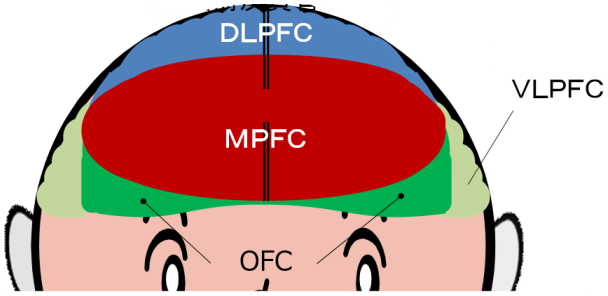

Figure 30: Location of each part on the brain

In this experiment, we measured a change in blood volume in participants' frontal lobe using an optical encephalography (OEG-16, Spectratech). This machine is designed simultaneously to measure change in the amount of blood in each part of frontal lobe not so deep by the multi-channel (up to 16 channels) method (Figure 31, 32). The apparatus, thus, is able to measure DLPFC, MPFC, VLPFC, and OFC mentioned above. However, because NIRS has low spatial resolution, which part of brains exactly reacts has to be estimated somewhat by measured results.

Figure 31: Spectratech OEG-16

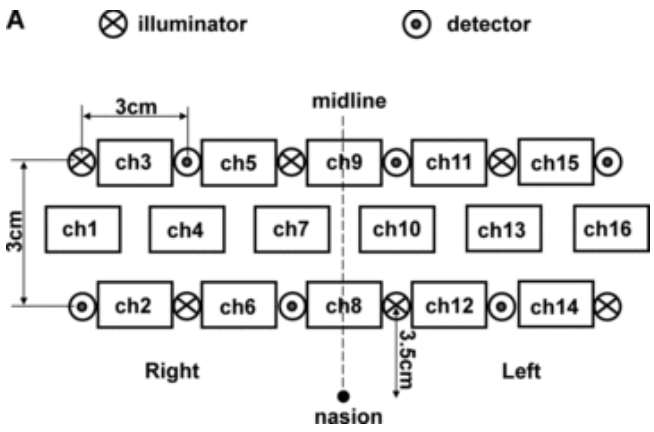

Figure 32: System of OEG-16

Electrodermal activity (EDA)

Electro-dermal activity(EDA), is the activity of the human body that causes change in the electrical properties of the skin. EDA can be divided into several categories. One of which is skin conductance reaction, which is the activity of sweat glands measured by electrical means. More specifically, when measuring sweat activity through skin conductance reaction, one flows a weak electrical current between two points on the palm of the hand or between two fingers and measures the change in the skin resistance caused by sweat from the voltage change.

Skin conductance reaction measures the reaction of autonomic nerves, which is an unconscious reaction to the experimental participants. Therefore, subjective evaluation

is impracticable [21]. Recent research results in biology from the past have shown that there is a high correlation between skin conductance reaction and mental states such as emotional stability, hypersensitivity, introversion, obedience, and pseudologia phantastica[22]. Skin conductance reaction is therefore considered to be an index of perception information processing.[23]

In this experiment, we used BAIOPAC MP150 and electrodermal activity amplifiers (GSR100C) to measure the skin conductance reaction of the experimental participants. As shown in figure 33, the participants were asked to place their index finger and middle finger of the non-dominant hand on a Ag/AgCl reference electrode. The cutoff frequency for this experiment was 0.05-1Hz, and the sampling rate was 1.0Hz.

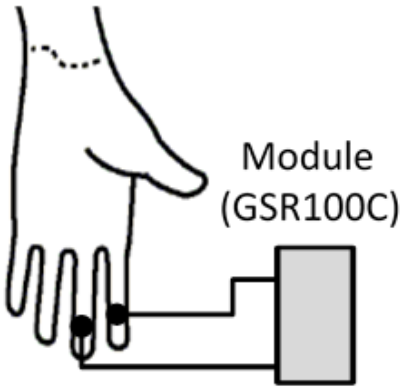

Figure 33: How to measure EDA

Photoplethysmography (PPG)

In this experiment, we measured photoplethysmogram(PPG) of participants, and gained heart rate computed by PPG. PPG is the one which is measure arterial system pressure wave arise from cardiac pump action at fingertips. Since blood vessel in fingertips is more developed than in other parts of the surface of the body, it is said that volume pulse wave can be effectively recorded.[24] Comparing to ECG which records heart rate and an activity of autonomic nerves, PPG records the influence of sympathetic nerve.[25]

Instant heart rate and photoplethysmogram. In our experiment, we measured the photoplethysmogram by means of BAIOPACMP150 and PPG100C pulse measurement amplifier, and calculated instant heart rate. As figure 3.14 is seen, we located photoelectric pulse sensor on participants' non-dominant hand. We set 0.05-3Hz to cut-off frequency and 0.5kHz to sampling rate.

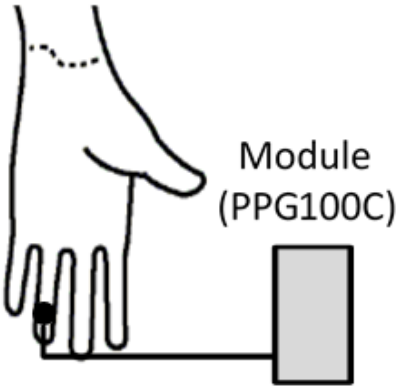

Figure 34: How to measure PPG

Electrocardiography (ECG) Electrocardiogram (ECG) is used to record an activity of hearts electrically, putting electrodes on a body surface. An instant heart rate is often measured by ECG. ECG is designed to record sum of potential change arise from repolarization and electrical depolarization of myocardial. The number of times of heart beats in constant time is called heart rate (HR). A time interval between R wave and next R wave is called R-R interval (shown in figure 35), and the number of times of heart beats in a minute is called BPM (Beats Per Minutes).

In general, contrast with the term, heart rate, used in a clinic, instant heart rate is used when it comes to the comparison between before and after exercise. Hearts are reflected by a function of an autonomic nerve, and influenced by both sympathetic nerves and parasympathetic nerves. Rising heart rate is caused by sympathetic nerves, and seen in the state of excitement and stress. On the contrary, lowering heart rate is caused by parasympathetic, and seen in the state of depression [26], [27]. In our experiment, the sampling rate was 0.5Hz, and the gain was 2000.

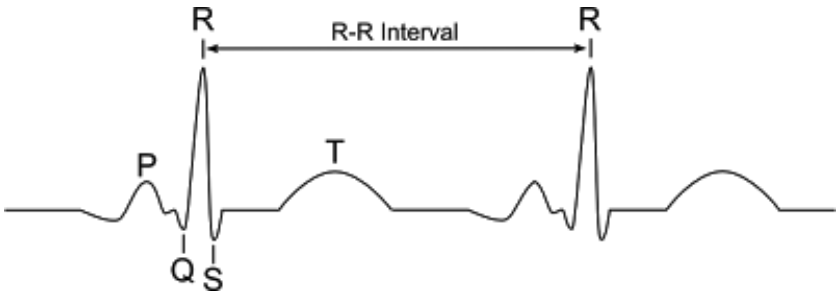

Figure 35: R-R interval

3.3 Ethical considerations

Participants were given information in advance relating to:
- Purpose and procedure of the study
- Statement that participation is voluntary and participants have the right to withdraw from experiments at anytime without any consequences
- All risks and discomforts that participants might face during or after experiments
- Length of time to participate experiments
- Person to contact regarding the information about the experiment
- Statement that the data gained from experiments are used only for the study and all the information relating to privacy is protected

All the participants agreed with all the information given to them, and signed on consent forms. (The experiment design followed the experiment policy of Faculty of Science and Technology at Keio University.)

4 Results and analyses of the experiments

4.1 Results and analysis methods

4.1.1 Data from the experiments

From the experiments, we recorded data of psychophysiological indexes about their HC, EDA, PPG, and ECG during closing eyes and watching videos, while we also collected their answers on the questionnaires explained in the former section. Data of each of the psychophysiological indexes listed below are subject to analyze;

HC Changes of mean between during closing eyes and watching each of the videos

EDA Mean during watching each of the videos

EDA Standard deviation during watching each of the videos

PPG Rate mean during watching each of the videos

PPG Rate median during watching each of the videos

PPG Rate standard deviation during watching each of the videos

ECG Rate mean during watching each of the videos

ECG Rate median during watching each of the videos

ECG Rate standard deviation during watching each of the videos

*For the data of HC, mean of HC during closing eyes right before watching a video is subtracted from mean of HC during watching the video.

4.1.2 Methods of standardization

In order to compare one participant to another on a test, data among each of the videos were standardized. Each participant watched 10 videos, and therefore each of them has 10 data for every item (e.g. Mean of EDA during watching a video) listed in the previous section (Data from the experiments). Since changes of psychophysiological indexes highly depend on participants' constitution, the 10 data of each participant must be standardized in order to make it possible to compare data among the participants. For the standardization, we used the equation below.

$$Z = \frac{X-\mu}{\sigma}$$

Z : Standardized data, X : Original data,
μ : mean of the 10 data, σ : standard deviation off the 10 data

This standardization enables us to compare 140 data from 14 participants. On the other hand, as every participant was given the same instruction to decide WOW score, WOW scores from the participants were not standardized.

4.1.3 Analysis methods

After all the data were standardized, all the 140 data can be compared in one scale. In order to figure out the relationship between the emotional expression "WOW" and psychophysiological reactions, we calculated correlation coefficient (r-value) between WOW scores and psychophysiological indexes. However, even when r is high, if the data set is too small, the correlation might not be valid. Thus, to validate the correlation, we applied student's t-test. The hypothesis is r = 0. Then, we calculated t-value with the equation below. (n: number of data)

$$t^* = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

From this t-value, p-value is also calculated based on t-distribution. When p is smaller than 0.05, we would be able to decline the hypothesis (r=0) at the 5% level. Which areas of r-value and p-value can validate the correlation is elaborated in later chapter "Results : Correlation between WOW score and each psychophysiological index".

4.2 Results : Analysis of answers on the questionnaires

Each of the participants answered three questions - WOW score, emotions associated with the experience of watching the video, and causes of the emotions - after watching each of the videos. 14 people participated in the experiments, and each of them watched 10 of the videos. Thus, 140 data (14x10) were collected from the questionnaires. The average WOW score and its standard deviation was 43.6 ± 28.7.

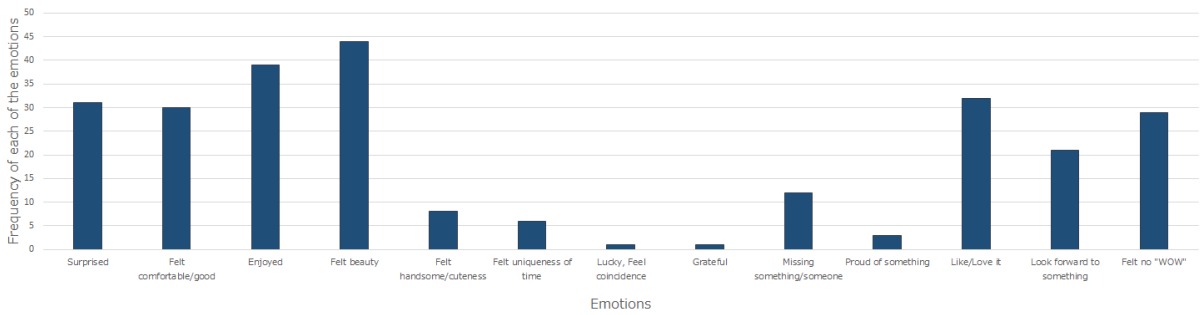

Figure 36: Frequency of each of the videos on the questionnaires

Figure 36 shows how frequently each of the emotions was answered on the questionnaires. Even though this frequency of course depends on what kind of videos are prepared, it is still indicated that people frequently have feelings of beauty, enjoyment, surprise, liking something, and being comfortable/good while watching videos relating to UX gained from interactions with products.

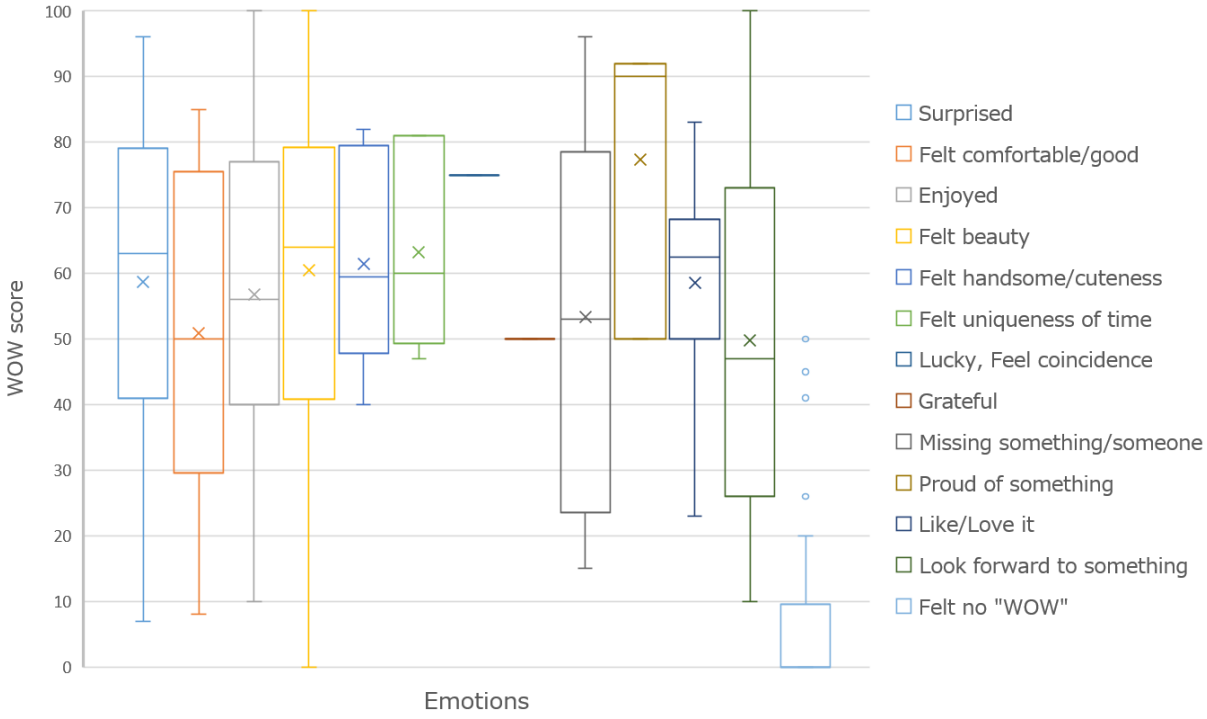

Figure 37: Box plot showing the distribution of WOW score of each emotion

Figure 37 shows the distribution of WOW score of each emotion. Even though the distribution of WOW score of each emotion highly varies, some characteristics are still able to been observed.
- Feeing of being comfortable/good was reported with relatively low WOW score.
- Feeling of missing something/someone was reported with relatively low WOW score.
- Feeling of looking forward to something was reported with relatively low WOW score.
- Feelings of beauty and being comfortable/good have relatively wide distribution.
- Feelings of being surprised and beauty are reported with higher WOW score.
- Feeling of liking/loving something has a small distribution.
- Feeling of no wow was reported with low WOW score and small distribution

Last thing from data of the questionnaire is about the relationship of the WOW score and the number of emotions associated with watching the video. The correlation coefficient between the WOW score and the number of emotions which the participants selected was calculated for each participant. Then, the average and the standard deviation of the correlation coefficient of all the participants were calculated. Also, the same calculation was applied for the causes.(one of the questions in the questionnaire.) The result was shown in table 3. Also, the feeling of no WOW and no cause (N/A) are not counted, because it means no emotion or no cause were associated.

Table 3: Correlation coefficient of the participants between WOW scores and numbers of emotions/causes

	Number of Emotions	Number of Causes
Average of correlation coefficient	0.66	0.71
Standard deviation of correlation coefficient	0.19	0.18

As shown in the table 3, there are strong positive correlations between the WOW score and the number of emotions/causes, and therefore it is suggested that as the video has multiple layers for emotions and causes, it can cause high WOW scores.

4.3 Results : Correlation between WOW score and each psychophysiological index

In this chapter, we are going to consider the relationship, especially correlation between the WOW score and data of each psychophysiological index. For example, we created a scatter plot showing the relationship between the WOW scores and standardized mean of EDA from every participant. Also, the correlation coefficient and P-value are calculated. In addition, we investigated how the relationship varies depending on emotions associated with the WOW UX. In order to have reliable results, the only six major emotions that are answered more than 20 times are focused. (Feeling of being surprised, being comfortable/good, being enjoyed, beauty, liking/loving something, looking forward to something.)

From the next section, we inserted some scatter plots which have correlations between the WOW scores and data of the psychophysiological indexes. For this study, when its P value is smaller than 0.1 and its correlation coefficient (r) is bigger than 0.2, it would be defined that it is suggested there is a correlation between them. Even though most of the researches relating to ergonomics and medical fields are set r = 0.3 as a bar to state the validation of correlation [30], we set r = 0.2 as the bar, because our experiments included several nationalities, both male and female participants, and different sets of videos for each participant, which might have made variations of the result bigger. Therefore, when r is between 0.2 and 0.3, it is recognized that there is a possibility to have correlation. The summary is in table 4.

Table 4: Summary of correlation efficient and P value

	$p \leq 0.05$	$p \leq 0.1$	$p > 0.1$
$\|r\| \geq 0.3$	Valid correlation	Valid correlation	Not able to conclude
$0.2 \leq \|r\| < 0.3$	Possibility of a correlation	Possibility of a correlation	Not able to conclude
$\|r\| < 0.2$	No correlation	No correlation	No correlation

4.3.1 Hemoglobin change and arterial oxygen saturation in brain (HC)

We measured oxyhemoglobin changes (HC) at 16 channels on the frontal lobe part. Then, r-value and p-value are calculated for each channel. According to the calculation results, only CH1, CH3, and CH14 had a valid correlation ($p \leqq 0.1$). Scatter plots for these three channels are left below.

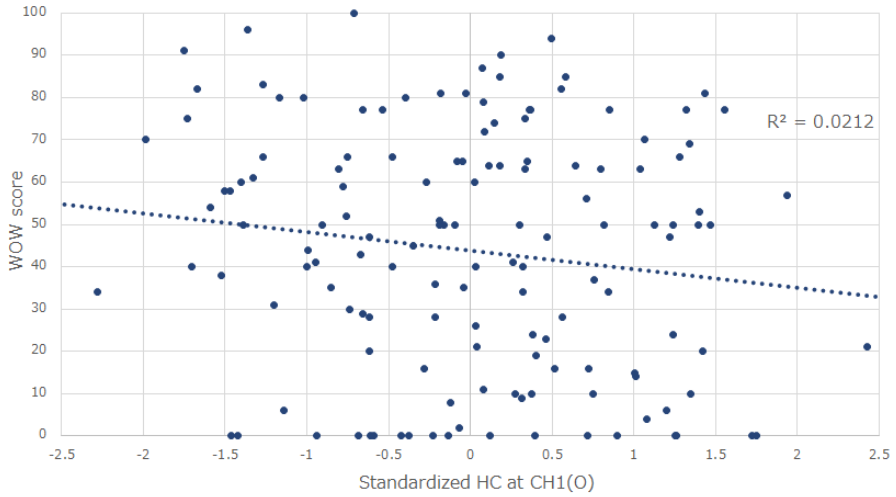

Figure 38: HC at CH1(O) and WOW score

$r = -0.15, p = 0.086$ (figure 38)
As p value is at the 10% level, it can be called that there is some level of negative correlation between WOW score and HC at CH1. It indicates that when people feel bigger WOW, CH1 would tend to become less active.

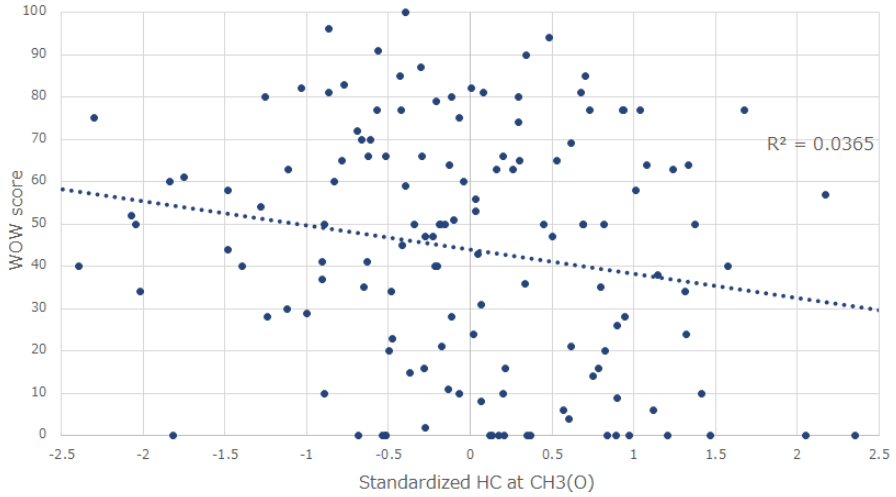

Figure 39: HC at CH3(O) and WOW score

$r = -0.19, p = 0.024$ (figure 39)
As p value is at the 5% level, it can be called that there is some level of negative correlation

between WOW score and HC at CH3. It indicates that when people feel bigger WOW, CH3 would tend to become less active.

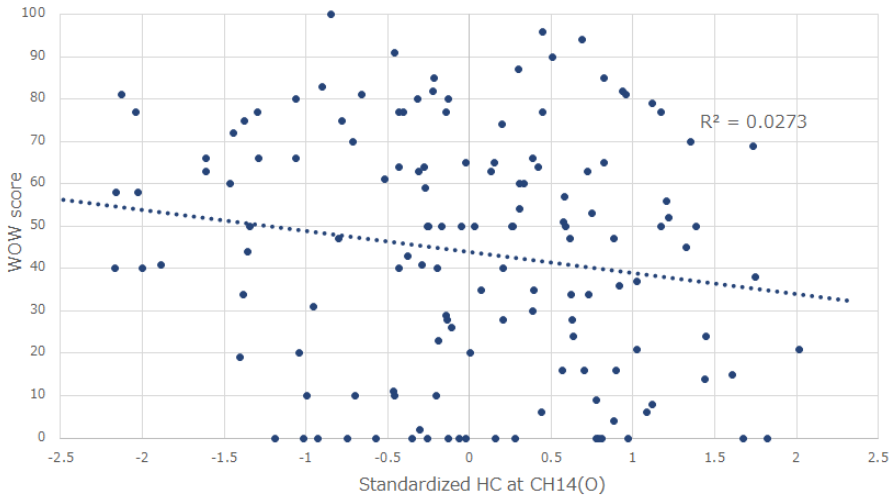

Figure 40: HC at CH14(O) and WOW score

$r = -0.17, p = 0.051$ (figure 40)
As p value is at the 10% level, it can be called that there is some level of negative correlation between WOW score and HC at CH14. It indicates that when people feel bigger WOW, CH14 would tend to become less active. Therefore, CH1, 3, and 14 have a possibility to have correlations with WOW score, and all of them would tend to be less active when people have bigger WOW.

As these 16 channels include 4 big parts - dorsolateral prefrontal cortex: DLPFC(CH5,8,11), Medial prefrontal cortex: MPFC(CH4,7,10,13), ventrolateral prefrontal cortex: VLPFC(CH1,2,14,16), and orbit frontal cortex: OFC(CH6,9,12) -, we also calculated r-value and p-value for the average score of each of these sets. However, there was not valid correlation between each big part and WOW score as shown in figure 41.

	CH1 + CH2	CH14 + CH16	CH5 + CH8 + CH11	CH4 + CH7 + CH10 + CH13	CH6 + CH9 + CH12
r	-0.13	-0.11	-0.11	-0.09	-0.09
t	1.52	1.28	1.28	1.09	1.05
p	0.13	0.20	0.20	0.28	0.30

Figure 41: Correlation between WOW score and each of the big parts of the frontal lobe

4.3.2 Electrodermal activity (EDA)

From 14 participants, 140 data of mean of EDA during watching each video were collected. (data were standardized in each participant.) Based on these 140 data, we created scatter plots as shown below. After each scatter plot, r-value (correlation coefficient) and P-value are mentioned.

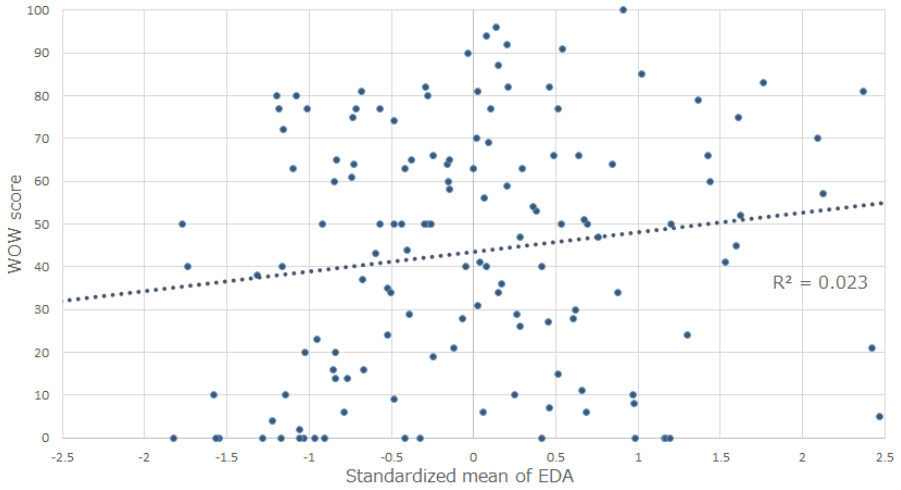

Figure 42: Mean of EDA and WOW score

$r = 0.15, p = 0.074$ (figure 42)
As r-value is smaller than 0.2, it is not clearly suggested that there is a positive (weak) correlation between Mean of EDA and WOW score. However, in the data, there was one outlier among the 14 participants. Average of the correlation coefficients of every participant was 0.13, while the correlation of the outlier was -0.81. Therefore, the outlier was excluded. Then, we recreate a scatter plot and recalculate the values as shown in figure 43.

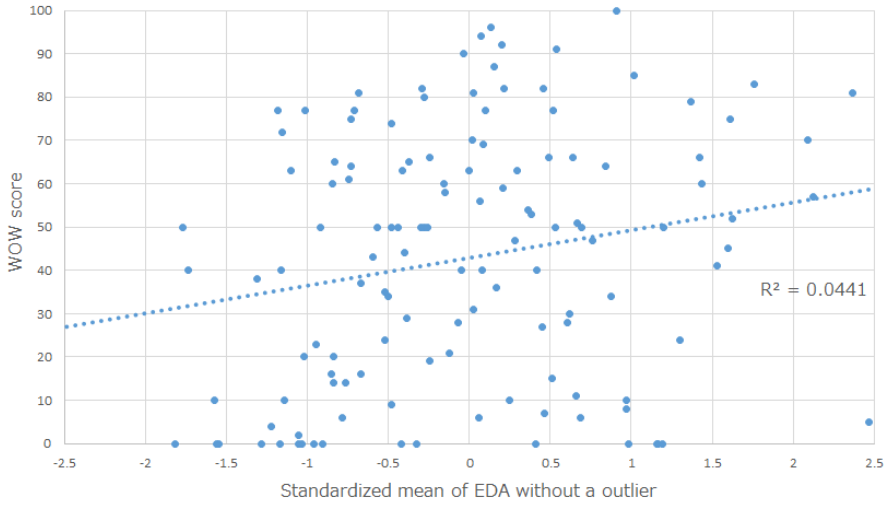

Figure 43: Mean of EDA and WOW score without an outlier

$r = 0.21, p = 0.016$ (figure 43)
Without the outlier, r is bigger than 0.2 and p is at the 5% level. Therefore, there is a possibility that WOW score and mean of EDA has a positive (weak) correlation.

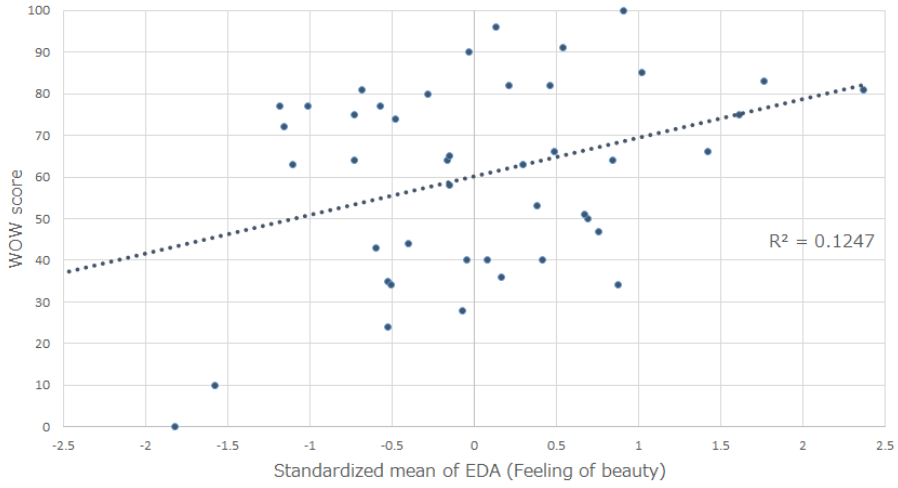

Figure 44: Mean of EDA and WOW score (feeling of beauty)

As the emotional expression "WOW" can be caused by several different emotions, such as feeing of being surprised and feeling of beauty, each emotion of WOW might have different psychophysiological reactions. Therefore, we calculated r-value and P-value for the major six emotions. And when these values meet the requirements ($|r| \geq 0.2$ & $P \leq 0.1$), we created the scatter plots for them, because it means there are correlations between WOW scores and the psychophysiological reactions.

$r = 0.35, p = 0.019$ (figure 44)
Figure 44 shows the scatter plot of "feeling of beauty". Here, r-value is bigger than 0.3 and P value is at the 5% level. Therefore, it is suggested that there is a positive correlation WOW score and mean of EDA when they have WOW with "feeling of beauty".

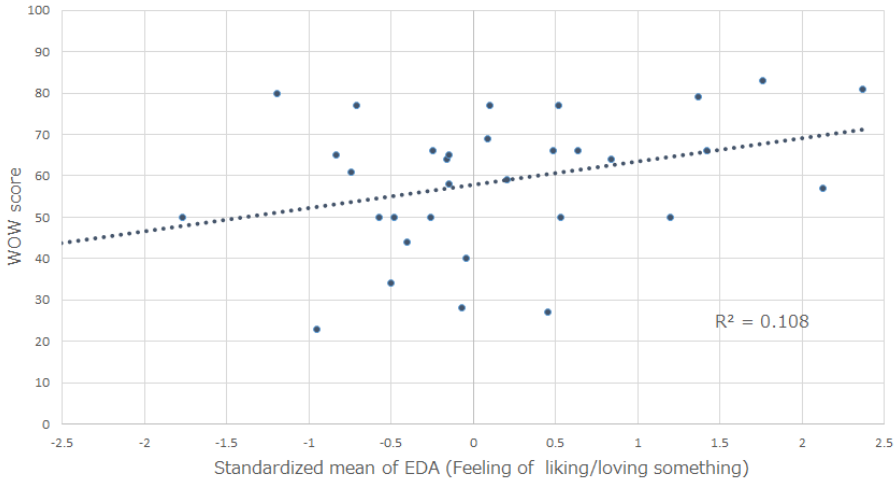

Figure 45: Mean of EDA and WOW score (feeling of liking/loving something)

$r = 0.33, p = 0.066$ (figure 45)
Figure 45 shows the scatter plot of "feeling of liking/loving something". As r is bigger than 0.3 and p is at the 10% level, it is suggested there is a positive correlation between WOW score and mean of EDA when participants had WOW with "feeling of liking/loving something".

4.3.3 Photo plethysmography (PPG)

We created scatter plots only when the r value and p value of the data meet the requirements (r ≧ 0.2 & p ≦ 0.1).

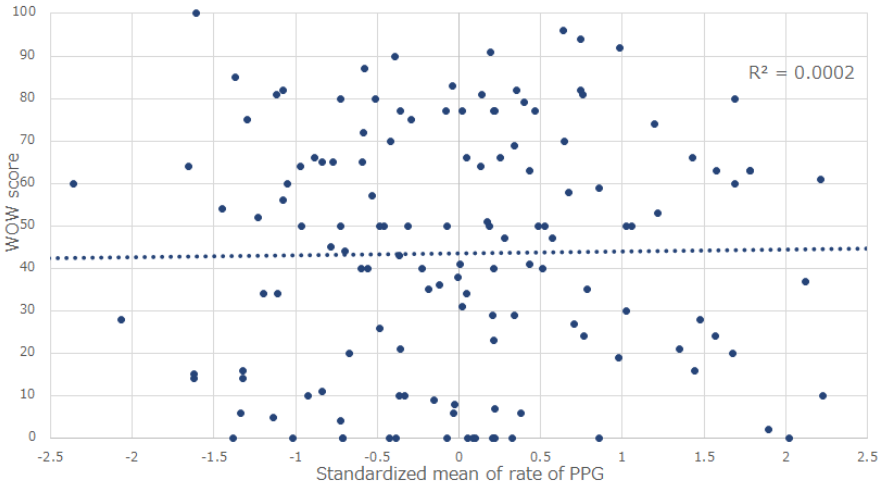

Figure 46: Mean of rate of PPG and WOW score

$r = 0.014, p = 0.87$ (figure 46)
Figure 46 shows the relationship between WOW scores and mean of rate (during watching videos) of PPG. Since r is close to 0, and p is close to 100%, it is suggested there is no correlation between rate mean of PPG and WOW scores.

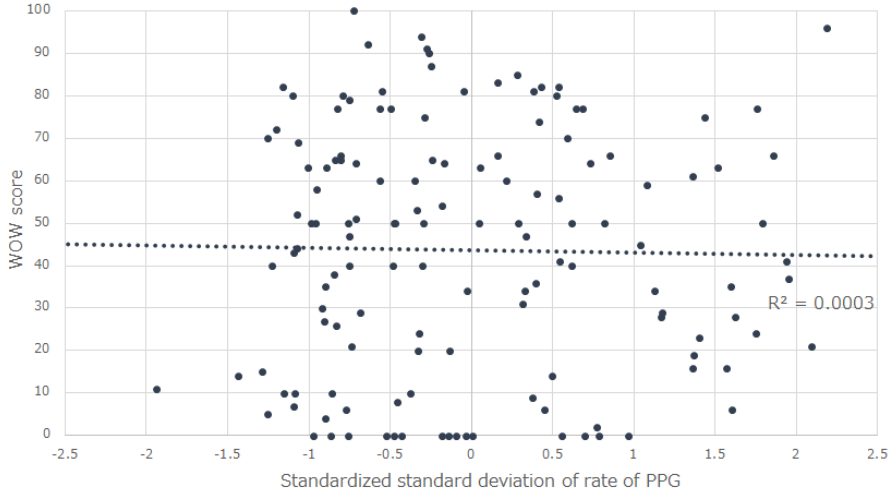

Figure 47: Standard deviation of rate of PPG and WOW score

$r = -0.018, p = 0.83$ (figure 47)
Figure 47 shows the relationship between WOW scores and standard deviation of rate (during watching videos) of PPG. Since r is close to 0, and p is close to 100%, it is

suggested there is no correlation between rate standard deviation of PPG and WOW scores. These results indicate (general) WOW UX would not have an influence on heart rate. However, when data of each of the emotions are focused, there are some correlations.

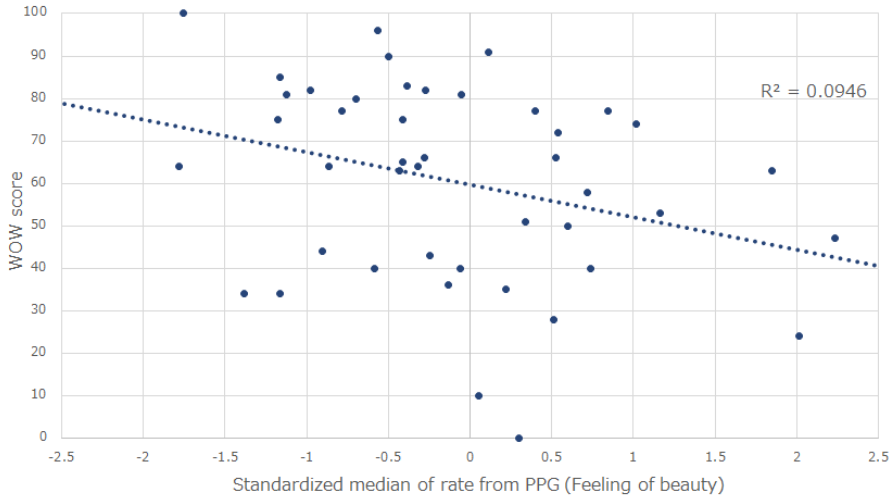

Figure 48: Median of rate of PPG and WOW score (Feeling of beauty)

$r = -0.31, p = 0.042$ (figure 48)
Figure 48 shows the relationship between WOW scores and median of rate (during watching videos) of PPG when participants had WOW UX with "feeling of beauty". As r is bigger than 0.3 and p is at the 5% level, there is a negative correlation between WOW score and median of rate of PPG with the feeling of beauty.

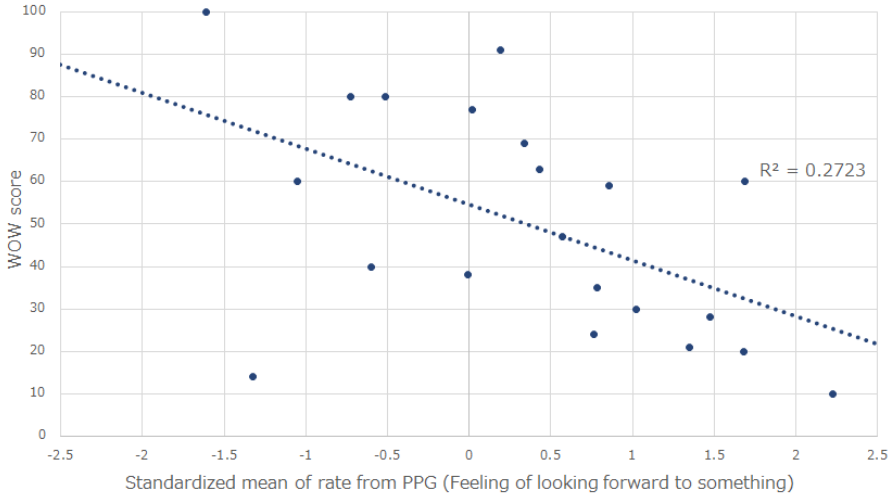

Figure 49: Mean of rate of PPG and WOW score (Feeling of looking forward to something)

$r = -0.52, p = 0.015$ (figure 49)
Figure 49 shows the relationship between WOW scores and mean of rate (during watching videos) of PPG when participants had WOW UX with "feeling of looking forward to something". As r is bigger than 0.5 and p is at the 5% level, there is a relatively strong negative correlation between WOW score and median of rate of PPG with the feeling of looking forward to something.

4.3.4 Electrocardiography (ECG)

We created scatter plots only when the r value and p value of the data meet the requirements ($r \geqq 0.2$ & $p \leqq 0.1$).

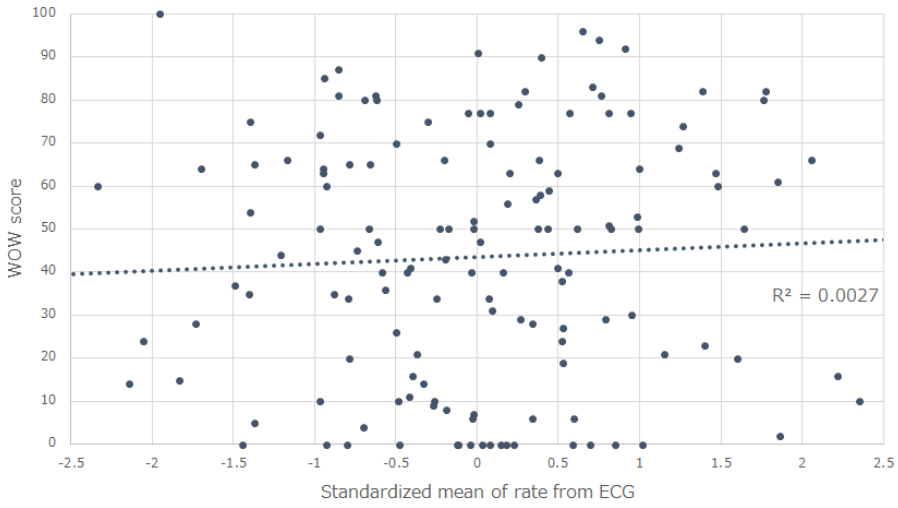

Figure 50: Mean of rate of ECG and WOW score

$r = 0.052, p = 0.54$ (figure 50)
Figure 50 shows the relationship between WOW scores and mean of rate (during watching videos) of ECG. Since r is close to 0, and p is bigger than 50%, it is suggested there is no correlation between rate mean of ECG and WOW scores when you focus on general WOW experience (not specific emotions).

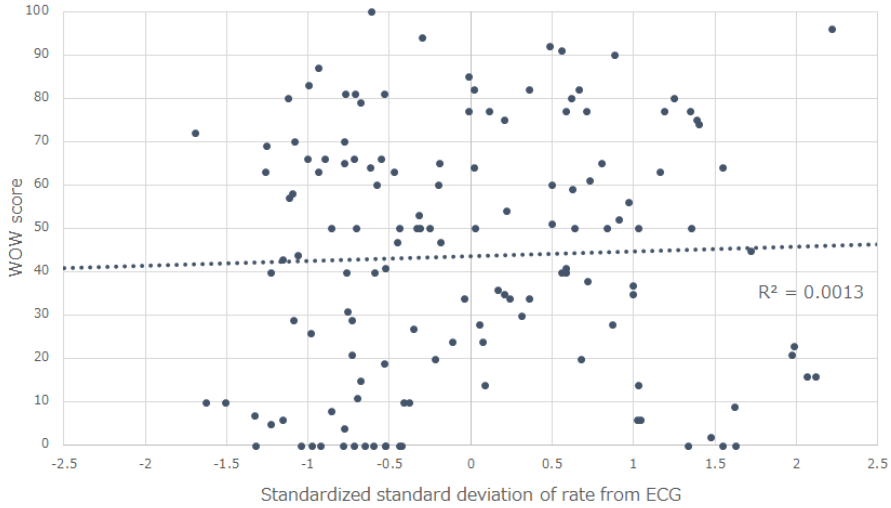

Figure 51: Standard deviation of rate of ECG and WOW score

$r = 0.037, p = 0.67$ (figure 51)

Figure 51 shows the relationship between WOW scores and standard deviation of rate (during watching videos) of ECG. Since r is close to 0, and p is high(67%), it is suggested there is no correlation between rate standard deviation of ECG and WOW scores. These results and the results from PPG indicate (general) WOW UX would not have an influence on heart rate. However, when data of each of the emotions are focused, there are some correlations.

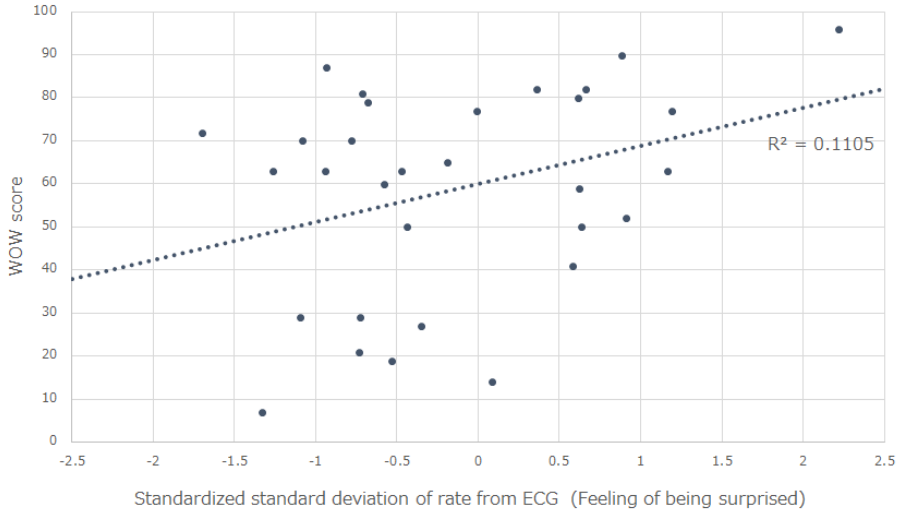

Figure 52: Standard deviation of rate of ECG and WOW score (feeling of being surprised)

$r = 0.33, p = 0.068$ (figure 52)
Figure 52 shows the relationship between WOW scores and standard deviation of rate (during watching videos) of ECG when they had WOW with feeling of being surprised. Since r is bigger than 0.3 and p is at the 10% level, it is suggested there is a positive correlation between rate standard deviation of ECG and WOW scores in this emotion, which indicates when they feel bigger WOW with feeling of being surprised, heart rates vary more greatly than usual.

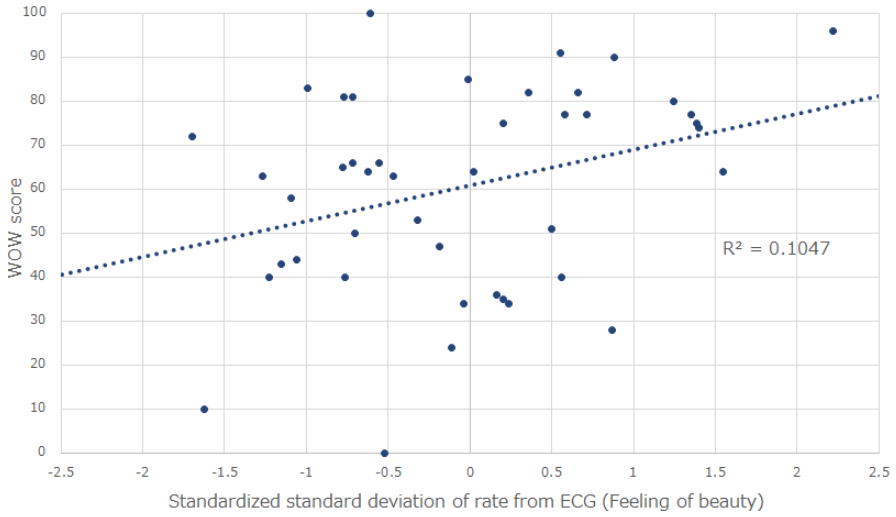

Figure 53: Standard deviation of rate of ECG and WOW score (feeling of beauty)

$r = 0.32, p = 0.032$ (figure 53)
Figure 53 shows the relationship between WOW scores and standard deviation of rate (during watching videos) of ECG when they had WOW with feeling of beauty. Since r is bigger than 0.3 and p is at the 5% level, it is suggested there is a positive correlation between rate standard deviation of ECG and WOW scores in this emotion, which indicates when they feel bigger WOW with feeling of beauty, heart rates vary more greatly than usual.

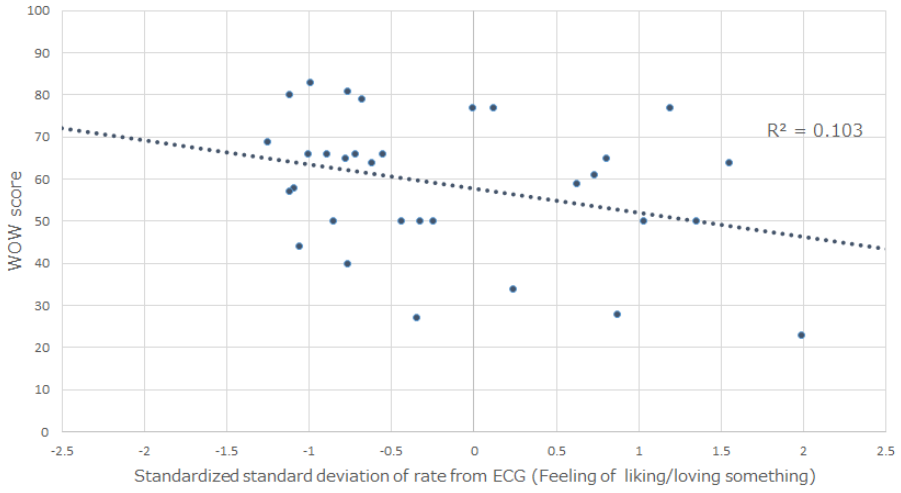

Figure 54: Standard deviation of rate of ECG and WOW score (feeling of liking/loving something)

$r = -0.32, p = 0.073$ (figure 54)
Figure 54 shows the relationship between WOW scores and standard deviation of rate

(during watching videos) of ECG when they had WOW with feeling of liking/loving something. Since r is smaller than -0.3 and p is at the 10% level, it is suggested there is a negative correlation between rate standard deviation of ECG and WOW scores in this emotion, which indicates when they feel bigger WOW with feeling of liking/loving something, heart rates vary less than usual.

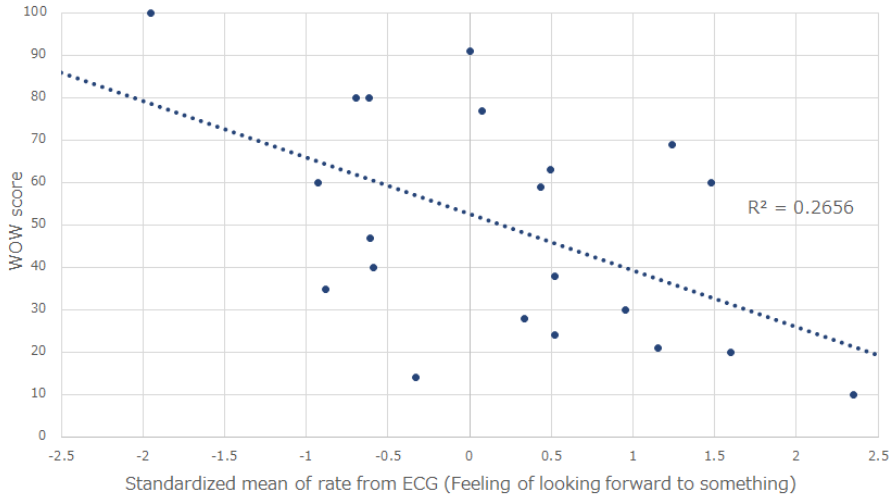

Figure 55: Mean of rate of ECG and WOW score (Feeling of looking forward to something)

$r = -0.52, p = 0.017$ (figure 55)
Figure 55 shows the relationship between WOW scores and standard deviation of rate (during watching videos) of ECG when they had WOW with feeling of looking forward to something. Since r is smaller than -0.5 and p is at the 5% level, it is suggested there is a relatively strong negative correlation between rate mean of ECG and WOW scores in this emotion, which indicates when they feel bigger WOW with feeling of looking forward to something, heart rates would become smaller.

4.4 Discussion/Interpretation of results

4.4.1 HC(NIRS)

The results of the experiments showed EC at CH1(O), CH3(O), and CH14(O) had (weak) negative correlations with WOW score, which indicates that when people have bigger WOW UX, CH1, CH3, and CH14 would be less active. The locations of these channels can be found in figure 56.

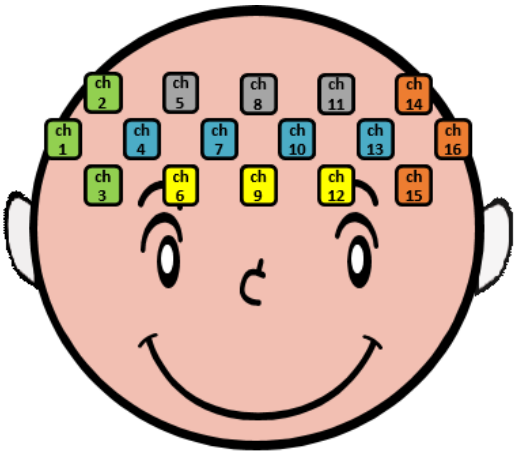

Figure 56: Location of each channel in the frontal lobe

A research suggests CH1 and CH14 would become more active with unpleasant feelings, (and CH15 would be less active with pleasant feelings).[31] As CH1 and CH14 became less active with WOW UX in our experiments that is the opposite reaction with the reaction of unpleasant feelings, the participants felt less unpleasant when they had WOW UX in comparison with normal feelings. As all of CH1, Ch3, and CH14 are identified as parts of ventrolateral prefrontal cortex(VLPFC), and a review in a research suggests VLPFC is regulation of emotion.[17] Therefore, the inactivity of VLPFC indicates high emotional states. By combining this notion and the results, WOW UX should be related high emotional state. Even though there are many studies trying to find the relationship between emotional state and activation on prefrontal lobe[32], there is no agreement for what emotions are connect to which channel on frontal lobes.

From this experiment, we could find CH1, CH3, and CH14 would be less active with bigger WOW UX in summary.

4.4.2 EDA/PPG/ECG

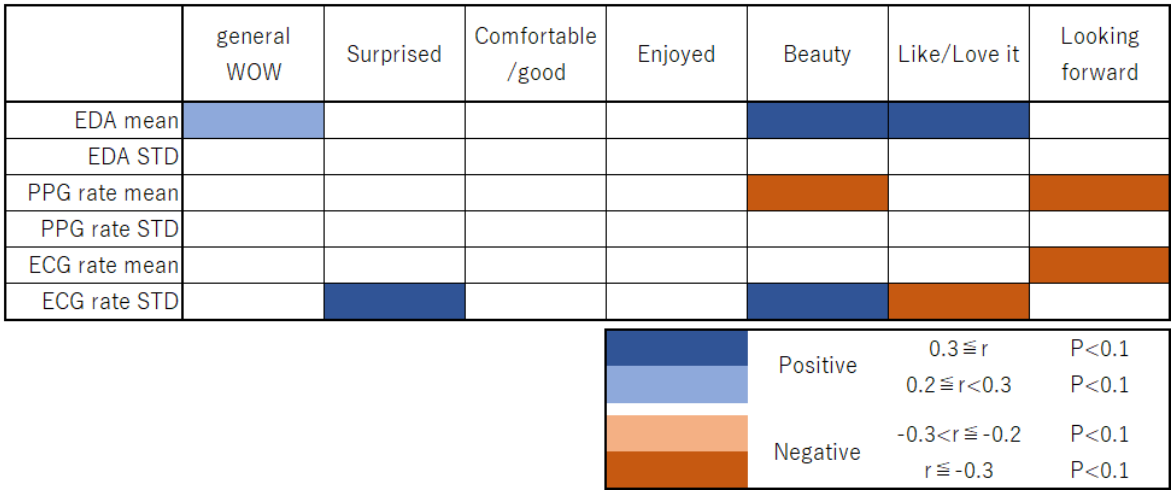

Figure 57: Summary of characteristics of correlation between WOW score and each psychophysiological indexes (for general WOW and each emotion)

The summary for the results of correlation between each of the indexes and WOW score is shown in figure 57. This figure the colored cells mean there is some positive/negative correlation, also deeper colors indicate relatively stronger positive/negative correlation (r is bigger than 0.3 or smaller than -0.3).

Electrodermal activity (EDA)
For EDA, the chart indicates WOW score and EDA has (weak) positive correlation. According to Kreibig's review[33], feelings of "amusement", "affection", and "surprise" have positive correlations with EDA, and feeling of contentment (this feeling is close to relaxation) has negative correlation with it. Moreover, a research stated increase of EDA level is an indicator of sympathetic arousal.[34]

Actually, "the feeling of liking/loving (affection) it" has a stronger positive correlation. In addition, as the feeling of surprise does not have positive correlation, the experiment reveals WOW with the feeling of surprise does not have correlation with EDA even though general WOW score has positive correlation with EDA (and feeling of surprise is said to have positive correlation with EDA). In addition, WOW with the feeling of beauty also has moderate positive correlation with EDA. On the other hand, standard deviation of EDA had no correlation with WOW UX.

In summary, WOW experience has a weak positive correlation with EDA, which is a similar reaction with feeling of amusement and affection. Feeling of surprise has the similar reaction, but the chart indicates WOW with feeling of surprise does not have correlation with EDA, so it was excluded. In addition, it is also indicated WOW UX increases arousal level. Finally, WOW UX with feelings of beauty and liking/loving it had moderate positive correlation with EDA.

Photoplethysmography (PPG)
WOW UX with the feeling of beauty and looking forward to something had moderate

negative correlations with heart rate (HR) mean from PPG. However, general WOW UX did not have any correlation with HR and HR variation.

According to Kreibig's review[33], feelings of contentment and affection has negative correlation with PPG HR as well, while feelings of joy and surprise has positive correlation.

In summary, even though HR mean and HR variability from PPG did not have correlation with general WOW UX, HR mean has negative correlation with WOW UX of the feeling of beauty and looking forward to something, and therefore these feelings have similar reactions with feeling of contentment. (Similar to feeling of affection too, but the feeling of liking/loving something did not have correlations and so it was excluded.)

Electrocardiography (ECG)

The general WOW did not have any correlation with HR mean and variability(standard deviation). However, HR mean had moderate negative correlation with WOW UX of the feeling of looking forward to something. Also, HR variability from ECG had moderate positive correlation with WOW UX with the feeling of surprise and beauty, and also negative correlation with WOW UX of the feeling of liking/loving it.

According to Kreibig's review[33], HR variation increase indicates feeling of joy and amusement, and its decrease indicates contentment. Therefore, WOW UX with the feeling of surprise and beauty shows similar changes as joy and amusement, while the feeling of liking/loving it shows similar changes with contentment.

4.5 Evaluation indexes of emotions surrounding WOW UX

For evaluating WOW UX, indexes listed below can be indicators of WOW UX. Therefore, by using these indexes, WOW UX can be objectively assessed.

- mean of EDA: WOW UX raises EDA activity.
- HC at CH1(O): would be less active with bigger WOW UX
- HC at CH3(O): would be less active with bigger WOW UX
- HC at CH14(O): would be less active with bigger WOW UX

However, since several different emotions, such as feelings of surprise and beauty are associated with WOW UX, and these feelings generate different (sometime opposite) psychophysiological reactions, it is not easy to find apparent psychophysiological reactions. In other words, there are several types of WOW UX depending on types of emotions, and when WOW UX with each specific emotion, there are more indicators of psychophysiological reaction to evaluate the UX as listed below.

WOW UX with feeling of surprise: This type of WOW UX can be evaluated with increase of HR standard deviation(variability) from ECG

WOW UX with feeling of beauty: This type of WOW UX can be evaluated with increase of EDA, decrease of HR from PPG, and increase of HR standard deviation (variability).

WOW UX with feeling of liking/loving something: This type of WO UX can be evaluated with increase of EDA, and decrease of HR standard deviation (variability).

WOW UX with feeling of looking forward to something: This type of WOW UX can be evaluated with decrease of HR from PPG, and also decrease of HR from ECG.

Therefore, even though only CH1, CH3 and CH14 of frontal lobes and EDA are indicators for general WOW UX, each emotion of WOW UX can be evaluated by other indicators, such as PPG, ECG, EDA, and other channels as well.

5 Consideration of the future appliance of this study for UX design

As Desmet talks about the importance of considering emotions for consumer product development in his book, it is important to have evaluation methods of emotions during interactions with products. [35]. Actually, in order to objectively evaluate UX, more and more researches are trying to evaluate UX through experiments on psychophysiological reaction.[36][37]

Through this study, we revealed contextual information and emotions associated with WOW experiences, these information would be helpful for product designers to understand what WOW UX is. Now, even though huge technology companies are trying to provide WOW UX as explained in the introduction, they still do not fully understand what contexts and emotions are associated with WOW UX. Therefore it would be the crucial first step to understand what WOW UX is, in other words, what they really want to provide. Especially, as Kano model suggests that WOW might be able to be caused by something users did not expect, and improving the quality of products (e.g. resolution of TV) less likely cause WOW experience, designers should be creative and imaginative.[13] However, being creative might have products further away from users' actual need. Therefore, the contextual information and emotions related to WOW UX can be used to make designers stay at user side as well as being creative both at conceptualization and evaluation phases.

Then, after finishing the product design phase, companies still need to understand psychophysiological reactions related to WOW UX in order to objectively evaluate WOW UX. With this evaluation, the design process would need to heavily rely on subjective surveys anymore, and so designers can have more precise evaluation. Sometime, designers rely on their feelings and subjective survey answers from specific users, which can isolate them from actual needs and true reactions with the products. Therefore, having objective psychophysiological evaluation should be beneficial for designers to think of actual needs and reactions.

In addition, we focused on WOW UX as it is indicated that companies are trying to provide "WOW UX" these days, but it will surely happen for companies to want to provide different kinds of UX in the future. Even in that situation, through following the process of this study, they will be able to understand what emotions and contexts are associated with the UX. Also, this process help them have objective evaluation methods as well.

6 Conclusion

This study was designed to start with revealing contextual information and emotions associated with WOW UX. Text mining on Twitter successfully revealed what emotions and contexts are associated with WOW experience. Emotions that were frequently associated with WOW experience were feeling of being surprised, beauty, being cuteness/handsomeness, uniqueness of length of time, liking/loving something. Also, the text mining also indicated that there were some similarities and differences between WOW experiences in general cases and WOW experiences in a specific situation (driving).

Based on the results, we designed a psychophysiological experiment for evaluating WOW UX. It is indicated that EDA and HC at CH1(O), CH3(O), and CH14(O) have relationship with general WOW UX. On the other hands, as indicated by the text mining, WOW UX includes several different emotions, and these have different psychophysiological reactions, which makes it difficult to establish a method for evaluating WOW UX on one scale. When each emotion associated WOW UX is focused, there are several relationships existed between WOW UX and its psychophysiological indexes. For example, EDA, HR from PPG, and HR variability can be good indicators for evaluating WOW UX with the feeling of beauty.

In summary, we could achieve to reveal contextual information and emotions associated with WOW experience through text mining, and establish methods for emotions associated with WOW UX. Also, as WOW UX is related to several different emotions, it was difficult to establish a standard method for evaluating general WOW UX, but each emotion associated with WOW UX is focused, there are several indicators to evaluate its WOW UX. These study would be helpful to evaluate WOW UX of products, and eventually help companies to provide more WOW UX to users.

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