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Master's Thesis

Academic Year 2016

Research on Embodiment of Urban Landscape Based on Human Heartbeat Information

Keio University

Graduate School of Media Design

Feng Liang

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Feng Liang

Thesis Committee:

Associate Professor Kouta Minamizawa	(Supervisor)
Associate Professor Kai Kunze	(Co-supervisor)
Senior Assistant Professor Marcos Sadao Maekawa	(Member)

Abstract of Master's Thesis of Academic Year 2016

Research on Embodiment of Urban Landscape Based on Human Heartbeat Information

Category: Design

Summary

City Wander has become a popular hobby in recent years. People enjoy exploring the city by walking, it is a hobby to relax oneself, and to discover new treasure of the city and one's life. In this research, I designed a City Wander recording and sharing service with wearable devices, which visualizes the heartbeat information on a map to show the relationship between human body and urban landscape, so that we can realize the embodiment of urban landscape. I firstly hypothesized that one's heart rate rises when he or she sees something he or she is curious about, and then test this using my first prototype device. I conducted an experiment with four participants, in popular City Wander areas such as Akihabara and Asakusa area in Tokyo. The data suggests that heart rate is significantly higher when participants see what they consider an interesting spot when compared with spots they are indifferent towards, implying that my concept is supported by quantitative physiological data responses. With the second prototype, which is a new kind of Instagram Service, I had a deeper study on the relationship between urban landscape and human emotion, and also to show the actual scenario possibilities of this research. Perspectives of this research direction are discussed in terms of the relationship between city and human body and even the emotion.

Keywords:

Embodiment, Heartbeat, Emotion, Personalized, Urban Landscape

Keio University Graduate School of Media Design

Feng Liang

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Chapter 1
Introduction

1.1 About City Wander

City Wander has become a popular hobby in recent years. People enjoy exploring the city by walking, they may take pictures of the views they think are beautiful, and may also go into a nice restaurant that they have never been to before. City walking is a hobby to relax oneself, and to discover new treasure of the city and one's life.

There is many existing services for City Wander these days, including internet map service, route tracking, and even Augmented Reality games, etc.For example, since everybody has different interest, the routes that would make him or her happy should also be different from each other. In order to provide a better route suggestion based one's interest, there is a project called "Urban Gems Project" [21] in UK. On the website of this project, people are asked to choose the more beautiful photo out of two for ten times, then based on the survey data, routes like "Happy", "Beauty", "Shortest" and "Quite" were generated(Figure 1.1).

Besides of the need for personal hobbies, city walking can be also be used for local promotion. For example, "Hiroshima Cat Street View" [8] gives people the experience of exploring the back streets of Hiroshima through a cat's eyes. Your sight becomes as low as a cat, and you can find some cat-like comment when you are exploring. By combining city walking and cat view, this service is effective for the promotion of Hiroshima's back streets.(Figure 1.2)

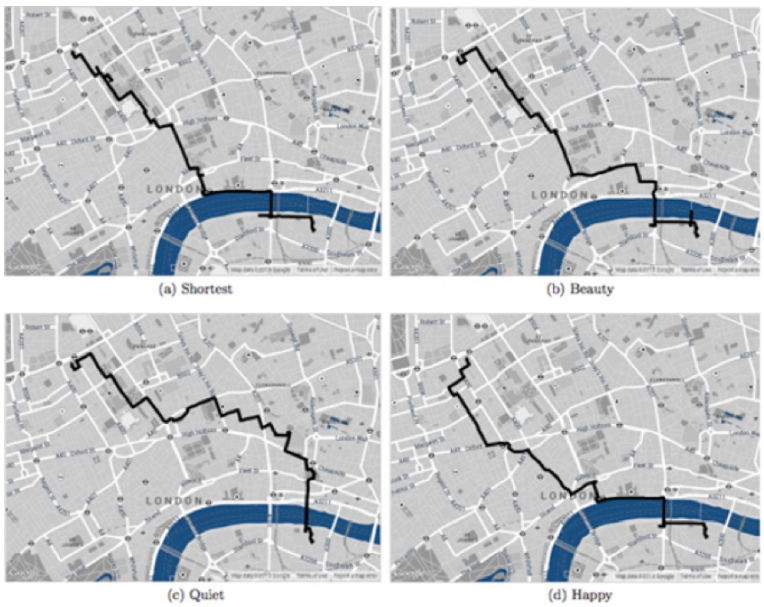


Figure 1.1: "Happy", "Beauty", "Shortest" and "Quite" routes in London generated by Urban Gems Project. [21]

Figure 1.2: Hiroshima Cat Street View provides a new kind of City Wander service through cats's eyes. [8]

1.2 Motivation

Nowadays, we have a lot of options to record our own physiological data, for example, the heart rate data. The wearable devices, such as Apple Watch, Fitbit, and many other devices for personal health care, are able to measure and record many kinds of physiological data. According to the worldwide wearables market research of year 2015-2016 [3], we can find that the top five Wearables Vendors Fitbit, Xiaomi, Apple, Garmin, Samsung and BBK, have a year-over-year growth up to 67.2% in total from last year to this year.(Figure 1.3) It can be told that more and more people can afford to buy their own wearable devices from this research. From the point of view of the research team, the wearable market keep maturing and expanding.

Top Five Wearables Vendors, Shipments, Market Share and Year-Over-Year Growth, Q1 2016 (Units in Millions)

Vendor	1Q16 Unit Shipments	1Q16 Market Share	1Q15 Unit Shipments	1Q15 Market Share	Year-Over-Year Growth
1. Fitbit	4.8	24.5%	3.8	32.6%	25.4%
2. Xiaomi	3.7	19.0%	2.6	22.4%	41.8%
3. Apple	1.5	7.5%	N/A	0.0%	N/A
4. Garmin	0.9	4.6%	0.7	6.1%	27.8%
5. Samsung*	0.7	3.6%	0.7	5.8%	4.5%
5. BBK*	0.7	3.6%	N/A	0.0%	N/A
Others	7.3	37.2%	3.9	33.1%	87.9%
Total	**19.7**	**100.0%**	**11.8**	**100.0%**	**67.2%**

Source: IDC Worldwide Quarterly Wearables Tracker, May 16, 2016

Figure 1.3: Top Five Wearables Vendors, Shipments, Market Share and Year-Over-Year Growth, Q1 2016 (Units in Millions).* IDC declares a statistical tie in the worldwide wearables market when there is less than one tenth of one percent (0.1%) difference in the unit shipment share of two or more vendors. [3]

Besides, with the fast and great advances of smartphone technology these years, these days smartphones are equipped with many functions. Most of the functions can help users in their daily life. Besides of the most primary functions of a mobile phone, the calling and texting functions, people can also do a lot of

things with only a smartphone. As a very typical scenario for smartphone usage in our daily life, people can take a photo and then share the photo which tagged with location information to the social networks. These functions enable smartphone to record many different kinds of data, for example, the GPS data which shows the locations user had been to.

As I introduced in the first chapter, City Wander has become popular around the world. The design concept of combining smartphone and City Wander has been suggested and won a great success with the Pokemon Go [1] this year (2016). Pokemon Go is an augmented reality smartphone game which is location-based.(Figure 1.4) The player need to walk in town to discover pokemons, which are the monsters in Pokemon series for players to catch, sometimes the player even have to go to specific spots in the city if they want to catch rare pokemons. In fact, many Pokemon Go players walked around the city with their smartphone more often than usual to play this game. According to the NBC news published just after the release of Pokemon Go [2], this game attracted millions of players to venture outside since they wanted to catch more and more pokemons. One of the interviewee said that, she wanted a pokemon so she just got up and went for a little walk. It shows that Pokemon Go also has the effect of encouraging people to go outside and walk through the city. In my opinion, Pokemon Go is one of the successful stories of walking through the city with wearable device, which shows this world-wide trend and there is a great deal of possibilities of services for City Wander.

Figure 1.4: Pokemon Go is a location-based augmented reality game on smartphone. [1]

Now we understand that there are large numbers of people can afford their own wearable devices and smartphones, also the services for City Wander have a great market needs these days. Latest advancement of wearable devices makes it easy to obtain physiological data such one 's heart rate with GPS information. This set of multidimensional data is collected and stored in a wearable device, however, this is not usually combined to extract specific information.

People have so much fun to walk around the city, even in Tokyo you can find there are many people, including the foreign tourists and local citizens, like to take a walk on holiday to explore the attractiveness of Tokyo. In the same time, more and more people own wearable devices to log everyday life including the heart rate data. So how about to collect the walking data and put them onto the same map? It may surprise us from what we can find by doing this information mapping. That is the motivation in the beginning I try to pursue. From this research, we can study the relationship between heartbeat and geographical characteristics succinctly. It would also be helpful to reconsider the attractiveness of the city by analyzing obtained user data. Besides, by observing the heartbeat information, we can examine whether human body may react to the spots in the town.

1.3 Purpose of Research

Although there are a lot of works that are related to public relations surrounding City Wander, to our knowledge, up until now there has been no service that is totally personalized based on physiological data (in other words, embodied data) such as heart rate, blood pressure, or the amount of sweating. Therefore, in this research, we would like to discuss the possibility of using wearable devices while city wander. Especially, I consider the relationship between one's interest and real-time heart rate, in order to provide a more personal City Wander service.

1.4 Structure of Thesis

In this paper, I am going to talk about my research about designing City Wander based on heart rate information in order to achieve the embodiment of urban landscape. The paper consists of 5 parts, Introduction, Related Works, Concept,

Prototype and User Test, and Conclusion. Firstly the general introduction of City Wander and my research motivation as well as purpose would be talk about. Secondly, I would show some of the related works to my research in three main categories. In Chapter 3 I would describe my research concept in detail such as the basic idea, system design and scenarios. And then I am going to show you the prototype and user test I conducted based on my original concept. Finally, the conclusion of this paper would be drawn in the last chapter.

Chapter 2
Related Works

2.1 Apply Sensory Modalities To City Wander

Nowadays people are allowed to continuously collect health data including walking information with their mobile devices. Joshua Juen [13] believes that walking speed is closely linked to morbidity in patients and is also useful to determine distance walked during six-minute walk tests, a standard assessment for both chronic obstructive pulmonary disease and congestive heart failure. They developed a middleware called MoveSense on smartphone to provide comparable readings to medical accelerometers. Six methods they developed were evaluated by using the conducted device. These methods were made for constrained treadmill walking to obtain gait speed during natural walking with older chronic pulmonary patients and train new models to predict speed and distance.

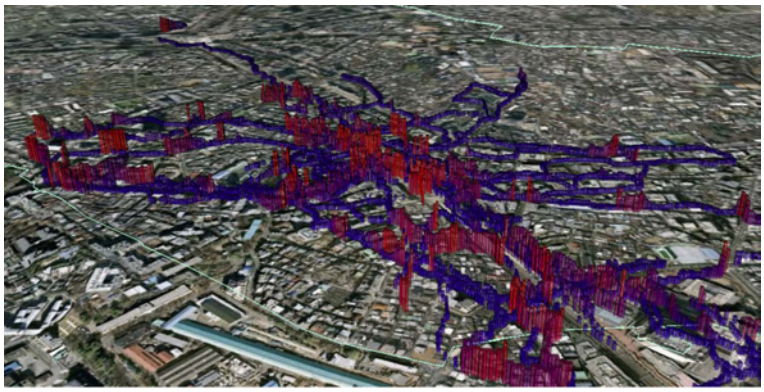


Figure 2.1: 20 students' curiosity levels are visualized by analyzing the walking speed. [17]

Although recommendation systems become popular these years, most of the existing systems provide the recommendation through the conditions users input

on a browser. In order to make suggestion of City Wander on the aspect of sensory modalities, Chihiro Sato [17] proposed a TTI Model, which aims to extract individual's curiosity level in urban spaces on people's spare time by collecting ones' behavior data with sensors. By depending on the walking speed, this model calculates one's real time curiosity level by analyzing his or her behavior. The authors evaluated this model with their sensor device prototype and elaborates possibilities on understanding one's interest in detail. (Figure 2.1)

Besides of walking speed, there are also many existing researches about using haptic to navigate people for City Wander. For example, Yuki Imamura [10] proposes a method for displaying unaware-usage haptic sensation of navigation. This research aims to solve the problem that people have to keep looking on a map when people visit an unfamiliar place, which sometimes causes missing of beautiful scenery. A haptic navigation system was developed to release human eyes from constantly looking into a map while daily walk and even sightseeing.

Assistive technology for individuals with visual impairment has also attracted increasing attention from researchers. J. Zhang [26] presented a comprehensive survey on the development of NSVI technology in five years. Two sensory substitution mechanisms are discussed and three navigation methodologies including positioning system-based, RFID tag-based, and vision-based methods had been presented.

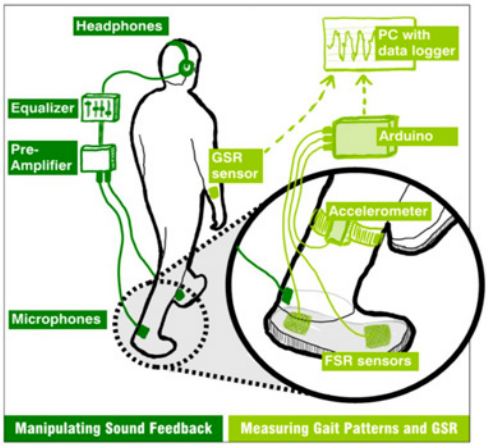


Figure 2.2: Lift: manipulating sound feedback; Right: sensing gait and galvanic skin sensor. [19]

Ana Tajadura-Jimnez [19] propose a shoe-based prototype to sense a person 's footsteps and alters in real-time the frequency spectra of the sound they produce while walking. The resulting sounds are consistent with those produced by either a lighter or heavier body. Our user study showed that modified walking sounds change one 's own perceived body weight and lead to a related gait pattern. In particular, augmenting the high frequencies of the sound leads to the perception of having a thinner body and enhances the motivation for physical activity inducing a more dynamic swing and a shorter heel strike. We here dis- cuss the opportunities and the questions our findings open.(Figure 2.2)

Matthias Berning [4] proposed a wearable sensory substitution system called ProximityHat, which uses pressure actuators around the head to convey spatial information. Compared to existing systems those are not suitable for everyday use, ProximityHat can detect the distance to surrounding objects with ultrasonic sensors and maps this information to an inward pressure in daily walking situation.

To figure out whether it is effective to use real-time on-screen guidance to help users take better photos with portable devices, Yan Xu [24] developed a photo-taking interface Using a three-camera array to provide real-time feedback. They also conducted user study to compare the quality of photos against to existing digital cameras. The results indicate the photos taken with their real-time guidance interface have significantly higher aesthetics scores.

2.2 Make Use of Vital Data on Training Performance

People do exercise in order to have good health. Therefore, to monitor and analyze one's vital data become a trend these years. Aiming to support people to enjoy walking with an appropriate physical load, Mayu Sumida [18] proposed a method to estimate physical load and its variation during walking only with available functions of a smartphone. Some heart rate prediction models to predict heart rate variation from walking data were build in this research. The proposed method was applied to actual walking data on various routes by different people.(Figure 2.3)

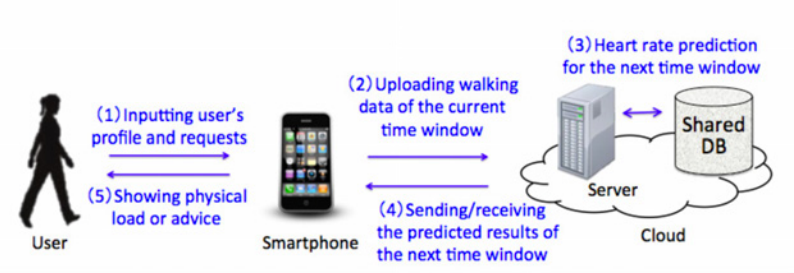


Figure 2.3: Outline of the proposed walking support system. [18]

Due to the importance of heart rate on training intensity, Janko Timmermann-[20] designed a demonstrator which encodes various heart rate zones with continuous vibration feedback. This demonstrator uses a tactile design build in a participatory design study and has shown to improve the awareness of the heart rate in user study.

It had already been suggested that a proper running rhythm, which is coordinated with breathing and strides, helps improve exercise efficiency and postpone fatigue. Tian Hao [7] presents a smartphone-based system called RunBuddy for continuous running rhythm monitoring. RunBuddy is designed to slove the problem that the sound of breathing has very low intensity and is susceptible to interference. Their user study results point out that, by leveraging the LRC model, RunBuddy correctly measures the running rhythm 92.7% of the time for both indoor and outdo1or.(Figure 2.4)

Stina Nylander [15] had also proposed a system called RunRight to give visual and audio for runners to run in a right way. This system firstly creates a visualization of the running movement based on acceleration and then provides audio feedback on the rhythm. This study would be helpful to technology developing of supporting athletes in learning desired movement.

Mads Mller Jensen [11] proposed a design space based on existing technologies, including heart rate monitoring, for run-training. By finding out that the existing technologies are limited to utilize technique-related information, they pointed out three questions to be addressed by designers of future run-training interfaces.

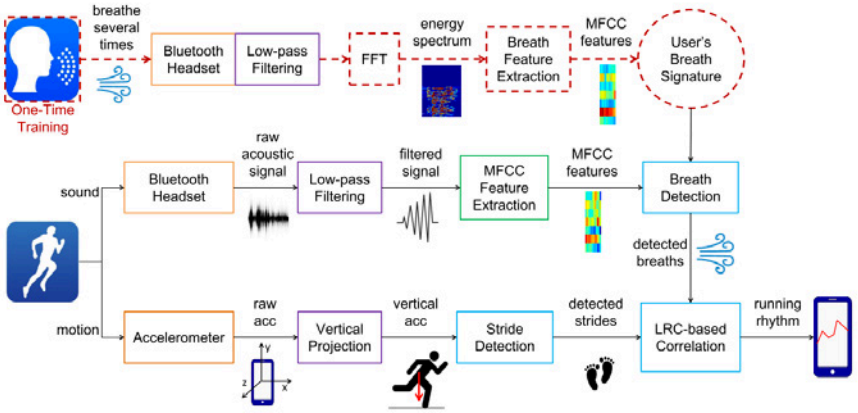


Figure 2.4: RunBuddy requires a one-time training, and comprises 3 major components: breath detection, stride detection and LRC-based calibration. [7]

On the aspect of rehabilitation, Diane Gromala [6] conducted a VR system designed for chronic pain patients. The system titled the " Virtual Meditative Walk " is build with biofeedback sensors and stereoscopic sound. Compared to the non-VR control, the user study results show that the Virtual Meditative Walk was more effective in reducing perceived pain.

2.3 Relationship Between Emotion and Vital Data

In the recent researches, it had been found that the vital data such as heart beat information show one's emotion in a way. Since sometimes emotion like the anxiety may do harm more than good to people, effective emotion regulation becomes a hot topic in studies of emotion and vital data. Yun Huang [9] designed a novel location-based mobile social application, which is called Emotion Map, to help people be more aware of their emotions and do the regulation on them. This application allows users to record their emotions with the date and time, location, and activity information. Their analysis shows promising results of the app. It was also found that Emotion Map improved some participants ' self-knowledge of their emotions and enabled better awareness of the emotion statuses of their friends and communities.(Figure 2.5)

Figure 2.5: The user interface for Emotion Map. [9]

Egon L. van den Broek [22] discussed the rare combination of speech, electrocardiogram, and a revised Self-Assessment Mannequin to evaluate people 's emotions. In the conducted experiments, 40 people watched 30 International Affective Picture System pictures in either an office or a living-room environment. Author analyzed the data with both basic emotion categories and the valencearousal model, which enabled a comparison between two representations.

Frdric Bousefsaf [5] introduced a new framework for detecting workload changes. This framework records the skin conductance and compares these responses to the stress curve assessed by a webcam-derived heart rate variability analysis. The results support the applicability of stress detection by remote and low-cost.

Jo Vermeulen [23] conducted a device called Heartefacts, short video clips composed of highlights depends on heart rate changes while watching videos clips. Their experiment results show that people do indeed have measurable reaction to their heartbeat patterns to six different emotions elicited by video clips. The users would be emotionally affected with showing heart rate changes when the watch

different kinds of videos. They designed Heartefacts using smartphone functions.

Since vital data can represent human's emotions to some extent, recently people started to use this kind of phenomenon to make more human-like robot and emotional device. Naoto Yoshida [25] made a toy bear system, BREAR, that can have physiological actions based on the Body-Emotional Model. The breathing, heart beating, temperature, and bodily movement make it more living thing-like and do better emotional expression.

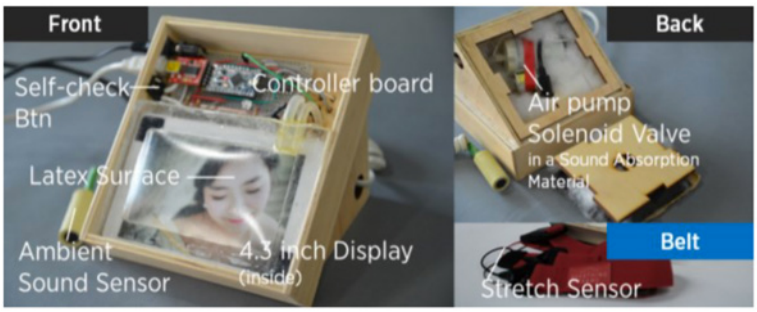


Figure 2.6: The Hardware of BreathingFrame. [9]

Jina Kim [14] also proposed a breath signal sharing device, BreathingFrame, that supports remote communication through providing the physical inflating movement of the other party 's breathing on the surface of a digital photo frame. Through user study with 8 couples, BreathingFrame is able to make users feel sentimental connectedness and the breathing action from the other party, and motivate their curiosity positively.(Figure 2.6)

Besides of the researches I mentioned above, there are also studies applied to the aspect of virtual reality. Jonathan Perrinet [16] proposed a pilot study on emotionally tinted interactions between real and virtual humans. Since they are interested in whole body and emotionally tinted situations of interactions, they conducted a walking task and compared situations of interactions between pairs of real humans. In this research, real subjects ' reaction to the behavior of an expressive virtual character complies with their reaction to the behavior of an expressive real human walker.

2.4 Summary

In this chapter, I listed up a number of related works of my research. Some of them are about City Wander and Sensory Modalities, which show that under the general trend of popularity of City Wander, more and more oriented-design devices had been made, as well as the related studies. And since people can easily record their vital data using wearable devices, the relationship between exercise, like running, and vital data is also one of the hot topics these years. Most of the researches aim to support users to have better training experience through monitoring and adjusting physiological signals. Last but not the least, even though the researches about emotions and vital data are exploring into a difficult study area, nowadays there are many works got positive results to show the physiological signal is related to emotions. And also, some of the studies even have good performance on affecting human emotions with vital data. To sum up, researches about City Wander, vital data and human emotions are meaningful and deserve taking a further look at it.

Chapter 3
Concept

3.1 Purpose

We live in the city we think we are familiar with, this confidence comes from the reason that we live here everyday, work here everyday and hang out with friends in different places of our city. But have you ever consider that there are some attractiveness that you have never known about your city? And the street you walk through everyday may also show some unexpected relationships between you and the geographical characteristics.

On the other hand, under the situation of being in a new city that you are not familiar with, for example, visiting a city you have never been to, there should be some other methods to provide the suggestion for you to go instead of looking into a travel guide. Both finding in travel guide and searching online are the traditional ways to look for recommended spots. However, these recommendations are made for most of the people by standard of the author. This may cause the problems that where generally interesting may not be attractive to you. Therefore, to provide a personalized service on City Wander guiding can improve people's everyday life in the future.

In the research on embodiment of urban landscape based on human heartbeat information, through considering how human body react to the city by evaluating the heart rate data, the interesting data set may become the key for us to work out the problems I mentioned above.

Relationship between Heartbeat and Urban Landscape

To study the relationship between heartbeat and geographical characteristics succinctly is the capital purpose of this research. Heartbeat is one of the vital data that can be easily observed, it is also affected by factors outside the body. By showing quick responses, heart rate data can tell us a lot surprisingly. Therefore, making use of this feature of heartbeat, we can also study the relationship between heartbeat and the geographical characteristics succinctly.

Reconsidering Attractiveness of City

By analyzing obtained user data, this research also aims to reconsider the attractiveness of the city. From the findings of data analysis, we may be able to reconsider the attractiveness, which has not been discovered, of the city. This would be helpful to urban design, especially for the city or street which is kind of outdated.

Examining Whether Human Body Reacts to Town

Another main purpose of this research is to examine whether human body may react to the spots in the town or not by observing the heartbeat information. This is also the necessary issue that should be solved before proposing new City Wander service based on our study. Because heart rate data is connected to many phenomenons of human body, by recording and analyzing the heart rate, our research aims to find out what affects the heart rate and how it affects.

3.2 Issues to be Solved

In Chapter 2, I introduced numbers of related works to my research. They show supportive data from 3 main categories- apply sensory modalities to City Wander, make use of vital data on training performance, relationship between emotion and vital data. There are lots of valid positive results provided in these related works. However, there are still some issues that have not been solved yet.

The first issue to be solved is that to figure out whether human body reacts to town or not when they meet various objects during the walk. Before proposing any service, to consider this issue is important because this research is about the embodiment of urban landscape, in other words, if human body do not react to objects in the city, it would lack of supportive evidence to suggest any relative City Wander service and it would be not point to studying on this research subject. This is the reason why to confirm that whether human body reacts to urban landscape or not while walking is the first issue should be solved firstly.

Secondly, how to evaluate the curiosity level (human body reacts because of what reason or looking at which object) is an essential issue in this research as well. Some related works I introduced in Chapter 2 also tried different ways to evaluate the curiosity level of people. Such as walking speed and questionnaire [17] . The physiological data is widely involved because it has a close connection to human body and can be measured with available devices. But even in the related works, there is no standard evaluation on curiosity level up to now. The method to test curiosity level in this research should be designed depending on the service I am going to propose and also the practical situations.

As the third issue of this research, how to collect data is also significant. Some related researches use existing devices such as the mobile phone as the device to record participants' emotions and the date&time [9]. And in some researches, authors build their own original devices to measure and get different kinds of data. To achieve the research purposes I described above, solving this issue based on the designed concept is necessary.

3.3 Basic Idea

What will happen if personal heart rate information are integrated with the map of city? In this case, user can record personal response to the city that is evaluated by the heart rate data with GPS information. This is interesting data set since we may be able to grasp how people react to the town based on this visualization. In addition, it may be more interesting if we could estimate one's interest based on heart rate information and taken photos with GPS data if one conducted city wander. So the basic idea of this research is to combine heart rate data with a

map, which focuses on putting the heart rate data and walking data (including walking route, pictures, etc.) on a single map in order to indicate how people react to the city.(Figure3.1) To bring forth this idea, I suggested an hypothesis that when the participant sees something he or she is interested in, their heart rate increases. To propose service combing the heart rate data with map, it is important to test this hypothesis because it can be a supportive evidence that heart rate shows human emotions.

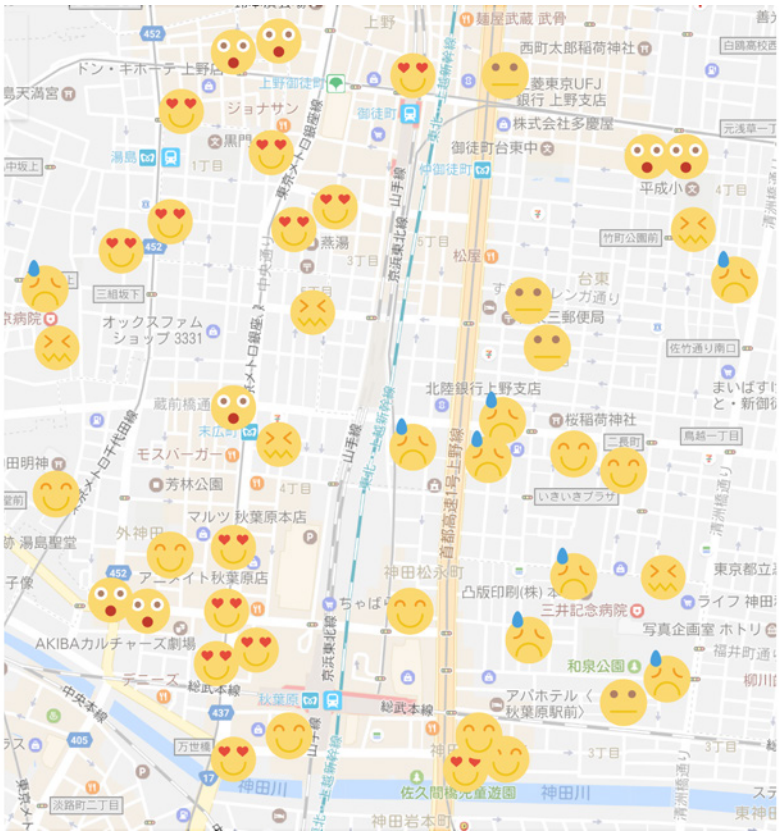


Figure 3.1: The basic idea of this study. By figuring out the relationship between urban landscape and human body we may find out the spots people feel happy, spots people feel sad, and the spots people feel tired, etc.

Some software enable to visualize spatial information of taken pictures onto the map. This is good data visualization method to understand what is the overall atmosphere of the city based on personal photos. One may consider that Google Street View can also provide similar experience concept, however, the information

is too massive and general to grasp the atmosphere of the city in terms of one's viewpoint. It would be easier for users to personally taken photos rather than machine in order to provide sensual experience to humans, leading to the feeling as if one had visited there.

Some may question that why I propose the idea of combining heart rate and map. There are many choices of combinations, especially the physiological data. As we all know that most of the existing life-log systems record not only heart rate information of user but also sleep time, walking steps and many other life data. Many of the wearable device users use their devices to do the life logging. Since most of the wearable devices are made to collect users' data all day if they put them on all the time, users would finally have a long list of raw data for themselves. However, these raw data always seems to be void of sense to most of users. Except the life-log report for health care purpose, when people look on these raw data they even don't know what to do with them. To show a typical example, when the user review his or her heart rate report of the day a year ago, the user may probably cannot tell that why this day his or her heart beat that fast on some points. In addition, heart beat is an observable vital data that even human being can feel it easily in everyday life, like you can tell that your heart beat really fast when you are nervous or excited. Therefore, rather than a simple life-log system, the system that map heart rate information and walking data together would be can make the City Wander experience more memorable and meaningful.

To summarize, since heart rate is an essential vital data which tells many different kinds of phenomenons related to human body, this research can realize the embodiment of urban landscape by putting the heart rate information and other walking data onto a single map.

3.4 System Design

Since the original concept I propose is to combine GPS data with heart rate information, which means that the system should be able to collect all the related data (time and date, GPS data, pictures, heart rate data) while user's City Wander and then visualized these data onto a map. According to this concept design,

the system should consists of two main parts, the data collecting and the data visualization.

From the graph of system design (Figure 3.2) you can find it more clearly with details. In this system, a wearable device with heart rate sensor and a commercial smartphone are combined to be the device equipped on the user when he or she walks in the city. Since we would focus on the heart rate data in this research, the wearable device on user's wrist should have a heart rate sensor that can measure continuous heart rate information. In order to take picture and record the GPS information, smartphone that with camera and location function would be also applied in this system. When the user is walking in the city, the wearable device would keep recording his or her heart rate data with the heart rate sensor. And then the heart rate data collected during user's City Wander would be transferred to the smartphone through Bluetooth. In the same time while user is walking, he or she can take pictures with the smartphone on his or her hand. The pictures took by user would be also tagged with the date&time and the location information. Since smartphone is able to detect the present position of user, the GPS data would be also recorded during his or her walk. In the next step, all these data the device collected during the walk would be sent to the internet so that the data can be well sorted together. Finally, the information of the user, including the walking route, pictures, and heart rate data, would be visualized on the Google Map which is widely used around the world.

3.5 Software Design

According to the concept of combining the GPS data with heart rate information, the software should have the functions like position tracking, heart rate monitoring, etc. And as another important element to make the City Wander more memorable, the photographing function is also significant in this software. So I designed the software as following:

This software is an iPhone app that can be able to run on current iOS. On the top page of the app (Figure 3.3), user can start to record his or her City Wander by pressing "Start Record", besides of this, user can also review the recorded City Wander by pressing "My Records". Once the user starts recording, the current position of user would be shown on the main page (Figure 3.4). By pressing the

camera icon, user can take picture whenever the user want. (Figure 3.5) After the walk, when user wants to stop recording, he or she can press the saving icon and save their City Wander. (Figure 3.6) To review the recorded City Wander, user can find the records on the "Records" page (Figure 3.7). And on the heart rate map, user can find out where people took pictures with high heart rate and low heart rate. (Figure 3.8)

3.6 User Scenario

Target Persona

For the software I described in the last section, the target persona can be someone who is fond of walking through the city on his or her holiday. And the target persona would probably enjoy recording the exploration in some form or another, for example, taking pictures and even sharing onto the internet. This is because of that the target persona would prefer to make his or her walk more memorable rather than just taking a walk. The target persona is always curious about the different attractiveness of the city, which makes he or she keep exploring the city by walking. It would be happy for the target persona to know where and what interests he or she more in the city.

Therefore, based on the software design and impression of the target persona, following is one of the detailed target persona I would like to introduce as example in the user scenario.

Christina Wilson, the example target persona, is an exchange university student from America. She decided to join the 1-year exchange program in Tokyo because of that she is interested in Japanese Culture. Christina is totally not familiar with Tokyo but she would like to explore Tokyo city by herself since one of her hobbies is City Wander.

Scenario

Following is the scenario for Christina Wilson to use our original designed software:

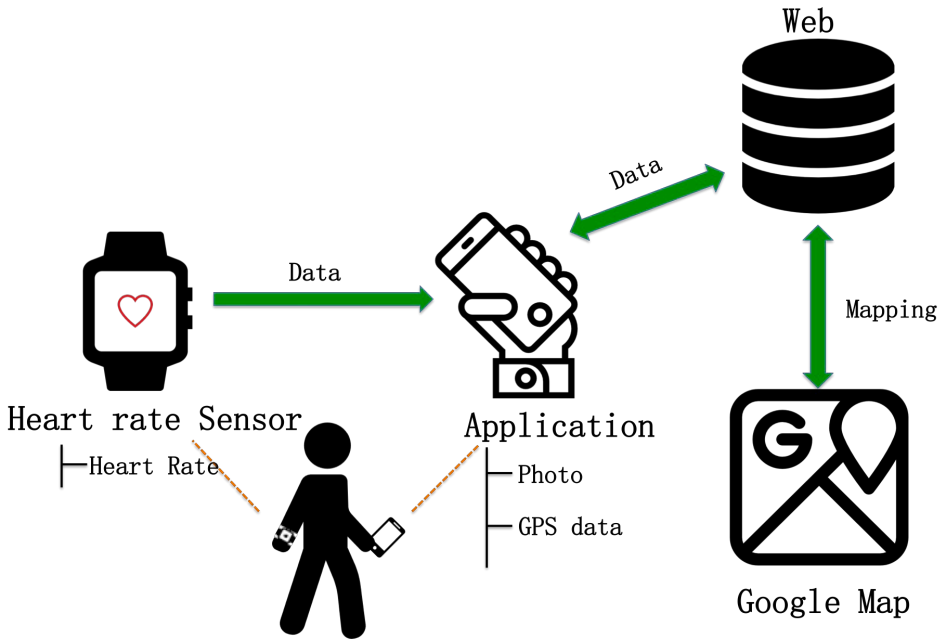


Figure 3.2: The original system design of the wearable device to collect City Wander data and visualize the walking data onto the map.

Figure 3.3: The top page of software.

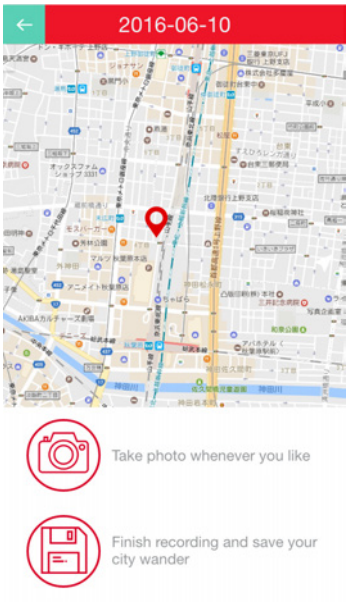


Figure 3.4: The main page while recording the walk.

Figure 3.5: User can take picture during the walk.

Figure 3.6: Save the City Wander after walking.

Figure 3.7: The user's City Wander would be recorded in the software.

Figure 3.8: On the heart rate map, user can find out where people took pictures with high heart rate and low heart rate.

TARGET PERSONA

Foreign Student

NAME Christina Wilson
AGE 20 **SEX** Female
CURRENT CITY Tokyo
HOMETOWN New York
OCCUPATION University Student

PERSONAL PROFILE

Born and raised in Manhattan, New York. There are 4 people in her family- she, her elder sister and parents. She likes outdoor activities and City Wander. Two months ago she went to Tokyo for the 1-year exchange program of her University. Christina loves to explore Tokyo and take photograph while she is walking in town. To share the experience of her life in Japan, she always posts pictures on Instagram.

Mental Model

- See → take pictures
- Walk→ observe

GOAL

- Want to record her City Wander.
- Would like to share her exploration in Tokyo.
- Want to know and share what attracts her in this city.

Figure 3.9: The target persona for the software.

On a sunny Saturday, Christina woke up in a good mood and decided to go out for a walk with her mobile phone and wearable device in Tokyo city. Two months have past since she came to Tokyo for the exchange program. Tokyo is still unfamiliar to Christina but she really enjoys keep exploring on holidays. On the days she walks through the city, Christina like to use the iPhone app "tOURs" to record her City Wanders. The concept of tOURs is to walk through the city along with our own body informations. Christina thinks that this app meets her needs of recording each walk with route and pictures, even her heart rate data. Compared to the existing software, this logging becomes more like a memory to her because she can remember what she was excited for by reviewing the points tagged with heart rate information.

Chapter 4
Prototype and User Test

4.1 1st Experiment Design

In the experiment designed for the first prototype, I supposed a hypothesis that one's heart rate would rise when he or she sees something he or she is interested in. It is for testing whether human body reacts to town.

Objective

The first experiment aims to collect physiological data (heart rate) and location data (GPS tracking, photos) simultaneously. And also the experiment should be able to examine whether one's heart rate would increase when participant sees something that he or she is interested in.

Procedure

Participants (three females and one male) did 30-minute or longer walk in one of several designated areas in Tokyo with the first prototype, the app on iPhone 5s which would record the GPS data and pictures the participant takes during the walk, and the Apple Watch on the participant's wrist, which would record one's heart rate during the walking. (Figure 4.1)The participants were asked to take pictures when they see anything they want to take a picture on. The heart rate sensor of the Apple Watch would take the heart rate value at the moment when the participant take a picture and it also record the heart rate once every minute. After the walk, participants were asked several questions such as "Which pictures you took are you interested in or indifferent?", "Is the data result synchronized with your feeling?" and "Is there anything impressive during your walk?". With the quantitative data such as heart rate and GPS data and the qualitative data

obtained by the questionnaire, I conducted an analysis of the data. All pictures taken were tagged with GPS information using the built-in function in iOS and the value of the heart rate at the moment when participants took a picture. Based on a subjective, two-alternative choice of the picture (interesting or indifferent), pictures were also tagged with the participants' preference. The dataset of each participant was analyzed using an unpaired two-sample t-test.

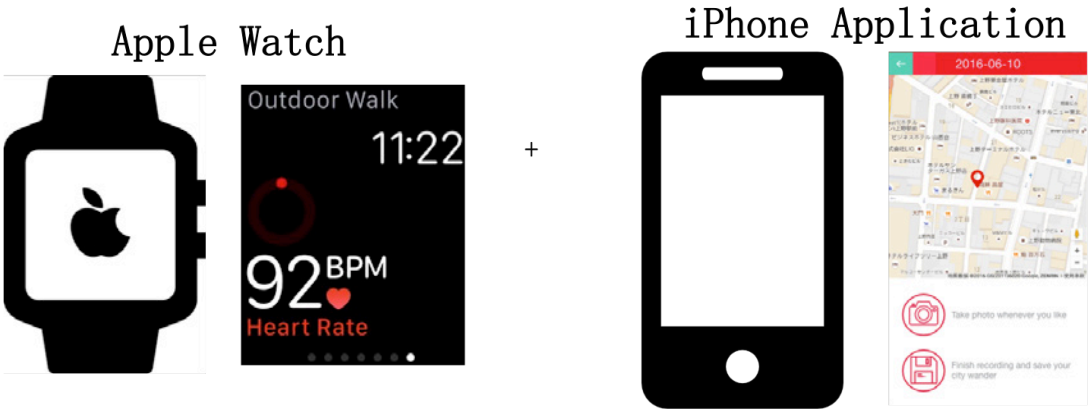


Figure 4.1: Apple Watch was used for heart rate measuring while the iPhone application recorded photos and walking route.

Locations

With regard to the locations for doing the experiment, I chose Asakusa and Akihabara areas. These areas were chosen not only due to the abundant attractive content in these two areas, but also for that their flat terrains, which help to avoid the influence of climbing and descending slopes or hills on the data.

4.2 1st Prototype

The first prototype consists of iPhone and Apple Watch. (Figure 4.2)

Figure 4.2: Participant used the first prototype which consists of iPhone and Apple Watch.

Figure 4.3: Participant walked with the first prototype.

Figure 4.4: Participants took pictures whenever they wanted during the walk with iPhone.

4.3 1st Evaluation and Result

In this feasibility experiment, 185 pictures and heart rate values during the walking. I numbered the experiments as A1 to D. A1 was done by the same participant as A2 in different areas (A1 took place in Asakusa area, A2 took place in Akihabara area) and B, C, D were the result of three different participants in the same area (Akihabara area). As an example, I pick up the analyzation of experiment A2 to introduce in detail. (Figure 4.5)

To visualize the trend of the heart rate data, Figure 4.6 shows the variations of the heart rate of Participant A2. When Participant A2 found a theater and a cafe, the heart rate increased. On the other hand, the heart rate dropped when A2 found a store, which A2 mentioned later was not of interest. Other than these tagged points I picked up in experiment A2, most of the other points in all the experiments also show a correspondence of the participants' personal interests. This trend suggests that the increase in the heart rate may be associated with the participants' interest.

Quantitative data and its statistical analysis showed that the hypothesis was

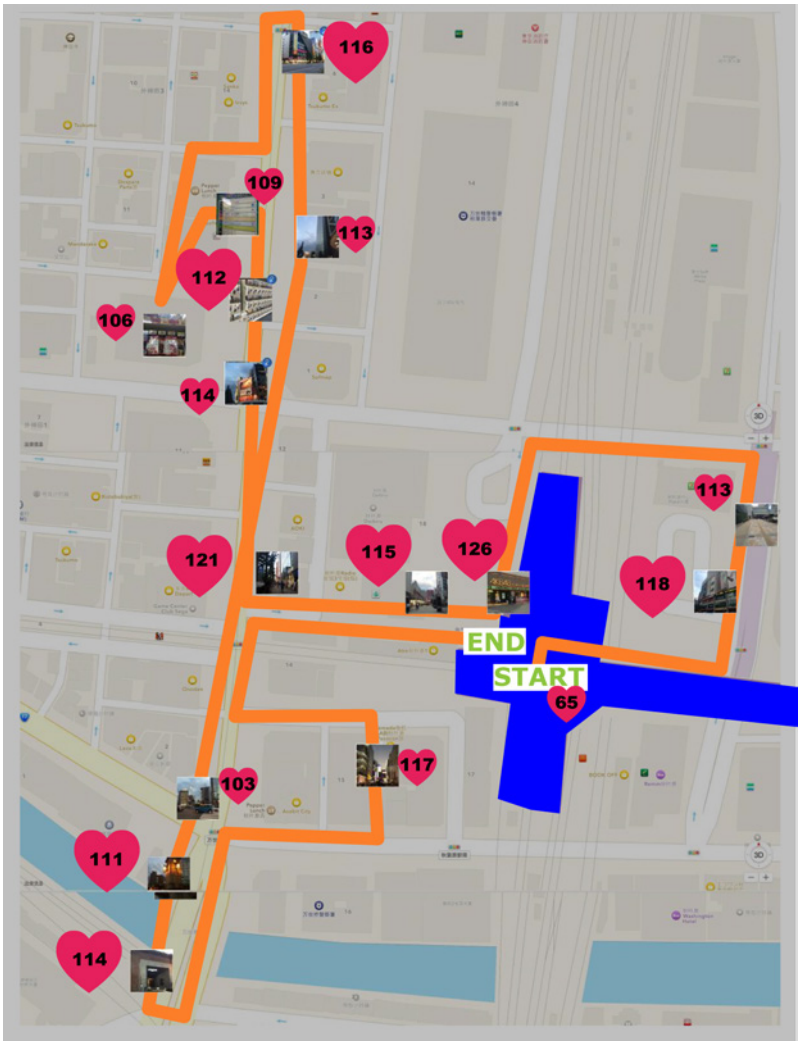


Figure 4.5: The route of experiment A2.

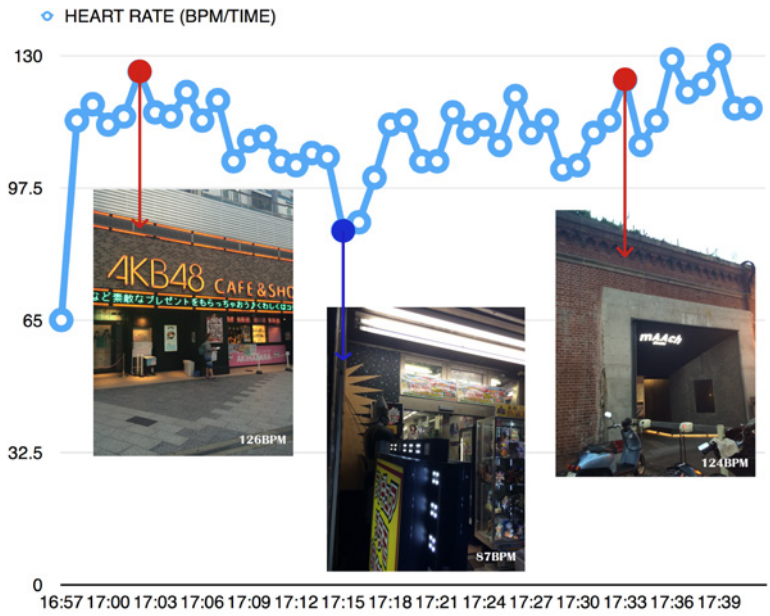


Figure 4.6: The heart rate graph of experiment A2, showing heart rate changes during the walk.

supported by the data. Table 4.1 summarizes the number of pictures that participants took during this feasibility study. It shows that participants tended to take more pictures when they were interested. To correlate with these behavioral responses (taking pictures) with the heart rate data of participants, I calculated averaged heart rates for each participant when they were interested in or indifferent to the pictured scene. (Figure 4.7) Using unpaired t-test, I found that there was a significant difference in averaged heart rate between moments where they took interesting and indifferent pictures in four out of five trial. In addition, statistical analysis with repeated one-way ANOVA showed that there is a significant difference in averaged heart rate between interesting and indifferent pictures that participants subjectively reported, suggesting that heart rate is a good indicator of personal preferences.

Following is heart rate map of Akihabara area with the experiment data. (Figure 4.8) According to each participant's heart rate data and subjective evaluations, I classified the spots they took pictures into 5 levels and put them on the map. This map shows a clear picture of how people's bodies reacted to the street. Even though they are heart rate spots from different people, spots of similar level

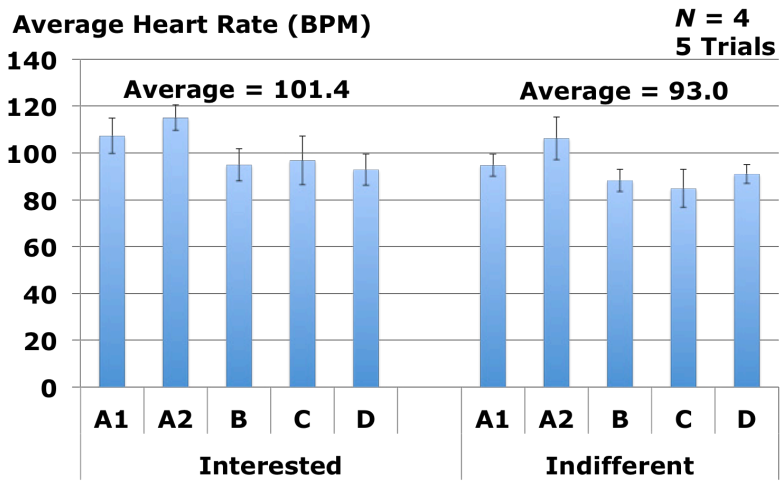


Figure 4.7: The average heart rate of Interested Pictures and Indifferent Pictures in all 5 experiments.

Table 4.1: t-test and Picture Analysis

Experiment No.	Participants	Interested Pictures	Indifferent Pictures	Sig.
A1	a(Female)	54	12	Significant
A2	a(Female)	13	8	Significant(p<0.05)
B	b(Female)	13	7	Significant(p<0.05)
C	c(Female)	35	10	Significant
D	d(Male)	30	3	Not significant

gathered together. It is a significant finding that the heart rate does show the relationship between human and urban landscape. For example, we can see that many orange and red spots gathered around the road from Akihabara station to the main street, where is the busiest section of Akihabara area.

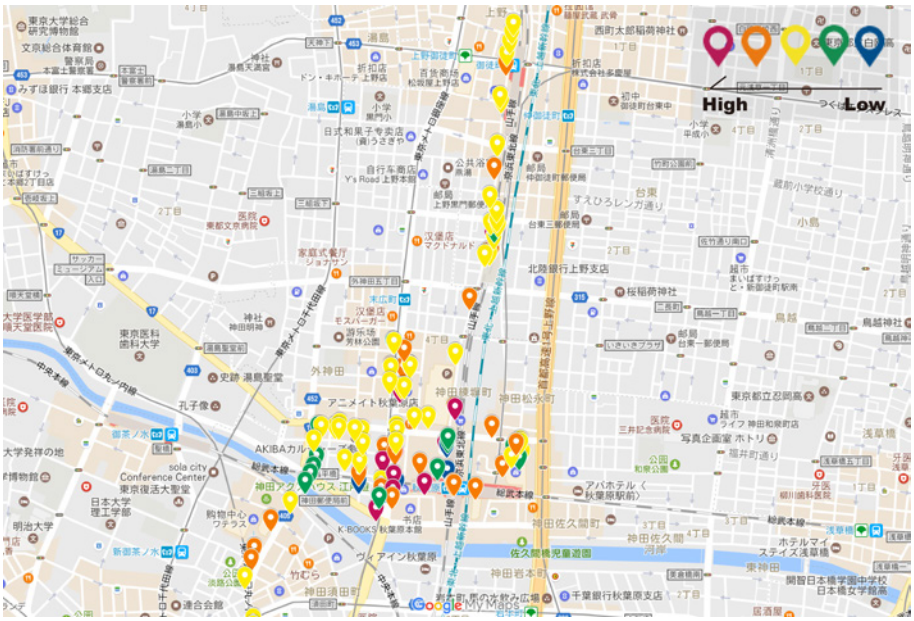


Figure 4.8: The heart rate map of Akihabara area with the experiment data.

User feedback also told us that my study is attractive enough during the walking. In the subjective questionnaire feedback, participants told us that "It is happy to see my emotion on the heart rate graph", "The graph matches to my feelings during the walking" and other comments that expressed that it was interesting to walk with wearable device because it visualized the physiological response of the participant during the walk in the city.

4.4 2nd Experiment Design

The second experiment is designed for participants' continuous usage of the software and to explore a new City Wander service based on the findings of first prototype and experiment.

Objective

The second experiment aims to make the City Wander service combined with heart rate information to be more practical, in other words, more users would prefer to use this service to record their walks. Besides, to explore the further possibility of this research is another objective of the second experiment.

Procedure

To have a continuous study, 2 participants (2 females) took part in the second experiment. This experiment is basically similar to the first one, participants were asked to walk through the city with the device (in this case, the iPhone and Apple Watch). What's different from the first experiment is that participants used the service for days, rather than just for one specific walk. The participants took pictures whenever they wanted on the street, and posted the pictures onto Instagram with tagging the current heart rate information. After the experiment, participants were interviewed about the feeling of using this service for days and what surprised them during the experiment.

4.5 2nd Prototype

In order to have a further study of this research and make it more practical for people to use the software, I design a second prototype for this research. From the evaluation of the first prototype, we have already known that heart rate of most of the people increase when they see something they are interested in. In the same time, they would probably take pictures of things those they curious about. So base on these results of 1st experiment, Instagram should be a suitable platform for the further study.

The second prototype is build based on the first prototype with adding the function of Instagram picture posting. (Figure 4.9) The iPhone would record the GPS information of user's current position, user can take pictures with the iPhone

camera just like with the first prototype. In the same time, Apple Watch on user's wrist would continuous record the heart rate of user and save the data to Health Care on iPhone. After taking the picture, user can upload the picture that tagged with current heart rate data to Instagram in order to share and record the City Wander.

Figure 4.9: The basic concept of the second prototype- a new Instagram service of posting pictures tagged with heart rate information.

There are also two main parts of the second prototype, the iPhone App and Apple Watch.(Figure 4.10) Being improved from the first prototype, the heart rate measurement changed from once per minutes to once five seconds. (Figure 4.11) This continuous heart rate recording improves the accuracy of detecting the heart rate of the moment when participant take picture.

On the basis of software design also conducted to the first prototype (Figure 3.4), in the second prototype the function of sharing to Instagram was added and mainly focused. (Figure 4.12) Participants took pictures and shared them to Instagram with the current heart rate information.

4.6 2nd Evaluation and Result

Since the second prototype and experiment aimed to explore the possibility of providing new service for City Wander which can be used practically in daily life, different from the data analysis of the first one, this time I mainly focus on how

Figure 4.10: The second prototype also consists of iPhone and Apple Watch.

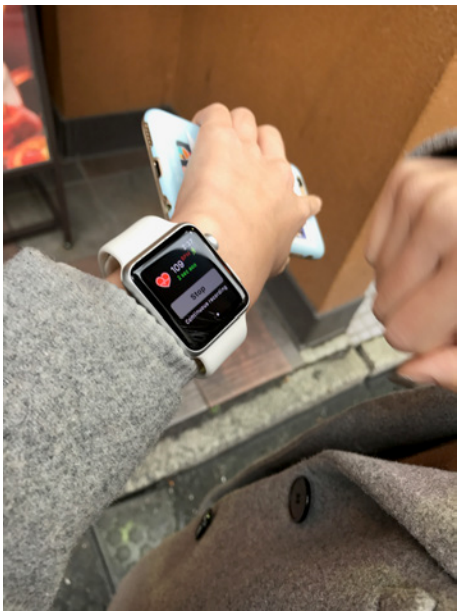


Figure 4.11: Apple Watch was conducted with the function of the continuous recording for heart rate.

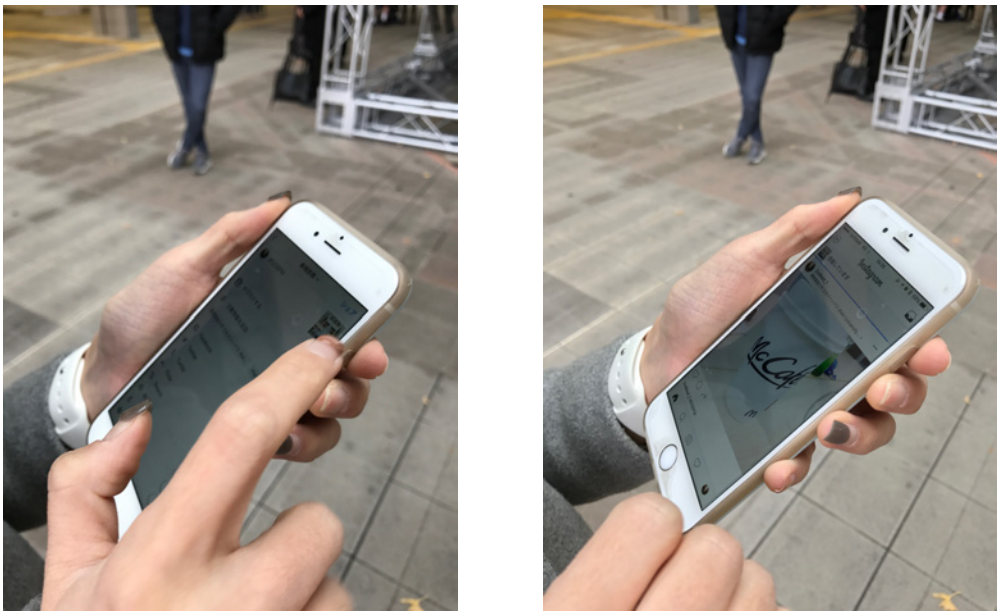


Figure 4.12: Instagram sharing was added to the second prototype as the main function.

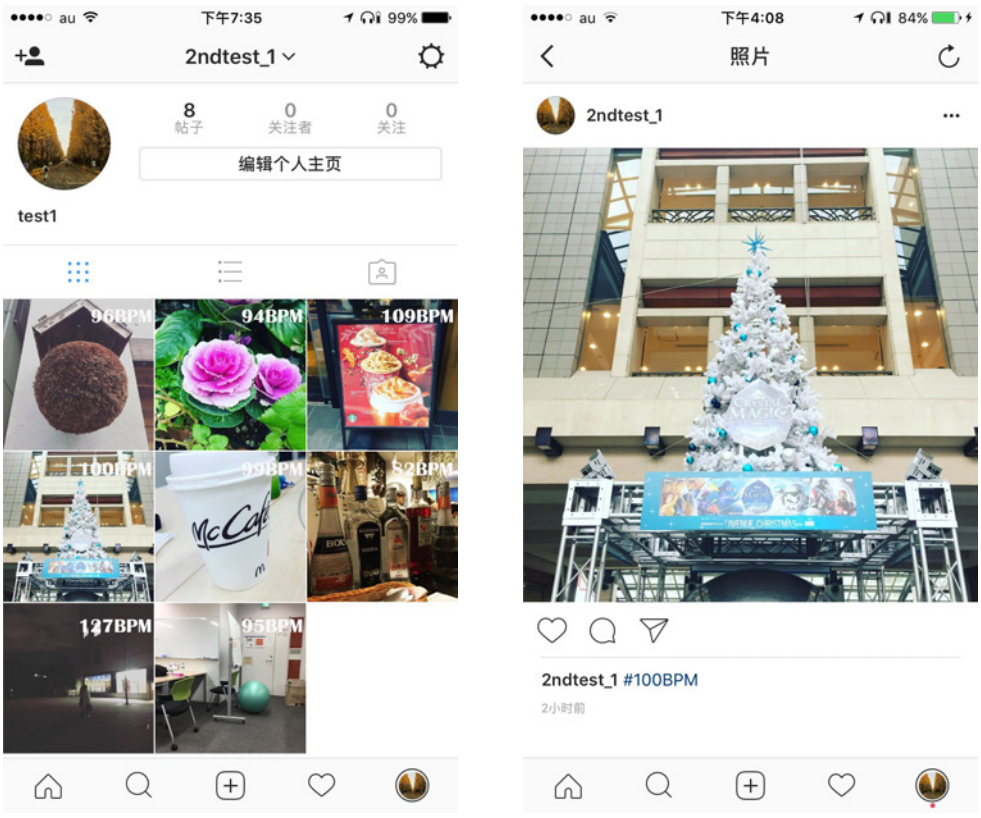
user felt about this new type of Instagram service.

2 participants took part in the 2nd experiment. Both of them are female and used this Instagram service for some days. (Table 4.2)

Table 4.2: Pictures and Participants in 2nd Experiment

Experiment No.	Participants	days	Pictures	Instagram usage (Usual, post/day)	Instagram usage (Experiment, post/day)
E	e(Female)	3	8	0.14	2.67
F	f(Female)	30	23	0.08	0.77

As the From one of the participants' results (the experiment E)for using this service three days, we can see most of the posts have a higher heart rate compared to her ground heart rate which is 90BPM (Figure 4.13). And this participant mainly post pictures in the same area which she studies in everyday, it means the



(a) 8 pictures were uploaded during 3 days. Most of the posts have a higher heart rate compared to her ground heart rate which is 90BPM.

(b) Pictures were tagged with the heart rate information.

Figure 4.13: The user test results of one participant for using a few days.

participant used this service in her daily life. (Figure 4.14)

Figure 4.14: The locations of the pictures she uploaded are mainly around her school at Hiyoshi, Yokohama.

After using this service for a few days, participant e commented "It is interesting to post pictures with present heart rate to Instagram because I have never considered about my heart rate.", and "The heart rate tag makes the life-log more memorable so that I can tell the memory of the walk more detailed when I review these pictures. And the heart rate tag also reminds me of the moment my heart beat fast.". Besides, as the suggestion, she said "If the software can notice me to take a picture when my heart rate is higher than my average value, it would be interesting to look into the pictures I took when my heart beat fast. This may tell my personal interest more practically.".

In addition, by comparing the usual Instagram usage and usage during the experiment, we can find that the second prototype made participants use Instagram more than before. (Table 4.2) It means the basic idea of this research is possible to be applied to different services and has positive effect to the existing services.

4.7 Discussions

In this study, I have proposed novel City Wander system and have tested the feasibility of the concept. Data from the first user study supported the hypothesis that one's heart rate rises when one sees something one is curious about. Using my proposed City Wander service, people could enjoy a more personal service that suggests unfamiliar spots that the person may like. And the service can help the user to realize a new attractive aspect of the city based on one's own heart rate data which shows the personal interests. In the second user study, by involving the widely used social network service, Instagram, new service is practical for more people to use. Even though it is not only under the situation of walking, it becomes a better life-log service compared to existing ones. Both of the evaluations show that the concept of this research is meaningful and can be applied to different kinds of services.

The device that consists iPhone and Apple Watch I used for experiments in this research (Figure 4.15) is not fully integrated during the feasibility study. To have a deeper study in the future, I am currently designing and developing the device to collect more accurate quantitative data in a more sophisticated way. I plan to implement greater integration between the 9-axis inertial motion sensors and GPS in iPhone, and the heart rate sensor in Apple Watch, for automatically collecting location and geographical (how steep the slope is) data and physiological responses of the user to walking in the city.

On the international conference UBICOMP 2016, my paper "Personalized record of the city wander with a wearable device: a pilot study", which is written based on this research, was presented on September 12-16, 2016 in Heidelberg, Germany. (Figure 4.16) During the conference, I received many good feedback and advices of this research. Most of the researchers thought that it is interesting to see the relationship between human emotion and heart rate, they are looking

Figure 4.15: The device I used for experiments in this research.

forward to the further study in the future.

(a) Poster of "Personalized record of the city wander with a wearable device: a pilot study".

(b) Poster presentation during the conference.

Figure 4.16: The paper about this research was accepted by international conference UBICOMP 2016.

Chapter 5
Conclusions

Purpose of Research

City Wander has become one of the popular personal hobbies recent years. More and more people enjoy exploring the city by walking, they try to memorize their walks with some kinds of ways such as taking photographs, walking with the wearable device that has life-log function. However, people hardly ever consider about the relationship between themselves and the city landscape. There is an interesting possibility that human body may react to the objects on street if they see something they are personally interested in. This is the purpose of this research in the beginning.

As the first purpose of this research, to study the relationship between heartbeat data and geographical characteristics of city succinctly is important. Since heart rate is known to be affected obviously by factors outside the body, to observe the heart rate changes should be an interesting data set to study the relationship between heartbeat and urban landscape. Secondly, this research also aims to reconsider the attractiveness of the city by analyzing obtained user walking data. If we can figure out what and where most of the people like, it would be helpful to urban design, especially for the city or street which is kind of outdated. The third purpose of this research is to examine whether human body reacts to town by observing the heartbeat information. This is also the necessary issue that should be solved before proposing any new City Wander service based on this study. Since heart rate data is related to many different kinds of phenomenons of human body, this research aims to find out what affects the heart rate and how it affects.

Introduction of Research

Along with the popularity of City Wander, there are more and more new products proposed on the mobile phone platform. One of the successful examples is the mobile phone game "Pokemon Go". [1] The Pokemon Go fascinate millions of players all around the world by combining City Wander with Augmented Reality game, it also makes people go outside to walk through the city more often than before.

This research, Research on Embodiment of Urban Landscape Based on Human Heartbeat Information, considers to study on the relationship between human heart rate and landscape characteristics of the city. Through doing experiments with conducted prototypes and analyzing the obtained data, this research aims to test the hypothesis that the heart rate increases when participant sees something he or she is interested in. With the supportive results of first experiment, the possibilities to create new City Wander services were also explored in this research.

Related Researches

There are many existing related researches of my study, some of them are about City Wander and Sensory Modalities to show that more and more oriented-design devices had been made because of the general trend of popularity of City Wander. Since people can easily record their vital data using wearable devices, the relationship between exercise, like running, and vital data is also one of the hot topics these years. Most of the researches aim to support users to have better training experience through monitoring and adjusting physiological signals. Last but not the least, even though the researches about emotions and vital data are exploring into a difficult study area, nowadays there are many works got positive results to show the physiological signal is related to emotions. And also, some of the studies even have good performance on affecting human emotions with vital data. To sum up, researches about City Wander, vital data and human emotions are meaningful and deserve taking a further look at it.

The Concept of This Research

The basic concept of Research on Embodiment of Urban Landscape Based on Human Heartbeat Information is to visualize the heart rate data of City Wander on the map in order to figure out the relationship between urban landscape and human body. Integrating personal heart rate information with the map of city, user's personal response, which is evaluated by the heart rate data with GPS information, to the city can be recorded. This would be interesting data set since we may be able to grasp how people reacts to the town based on this visualization. Further more, it may be more interesting if we could estimate one's interest based on heart rate information and taken photos with GPS data if one conducted City Wander. So as the solution, I combine heart rate data with a map, which considers on putting the heart rate data and walking data on a single map. To bring forth this idea, we suggest an hypothesis that when the participant sees something he or she is interested in, their heart rate increases.(Figure3.1) To propose service combing the heart rate data with map, it is important to test this hypothesis because it can be a supportive evidence that heart rate shows human body does react to town.

Since the wearable device, for example the Fitbit, market is growing very quickly these two years [3], I choose to use wearable device to measure the heart rate of users in this research. In addition, even though most of the wearable devices are able to do the life logging, users find it not that meaningful when they look into the raw data. Therefore, this research can also be a key to make the life-log service more memorable by adding the heart rate information.

By visualizing the walking data (including the heart rate data, GPS data, pictures) on the map, this research may show the relationship between human body and city to realize the embodiment of urban landscape. With the walking data mapping, this research can be applied to many new City Wander personalized services which based on the personal interests detected from the heart rate data. Based on this research, there are many practical possibilities for proposing new City Wander services. These services may be more useful on the city exploration for City Wander fan, as well as for the tourists when they visit an unfamiliar city.

Prototypes and User test

In this research, two prototypes were conducted for different reasons and both of them consist of iPhone and Apple Watch. The first prototype was built for recording one complete walk of user (last 30-minute and longer) to do the first experiment which aims to test the hypothesis that one's heart rate would increase when he or she sees something he or she is interested in. It would record walking data including position, pictures, and also the heart rate data (at the point of participant takes picture and once a minute).

And to explore the practical possibility of this research, the second prototype was conducted for participants to use for some days (3 days and longer) in daily life. This prototype is basically the same as the first one but adding with the Instagram posting function. And the heart rate function was improved to do the continuous recording (once in 5 seconds). Participants this time were not asked to go for a single walk but to upload picture with the second prototype whenever they want in a few days. This experiment aims to test that whether this kind of service based on my research is practical or not for more people to use.

Result and Discussions

In the first experiment, I have proposed novel City Wander system and have tested the feasibility of the concept. Data from our user study supported the hypothesis that one's heart rate rises when one sees something one is curious about. Using our proposed City Wander service, people could enjoy a more personal service that suggests unfamiliar spots that the person may like. And the service can help the user to realize a new attractive aspect of the city based on one's own heart rate data which shows the personal interests.

The second user study shows that it is possible to apply this research to new services of City Wander and life logging. Since Instagram is one of the widest used social network service, most of the people are accustomed to posting pictures to it. By combining the Instagram to heart rate data, participants found it more memorable to record their walks with heart rate. When they looked back their timeline on Instagram, they can easily recall the memory because that they

remembered their heart beat fast or not at that moment.

From the heart rate map made with the experiment data of different participants, we can see that spots of similar level always gathered together. (Figure 4.8) On the heart rate map, it is obvious that heart rate does has some meanings-specific heart rate value relates to the characteristic of specific city spot. People's heart rate rise may because there is a slope, most people show high heart rate on a road may because it is a road that people like to run on. The calculated data of heart rate always means something on the heart rate map. This result indicates that heart rate is a valid data to show the relationship between urban landscape and human body.

Future Work

Through the conducted prototypes and experiments, it had been supported that the concept of this research is meaningful and can be applied to practical scenarios. To have a deeper study in the future, the device need to be more automatic to collect more accurate quantitative data in a more sophisticated way. As future work, I would also want to have a try on using other wearable devices to record the heart rate data. Though so far the system consist mobile phone and wearable device that has heart rate sensor, in the future I would like to involve smart eyewear in the system. Smart eyewear such as the JINS MEME can do the eye tracking these days. [12] I believe it would be interesting to analyze the eye tracking data of user because it may also show the personal interest of user like the heart rate data. I also would like to explore more possibilities of this research such as launch a web-based service, which may achieve customized routing for City Wander.

Summary

As conclusions, firstly, this research shows that human body would react to town while walking. Secondly, people's heart rate tends to increase when people see something they are interested in. Thirdly, by visualizing the heart rate information and taken photos onto the same map, people could see attractive spots of the city.

Besides, the idea of combing heart rate data and GPS information is practical and can be applied to different kinds of services. To sum up, the embodiment of urban landscape based on human heartbeat information can be realized by visualizing on map.

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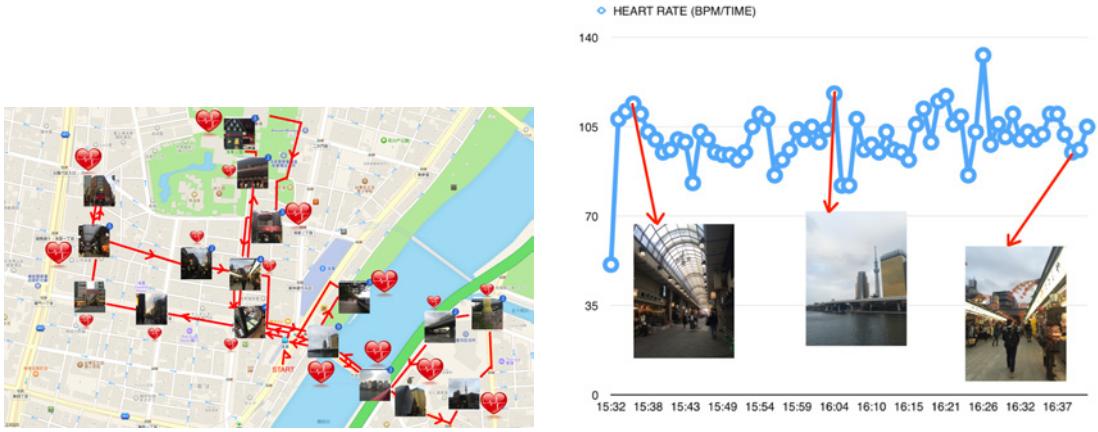
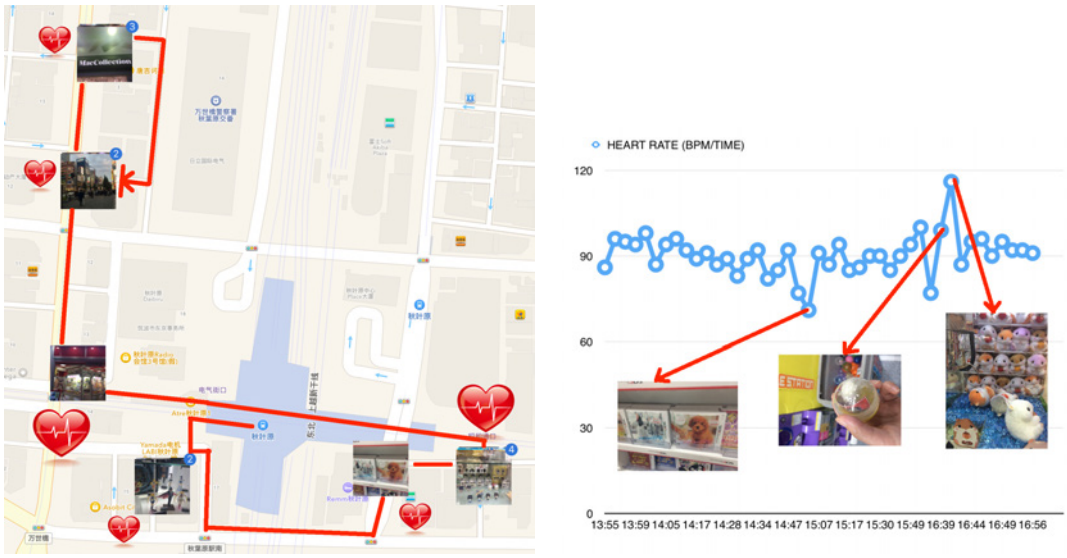
Appendix

A Other sample Experiment Results



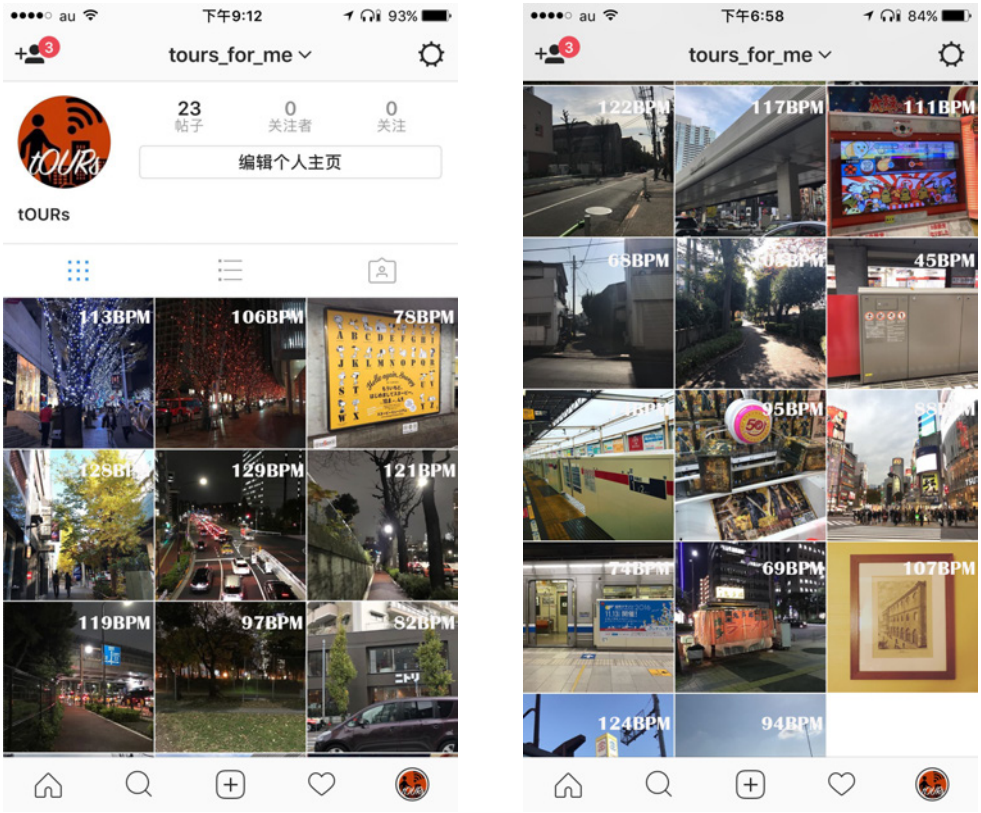
(a) Heart Rate&Photo Mapping (b) Heart Rate Graph

Figure A.1: Result of Experiment A1



(a) Heart Rate&Photo Mapping (b) Heart Rate Graph

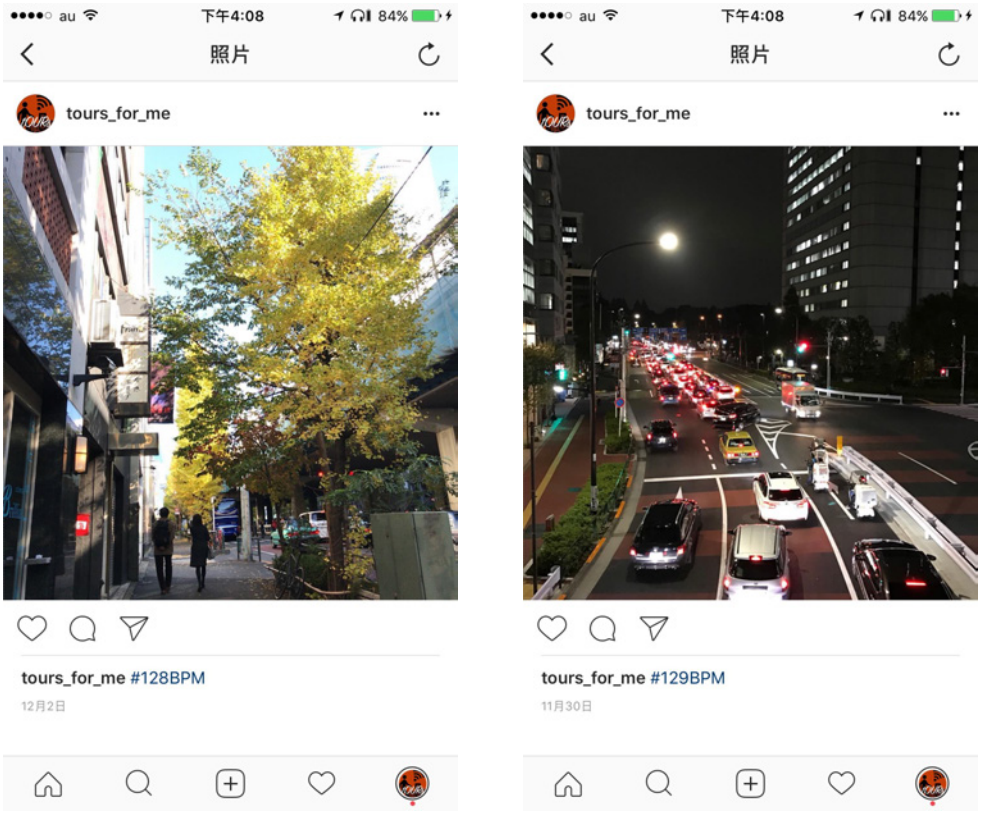
Figure A.2: Result of Experiment B



(a) Parts of Instagram posting results.

(b) Parts of Instagram posting results.

Figure A.3: Participant posted 23 pictures in Experiment F during 30 days. Most of the posts have a higher heart rate compared to her ground heart rate which is 95BPM.



(a) Picture posted by participant at Roppongi. (b) Picture posted by participant at Aoyama-itchome.

Figure A.4: In Experiment F, the participant showed high heart rate even in different places, it means the service had been used in participant's daily life.