STUDY OF SOUND AND HAPTIC FEEDBACK IN SMART WEARABLE DEVICES TO IMPROVE DRIVING PERFORMANCE OF ELDERS

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ผลป้อนกลับของเสียงและการสั่นผ่านอุปกรณ์สวมใส่อัจฉริยะเพื่อเพิ่มสมรรถนะการขับขี่ของผู้สูงอายุ

นายจุฬารัศมิ์ นาถประทาน

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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จุฑารัศมิ์ นาถประทาน : ผลป้อนกลับของเสียงและการสั่นผ่านอุปกรณ์สวมใส่อัจฉริยะเพื่อเพิ่มสมรรถนะการขับขี่ของผู้สูงอายุ (STUDY OF SOUND AND HAPTIC FEEDBACK IN SMART WEARABLE DEVICES TO IMPROVE DRIVING PERFORMANCE OF ELDERS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. นกุล คูหะโรจนานนท์, 70 หน้า.

ปัญหาอุบัติเหตุทางจราจรในประเทศไทยยังเป็นสิ่งที่น่ากังวล เกือบครึ่งหนึ่งของรายงานอุบัติเหตุทางจราจรในประเทศไทยปี พ.ศ. 2557 เกี่ยวข้องกับรถส่วนบุคคล และตัวเลขนี้มีทีท่าว่าจะเพิ่มขึ้น ตามจำนวนรถที่เพิ่มขึ้น ปัจจุบันทรัพยากรมากมายถูกลงทุนไปกับสิ่งนี้เพื่อหวังให้ปัญหาเบาบางลง และเทคโนโลยีใหม่ๆก็ถูกนำมาเพื่อแก้ปัญหานี้

ในการศึกษานี้ เราทำการนำเสนอการใช้อุปกรณ์สวมใส่อัจฉริยะ ผู้ขับขี่ที่สวมใส่อุปกรณ์นี้จะสามารถรับข้อมูลของสัญญาณไฟจราจรได้ผ่านสัญญาณเสียงและการสั่น ในการทดลองนี้ผู้อาสาทั้งหมดจำนวน 22 คนจะถูกจับเวลาในการเหยียบเบรคเพื่อดูว่าการใช้อุปกรณ์สวมใส่อัจฉริยะมีผลต่อเวลานี้หรือไม่ ผลที่ได้คือ เวลาในการเหยียบเบรคที่เพิ่มขึ้น 12.39% และ 10.19% สำหรับสัญญาณเสียงและสัญญาณสั่นตามลำดับ ซึ่งเป็นผลดีกับการขับรถ เพราะเวลาเบรคที่สั้นลงอาจหมายถึงการหยุดที่กะทันหันกว่า

นอกจากนั้นเรายังมีการทำแบบสอบถามกับผู้อาสา แบบสอบถามมีเกี่ยวกับข้อมูลเบื้องหลัง ดัชนีวัดภาระของนาซา และ แบบจำลองการยอมรับเทคโนโลยี ซึ่งมีจุดประสงค์เพื่อประเมินว่า ปัจจัยที่มีอิทธิพลต่อการเหยียบเบรกคือปัจจัยใด และ ปัจจัยที่มีผลต่อเจตคติของผู้อาสาคือปัจจัยใด ซึ่งได้ผลว่าสิ่งที่มีความเกี่ยวโยงกับเวลาในการเหยียบเบรคมากที่สุดคือ อายุ ประสบการณ์ในการขับรถ และ การสวมใส่แว่น ในส่วนของดัชนีวัดภาระของนาซา สิ่งที่ผู้อาสามองว่าเป็นสิ่งที่หนักที่สุดในการใช้งานคือความไม่พอใจ ในส่วนสุดท้าย แบบจำลองการยอมรับเทคโนโลยีนั้น ความรู้สึกว่ามีประโยชน์ และ ความคิดของสังคม เป็นปัจจัยที่มีผลต่อเจตคติของผู้อาสา

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Traffic accident is a concerning issue in Thailand. Almost half of the reported traffic accident in 2013 involved personal cars, and the number has a potential to rise as the number of cars increases. Many resources have been allocated to lighten this issue, along with new technologies.

For this study, we proposed a smart wearable device, a device that drivers can wear to receive information regarding the state of upcoming red lights, in sound and haptic forms. A total of 22 drivers were measured on how long they applied the brake and were observed if introducing the smart wearable device would have influence on the time. The result is the increase in brake time by 12.39% and 10.19% for sound feedback and haptic feedback respectively. This benefits driving as shorter brake time could imply a more sudden stop.

We also conducted a survey to ask participants about their background, their assessment on NASA-TLX, and TAM. This is to further study the factors that influence the brake times and to find out what could affect the participants’ attitude toward the device. For background, age, driving experience, and whether one wear glasses while driving are the most influential factors toward brake time. For NASA-TLX, the participants found frustration to be the heaviest task while using the device. And lastly, perceived usefulness and social norm is the most important factors that influence participants’ attitude toward the device.

Department:	Mathematics and Computer Science	Student's Signature	....
		Advisor's Signature	....
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Chapter 1

INTRODUCTION

In Thailand, almost half of reported traffic accidents in 2012-2013 involved personal cars. From a total of over 60,000 accident reports, personal cars, personal pick-up trucks, and taxis covered over 28,000 reports [1]. Moreover, according to report on Road Safety from WHO in 2013, Thailand had an estimated road traffic death rate per 100,000 as high as 38.1. Compare it to second highest in South East Asia, Malaysia, at 25.0, Thailand had a noticeably higher death rate from traffic accident [16]. The leading causes of these accidents as reported were sudden cut-in and tailgate [1]. While these could have been caused solely by risky driving style in Thailand, it can also suggest that having drivers more aware of their surrounding could benefit their driving. In other words, to drive safely in Thailand one should concentrate on driving and keep distraction to the minimum.

One way to consider driving safety is to categorize activities into a main task, driving, and all the other tasks as distraction, or secondary tasks. This is because switching between these tasks takes time and attention from the drivers. Especially in the risky environments, if drivers become unaware of their surroundings, accident can happen. Moreover, the risk of traffic accident becomes higher when the duration of secondary tasks is longer [2], [9], [10]. Thus, if secondary tasks can be reduced, it could benefit drivers.

Elders whose senses degraded: eye, ear, skin [3], [8] have potential to perform secondary tasks longer, especially with degraded eyes. This is because most, if not all, of traffic signs, especially in developing countries, rely heavily on sight. Traffic lights, stop signs, turn signs, routes, and direction signs, all of these need eyes to make sense of it. Not to mention the sooner they are seen and understood, the safer it is for everyone including the drivers. This research will compare between people age above and below 40 as this is a turning point that starts to show eyesight deterioration [4] and is widely studied by many researches [5,6,7].

This research is conducted under a hypothesis that: with the introduction of smart wearable device providing haptic and sound feedbacks, elderly drivers will be more aware of their surroundings, and thus, spending more time to apply brake in their cars when face with red light. In other words, those who react slowly will need to brake more suddenly, resulting in shorter brake time. Thus, we will measure on how long our drivers apply the brake.

The research will further unveil the usability, burden, and technology acceptance among users, as this device may have potential to be used under intense and unsafe situation, and to keep this experiment safe. In the end, we hope to introduce a smart wearable device that can improve drivers' performance.

Chapter 2

BACKGROUND

In this chapter, we will focus on the related studies and information about traffic accidents as well as elderly specific issues. This is to explore the pattern and observation on causes and solutions for traffic accident, and to hopefully expand the collection of solutions.

2.1 Literature review: Elderly driving performance under influence of navigation system

A study on elderly's perceptual and cognitive abilities has been done to weight the benefit of in-car navigation system for drivers. As it turned out, sometimes, the additional information for the drivers become a distraction itself due to visual and cognitive load.

The study conducted the experiment in a simulation with several sensors to monitor the participants' reaction to several feedbacks introduced. The feedbacks used in this experiment were visual, haptic, and sound. The participants both young and old then drive in the simulator with the feedback to help them navigate the route.

The result was that, for older drivers, their cognitive loads are almost at their capacity. And thus, they only benefit from one or two feedback at a time. In other words, when more types of feedback are introduced, their cognitive was overloaded and they perform worse. Contrast with younger drivers who can handle more feedback types. It is better to introduce low number of feedback to elderlies.

2.2 Literature review: Elderly limitation

From several studies, human eyes can start to deteriorate from the age of 40 [4]. The age of 40 is also widely studied by many researched [5,6,7]. With increasing in age of population throughout the world, there will always exist elderly population who need to drive for themselves, even with unsafe situation, intentional or not. Though some elderly remain healthy throughout their lives, some do take a hit, and they are unaware of their gradual deterioration. Because of this, sometimes, people only realize that their senses deteriorate after something bad happens.

Apart from visual limitation, elderlies also have several other sensory limitation that may or may not developed over time [3]. Hearing is one of the sensory that can also deteriorate at old age, especially the hearing of high frequency sound. This is explained by the loss of inner hair cells on cochlea, which act as a receiver for higher frequency. The cause of this lost could be from noisy environment, diet, or genetic [3]. Females usually have better hearing compare to male counterparts, until at the age of over 60, which both genders have similar hearing ability. Thus, to take this into account, a device for elderlies that use sound should not rely on high frequency sound.

Another limitation in elderlies is attention and memory. One factor that impacts this limitation is information processing which results in decline cognitive function, an ability to acquire information. Because of this, switching between tasks can be challenging for elderlies as they have to retain a memory of one task and reprocess information on a newly switched task. This can causes elderlies to react slower to a new task, and sometimes make a very severe distraction. To accommodate this limitation, many tools have been crafted to encourage users to focus on only one task, and make it clear of which task is being worked on.

The other limitation is motor control, or muscular coordinate and strength. General tactile sensitivity and other sensories deteriorate with age. This can be caused by deteriorating among neural impulses, which lead to loss in accuracy of hand-eye coordination as well as having slower speed. This means, to accommodate this, an instrument should be large enough and tolerate inaccuracy of elderlies.

From limitations above, there have been several attempts to introduce addition feedbacks for drivers. These additional feedbacks are usually based on three sensoria: visual, audio, and haptic [13,14].

We propose an additional audio and haptic feedbacks to help drivers in real-road scenario. We will measure the performance of the drivers with and without the additional feedbacks as well as conducting a survey afterward.

2.3 Traffic distraction – the secondary task

When we consider driving as a main task, we usually consider every other event that causes the attention to shift as distraction or secondary tasks. Many researches were studied to identify and categorize secondary tasks into events inside and outside of the vehicles [11,12].

Another way to categorize secondary task is how long the activities take drivers' vision away from the road, or cognitive demand. This can range from quick glance activities like following traffic and adjusting fan to longer activities like answering phones and looking at the name of the street [11].

These categories are then further studied to find the causes (crashes, near misses etc.) and solidify policy making [2]. Therefore, from the example of categorizations above, this paper will focus on eyesight. This is because today traffics focus so much on cognitive feedback. Drivers have to shift their vision constantly to look at signs, traffic lights, pedestrians, and surrounding vehicles. This limits drivers' channel of information to only their eyes, and when their eyes deteriorates, their driving skill follows.

There are many developments that reflected these studies and suggested alternative ways for driver to receive information. Personal navigation is one of the product that helps driver understand their routes and surrounding, usually with sound. [4] With this device, the information from outside will be brought into a car for easier access. It will also help suggest or dictate the routes that drivers can be taking, lowering the need to think and calculate the route even more. Most importantly, it usually can give information in sound form, along with visual form.

Traffic raised stripes are another example of traffic instruments to help provide another feedback to the drivers [5]. These instruments are usually installed on roads in crowded areas or in high risk pedestrian areas such as hospitals or schools. Its basic function is simply to rumble the cars when driven over to warn drivers that they are heading toward high risk areas.

This experiment will try to introduce drivers to a device that simplify and imitate sound and haptic feedback of voice navigation and raised stripes respectively. Having a small device that one can wear around without the needing to install relatively big device in car or instrument on road will be beneficial.

2.4 Measurement for task intensity - Self-report assessment

Contrast to performance assessment which records objectively with an instrument, self-report assessment uses NASA-TLX or Likert scales and lets participants record their own judgements. These processes are to be used post-experiment to provide non-intrusive user experience as well as a cool-down and question-answer session for further findings. The participants can also be observed in this phase to see their reaction and attitude toward the experiment.

However, as noted, this approach gathers mostly subjective opinions of the users which need to be carefully digested. For example, when asked if the task was difficult or not, some participants may claim they had no problem even though they struggled to do the task compare to other participants. Unless this is to measure participants' opinions directly, the records should be used along other objective measurements.

Yet, when this is used along with objective measurements on an aspect of users' technology acceptance, we can better understand their attitudes toward the technology as well as correlation between the attitudes and objective measurements. There are several factors that affect the users' attitude toward a technology. And for target audiences who are not familiar with technology, the first impression is very important. One of the factors is comfort. With technology for safety, the usefulness of the technology might push for initial usage. However, to keep the usage, the technology should be comfortable to use for the users, both physically and mentally. Another potential factor is trust. Especially in technology for safety, the device must carry enough trust from the users to make sure that it is indeed safe to use. Last potential factor is social norm. Especially in a country like Thailand, factors like self-image and social pressure play a large role in the culture. Bonus potential factor is government policy. This will likely affect the decision for drivers to use technology, but this is not exactly decided by users themselves.

In short, self-assessment could be used to contrast with participants' actual performances to further understand the relationship between participants' opinions and their performances. This can then be set as a base for future policy or products to maximize safety and efficiency while driving.

Chapter 3

METHODOLOGY

In this chapter we focus on the planning and preparation for the experiment. The experiment will be conducted by observing participants drive while they wear a device to help with their braking.

3.1 Hypothesis

From our research, we have a hypothesis that older drivers have to spend more time to notice red light, thus leave less time for a brake. If we introduce a device to notify them about the red light, they will spend more time on braking.

3.2 Location and Setting

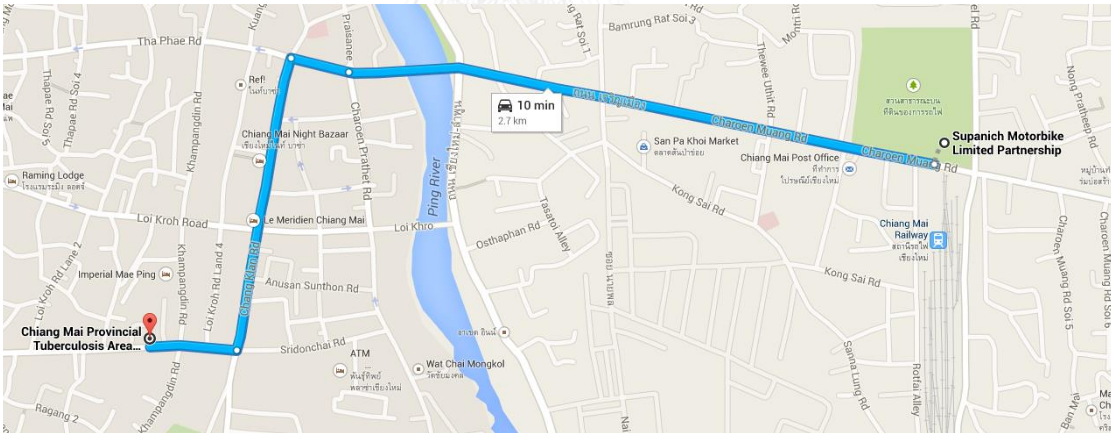

Figure 1 Route in Chiang Mai (2.7 km, ~5.4 roundtrip)

The location chosen for this experiment is the route from Chiang Mai Provincial Tuberculosis Area Centre to Chiang Mai train station, as seen in Figure 1 Route in Chiang Mai. The route is approximately 2.7 kilometres in length and has 7 red light for a one-way trip. This means the drivers will spot red lights every 300-400 metres which help keep the speed low for safety and consistency. The reason Chiang Mai was chosen is because of the availability of participants and the characteristic of a busy city. Being in urban area also leads to relatively crowded streets that represent generic busy vehicles and pedestrians with a high amount of signs and labels, as seen in Figure 2 Chiang Mai urban area.

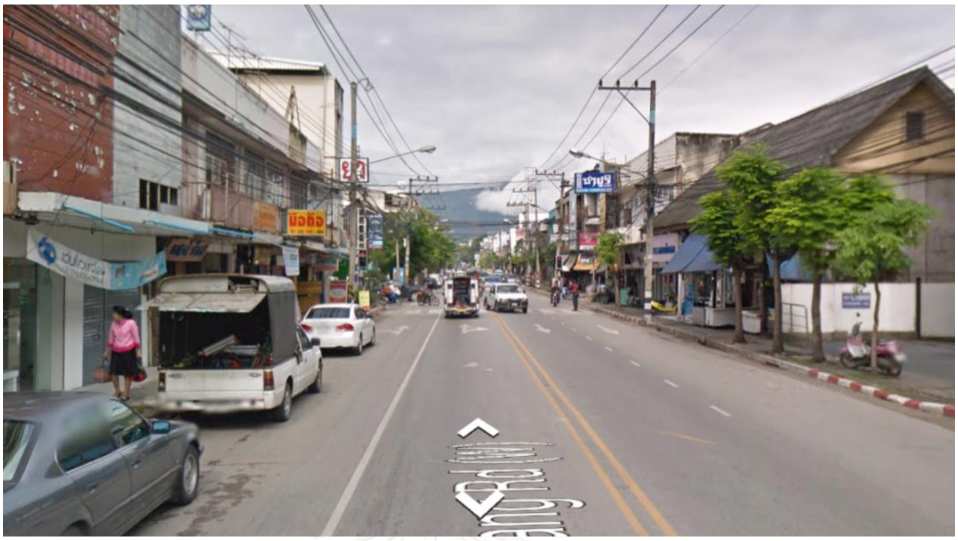

Figure 2 Chiang Mai urban area

Unfortunately, because of the change in traffic congestion throughout the day, each participant might have different situations during the experiment. Some participants might have to drive around more than one trip to have enough stops at red lights. Some might have driven a long trip from their home, and many participants might be unfamiliar with the routes and the red lights. This may affect the participants' efficiency and attention in the experiment.

Nevertheless, the route is relatively straightforward and was consistently busy throughout the way. Thus, the setting provided a generic common busy city where distractions are high. A good match for experiment focus on distractions.

3.3 Participants

There were a total of 3 groups of participants. The first group was mostly to test the feasibility and safety of the experiment and the device. The second group is mostly to collect data from elders. And lastly, the third group is to collect data for younger drivers.

3.3.1 Pilot participants

The experiments started with a closed group of author’s acquaintances. The initial test was made with three objectives.

First objective is to check the feasibility of the smart wearable device. As the device has to be worn by many participants, it should have the flexibility and comfort to make sure all participants can wear it without losing their grips or breaking the device. The initial test also helped the author to discover and keep the device hygienic between the experiments.

Second discovery is to test for consistency of the measurement. As the experiment would be measured by a stopwatch controlled manually by the author, several plans and conditions were made to keep the measurements more consistent. Fortunately, it was fairly easy to glance at drivers’ legs to see if a brake was being applied. Thus, the pilot test helped prepare the author for the right timing and the flow to observe during the experiments.

The last objective for the pilot phase is to make very certain the experiment is safe. Introducing a new source of distraction into driving cars has to be taken extremely carefully to make sure it does not cause the inevitable. The pilot test started off very slowly and carefully with several feedback from the participants. The test helped setting up a plan on how and when to equip the device onto the drivers. And set an iron rule: do not touch drivers while driving.

3.3.2 First batch participants

The first batch of experiment was conducted focusing on nine drivers who are over 40 years old. The initial hypothesis was that, if the device has any effect on drivers, the elderly drivers should be affected more as their sensory feedback are more likely to be deteriorated. All of the participants have a car and have enough experience to drive safely. The detailed information of each participant such as age and driving experience can be found in Chapter 4: Result.

3.3.3 Second batch participants

The second batch of the experiment was done with 13 participants. This time, most of the participants are below 40 years old to provide data for comparison with the first group. The hypothesis for this phase was that, younger participants should have better sensory feedbacks, thus the additional feedbacks from the device would have lesser effect on them. Same as before, the participants have their own car and are confident with their driving skill and experience.

3.4 Prototype Device

In this experiment, a prototype device was made to simulate a wearable device that can send sound and haptic feedbacks to the driver. We chose a smart wearable device as the technology of choice to avoid the need to install and mobility. The small form factor can keep the experiment to be less intrusive. The device can be broken down into 3 parts: the arm strap, the feedback device, and the trigger device.

The first part, the arm strap, is meant to be worn by the drivers as well as holding the feedback device. For this part, we use generic cell phone armband that has thin layer of cloth. This is to make sure sound and haptic can be felt through the armband. We also chose an armband that is easy to equip and remove. This is to make sure we can conduct experiments safely and swiftly. Lastly, we tried to choose the armband with materials that absorb least sweat and easy to clean. This is to keep the device hygienic and comfortable to wear.

The second part is the feedback device itself. For this, we use a generic Android cell phone with Bluetooth connection. The device then have to be installed with an application Remote Vibration and Tablet Remote to receive a command from the trigger device. We set the device up by connecting it to the trigger device and insert it into the armband, as seen in Figure 3 Armband and Feedback device.

Figure 3 Armband and Feedback device

The third and last part of the device is the trigger device. This is another Android cell phone that has Bluetooth connection with the same applications installed. Once we connect this trigger device to the feedback device, we can use this to control when to dispatch the feedback for the participants.

The picture of the device in action can be seen in Figure 4 During experiment.

Figure 4 During experiment

3.5 Experiment

On the test site, the experiments were conducted one by one. Each experiment involves one driver and one observer. Passengers can ride along during the experiment to simulate generic familiar driving experience. It usually takes less than one hour per each experiment.

The test starts by the participant arrives at the test site with their car. A brief information about the experiment is given to the participant along with the tasks and the routes. At this point, the device is shown and equipped onto the driver's arm. The driving test then can start. After the driving test is finished, the survey then follows, and the experiment ends.

3.5.1 The driving test

In driving test, the participants equip the device and drive on the given route. They stop at red lights along the way. At each red light stop, the measurement is made by the following steps:

1. Let the testers drive normally
2. When approaching red light, at least 200 metres away, the observer triggers one of the three feedbacks (sound, haptic, or none)
3. When the tester starts to apply the brake, the observer starts the stopwatch
4. When the tester comes to a stop or re-applies accelerator, the observer stops the watch and notes down the duration.
5. Repeat the experiment with every red-light.

The reason we chose to measure brake duration instead of general respond time is because the device is not meant to induce reaction immediately. As driving safely involves casual deceleration or coasting, the device simulates more as a yellow signal in traffic light rather than red light, which is discussed to affect drivers' behavior [15]. Instead, we would like to observe how aware the testers are with extra information we have introduced.

For this experiment, because the traffic on the route is relatively busy, participants did drive carefully, topping the speed only at 60 kilometres per hour. This allows the feedback distance of 200 meters to be plenty sufficient for braking. If the speed of the cars were going faster, the feedback distance would need to be further, make sighting red lights with eyes even less viable.

3.5.2 Experimental design

There were many choices made to keep the experiments consistence and natural for the drivers. First, the term brake time used in this experiment is a duration starts from the moment the driver touches the brake pedal until the car stops or the accelerator pedal is applied again. The reason for this specific definition is made under assumption that the more prepared the driver is, the longer the brake is applied. If the car comes to a stop or the accelerator is applied again, we assume that the driver is certain of the safety and is ready for the next steps after stopping the car.

The second rule set is to trigger feedback at least 200 metres before red lights. This rule was made from the fact that, the route used in this experiment has a very short distant between red lights. Some red lights are only 400 meters apart, thus, the drivers usually cannot get their cars to be faster than 60 km/hr or approximately 16.67 m/s. This means, for most drivers who spend 8-12 seconds to stop their car (approximately 130 - 200 meters at 60 km/s), they usually start applying the brake less than 200 metres from red lights. Thus, 200 metres leave enough room for drivers to stop their cars, at the speed less than 60 km/s.

Chapter 4

Result

4.1 Demographic data

For our experiment, there were a total of 22 participants. These participants status were collected via a survey at the end of the experiment. 12 of participants are males and 10 are females. Age of participants range from 26 to 67 years with mean of 38.77 years and standard deviation of 13.07. By average, our participants have driving experience of approximately 16 years. However, the driving experience range quite extremely from 9 months to 40 years. Though most have different degree of eyes condition, only 7 participants use eyewear while driving. The full detail can be found in Table 1 Participant Demographic data below.

Table 1 Participant Demographic data

Testers #	Age	Gender	Driving Experience (Years)	Familiarity with Smart devices	Car Type	Use Eyes device while driving
1	42	Male	20	1	truck	No
2	42	Male	10	1	truck	No
3	41	Male	20	1	sedan	No
4	51	Male	15	3	SUV	No
5	47	Female	23	1	sedan	No
6	43	Female	28	3	sedan	No
7	59	Female	35	3	SUV	No
8	56	Female	31	2	sedan	Yes
9	61	Male	39	3	SUV	Yes
10	29	Male	16	1	sedan	No
11	28	Female	4	2	sedan	No
12	37	Male	17	3	sedan	No
13	27	Male	5	1	sedan	No
14	27	Female	7	2	sedan	Yes
15	32	Female	14	2	sedan	Yes
16	28	Male	12	4	SUV	No
17	27	Female	4	1	sedan	Yes

18	27	Female	2	2	sedan	Yes
19	29	Male	0.9	3	eco	Yes
20	67	Male	40	3	SUV	No
21	26	Male	11	1	sedan	No
22	27	Female	7	3	sedan	No

4.2 Performance – Overall

The performance results were measured by observer during the experiment using a stopwatch. A total of 264 recordings were made on each stop at red light. These recordings are split into 3 types by feedback being introduced. Out of 22 participants, 17 participants show an increase in duration of brake time under sound and haptic feedback. Within other 5 participants, 3 increase brake time with only one type of feedback, and the last 2 decrease their brake time when they wear the device. Interestingly, out of 5 participants who decrease their brake time, 4 were under 40 years old, 4 were females, and all 5 were driving a sedan car.

Below in Table 2 Raw brake time, shows all the result from measurement. The brake time is the duration measure from the moment the driver start hitting the brake until the car stops. We measure the duration in seconds. The range of brake time range from a sudden stop at less than 5 seconds to a long stop that is more than 20 seconds.

Table 2 Raw brake time

	Brake time (s)		
Testers #	None	Sound	Haptic
1	8.16	8.9	10.93
	7.5	5.6	10.97
	9.53	11.34	9.34
	8.18	9.22	9.87
2	8.53	11.97	7.16
	8.78	10.88	11.6
	8.18	10.47	12.34
	8.62	9.28	8.87
3	6.84	9.16	10.1
	8.16	11.28	9.62
	8.87	7.59	6.41
	8.3	10.97	10.38
4	9.18	11.13	8
	9.34	10.06	10

	9.09	9.5	11.38
	8.65	8.91	10.37
5	8.87	9.59	7.82
	8.42	10.1	10.78
	6.78	10.75	11.03
	7.44	8.85	8.53
6	7.44	7.52	9
	8.03	11.6	9.62
	8.34	8.03	11.25
	9.78	9.4	9.5
7	8.37	11.22	12.78
	6.41	3.4	10.41
	7.13	8.19	7.97
	8.91	15.68	11.81
8	20.28	13.47	7.84
	11	16.75	13.31
	11.44	23.28	13.03
	12.88	18.28	10.72
9	9.97	7.35	12.78
	8.81	9.38	11.15
	11.29	13.4	13.66
	9.96	11.87	10.48
10	8.16	7.57	8
	9.25	8	10.12
	9.5	9.5	12.34
	11.18	13.41	14.5
11	5.6	7.72	7.72
	7.52	7.81	8.22
	7.88	10.47	9.84
	9.72	11.37	10.16
12	7.65	8.91	8.97
	8.16	8.97	9.22
	8.34	10.84	9.44
	8.53	10.96	12.47
13	7.89	9.69	9.75
	8.53	9.78	10.13
	8.94	9.98	10.66
	9.28	11.18	10.84
14	4.91	7.63	7.88
	9.98	7.88	8.15
	9.78	8.22	9.54
	8.22	8.56	10.72

15	7.72	7.37	7.57
	9.09	7.56	7.75
	10.46	8.18	8.43
	10.53	9.59	9.22
16	8.25	10.12	9.25
	8.37	10.57	10.62
	8.85	12.44	11.4
	9.9	13.31	12.03
17	8.85	8.25	8.94
	9.81	10.13	9.44
	10.22	10.75	10.72
	10.31	12.65	12.68
18	8.07	11.19	9.59
	8.44	11.38	9.96
	9.87	11.81	11.65
	11.28	12.56	12
19	7.91	7.72	7.59
	8.38	8.25	7.94
	9.44	10.72	10.31
	9.87	10.63	10.84
20	6.65	8.94	7.98
	7.75	11.47	8.78
	10.37	11.81	8.98
	10.5	12.56	10.54
21	6.6	4.69	6.85
	10.09	6.74	8.09
	13.94	13.18	8.5
	16.28	15.17	9.12
22	5.85	6.36	7.47
	6.72	7.84	9.94
	8.31	8.5	11.38
	12.53	9.65	12.34

Table 3 Average brake time

Testers #	Average None (s)	Average Sound (s)	Average Haptic (s)
1	8.34	8.77	10.28
2	8.53	10.65	9.99
3	8.04	9.75	9.13
4	9.07	9.90	9.94
5	7.88	9.82	9.54
6	8.40	9.14	9.84
7	7.71	9.62	10.74
8	13.90	17.95	11.23
9	10.01	10.50	12.02
10	9.52	9.62	11.24
11	7.68	9.34	8.99
12	8.17	9.92	10.03
13	8.66	10.16	10.35
14	8.22	8.07	9.07
15	9.45	8.18	8.24
16	8.49	11.61	10.83
17	9.80	10.45	10.45
18	9.42	11.74	10.80
19	8.90	9.33	9.17
20	8.82	11.20	9.07
21	11.73	9.95	8.14
22	8.35	8.09	10.28

From Table 3 Average brake time above, we found that, on average, using the device increase the brake time by 12.39% and 10.19% for sound and haptic feedback respectively. The standard deviation for no feedback, sound feedback, and haptic feedback are 1.42, 2.01, and 0.99 respectively. Implying that even though sound feedback has higher average brake duration, the result could vary wildly from person to person. Still the increase in duration of one second can translate roughly to 13.89 meter when a driver drives at 50 KM/Hour.

Table 4 Descriptive Statistics of brake time, age, and driving exprience

	Minimum	Maximum	Mean	Std. Deviation
Average None (s)	7.68	13.90	9.0495	1.42194
Average Sound (s)	8.07	17.95	10.1709	2.00885
Average Haptic (s)	8.14	12.02	9.9714	.98720
Age	26	67	38.77	13.067
Driving Exp (years)	.90	40.00	16.4045	11.93317

4.3 Performance – Comparison

Table 5 Performance comparison

Independent Samples Test - Age >=40 vs Age <40

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
AverageNone	Equal variances assumed	.659	.427	.060	20	.953	.03750	.62382
	Equal variances not assumed			.057	13.967	.955	.03750	.65363
AverageSound	Equal variances assumed	.888	.357	1.204	20	.243	1.02500	.85106
	Equal variances not assumed			1.132	12.214	.279	1.02500	.90527
AverageHaptic	Equal variances assumed	.763	.393	.892	20	.383	.37883	.42477
	Equal variances not assumed			.902	19.880	.378	.37883	.42020

From Table 5 Performance comparison, comparing elderly performance to younger one, there is no significance in each feedback type. With mean difference as 0.037 seconds for none-feedback, it is implied that the difference between feedback for younger and older drivers are quite minimal.

For haptic feedback, the mean difference is 0.378 seconds which mean the different is unnoticeable. And lastly, for Haptic, the mean difference is 1.02. Although not statistically significant, this is the biggest difference for elderly and younger drivers.

4.4 Improvement – Overall

To test credibility of brake time increased, paired sample T-tests were conduct for both sound feedback and haptic feedback. With significance (p-value) of 0.001 for sound feedback and 0.012 for haptic feedback, we can conclude that both change are statistically significant.

Table 6 Paired Sample T-Test for sound and haptic against none feedback

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
None - Sound	-1.12136	1.37266	.29265	-1.72997	-.51276	-3.832	21	.001
None - Haptic	-.92182	1.57439	.33566	-1.61986	-.22377	-2.746	21	.012

From all of the above measurement in Table 6 Paired Sample T-Test for sound and haptic against none feedback. It is possible to conclude that the improvement from using the device is statistically significance. For sound feedback device, the result has confidence interval of 99.9%, and for haptic feedback, the result has confidence interval of 98%.

4.5 Improvement – Comparison

Table 7 Paired Sample T-Test for sound and haptic against none feedback - Older drivers

Paired Samples Test - Old

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Sound - None	1.66000	1.10567	.34964	.86905	2.45095	4.748	9	.001
Haptic - None	1.10800	1.52042	.48080	.02036	2.19564	2.304	9	.047

Table 8 Paired Sample T-Test for sound and haptic against none feedback - Younger drivers

Paired Samples Test - Young

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Sound - None	.67250	1.45373	.41966	-.25116	1.59616	1.603	11	.137
Haptic - None	.76667	1.66820	.48157	-.29326	1.82659	1.592	11	.140

When we compare overall performance between both groups in Table 5 Performance comparison, we found no significance difference. However, when we split the data and calculate for both side, only the elderly seem to have significant improvement. In Table 7 Paired Sample T-Test for sound and haptic against none feedback - Older drivers, older drivers gain significance brake time increase from both sound and haptic device, at p = 0.001 and p = 0.047 respectively. Contrast with Table 8 Paired Sample T-Test for sound and haptic against none feedback - Younger drivers, both sound and haptic have p-value higher than 0.1, making them insignificance.

This shows that, for elders, the device statistically significantly help increase their brake time. However, for younger drivers, this was not the case. Therefore, the device we introduced matched our hypothesis.

4.6 Correlation between demographic data and performance

From performance result, we suspect that participants' background has some effect on the brake time. To study further, we conduct a correlation analysis between each feedback and participants' background.

Table 9 Correlations Matrix of demographic data vs brake time

		Average None	**Average Sound**	**Average Haptic**
Age	Pearson Correlation	.114	**.356**	.262
	Sig. (2-tailed)	.612	.104	.239
Gender = Male	Pearson Correlation	-.021	-.032	**.051**
	Sig. (2-tailed)	.927	.887	.823
Driving Experience (year)	Pearson Correlation	.151	**.294**	.279
	Sig. (2-tailed)	.502	.184	.208
Familiarity With Smart Device	Pearson Correlation	-.144	.034	**.183**
	Sig. (2-tailed)	.521	.879	.415
Use Eyewear while driving	Pearson Correlation	**.446**	.250	.119
	Sig. (2-tailed)	.037	.262	.597
Drive Sedan	Pearson Correlation	.172	-.010	**-.222**
	Sig. (2-tailed)	.444	.964	.320

From the correlation matrix using two-tailed Pearson correlation in Table 9 Correlations Matrix of demographic data vs brake time, none of the background has noticeably high correlation coefficient toward performance. The highest coefficient captured was the result from participants who wear glasses during the experiment, at 0.446 (sig. 0.037).

The second highest correlation coefficient is from the age of participants at 0.356 (sig 0.104). And the third highest coefficient result from the data of participants’ driving experience at 0.294 (sig. 0.184).

The other factors has correlation coefficient of -0.222 (sig. 0.320), 0.183 (sig. 0.415), and 0.051 (sig. 0.823) from driving sedan, familiarity with smart device, and gender respectively. These background might not be a significant factor but they might be clearer with further study.

4.7 NASA-TLX

The participants self-assesse their opinions on how heavy the task of using the smart device was via the survey. The survey asked participants to rate in Likert-scales style of 1 to 5: Easiest (1), Easy (2), Medium (3), Hard (4), Hardest (5). The questionnaire focuses on 6 aspect of task: Mental demand, Physical demand, Temporal demand, Performance, Effort, and frustration.

Table 10 NASA-TLX input by participants

Testers #	Mental	Physical	Temporal	Effort	Frustration	Performance
1	2	3	3	2	3	3
2	2	2	3	2	2	2
3	3	3	4	4	4	2
4	4	3	4	3	2	2
5	2	4	2	2	4	1
6	2	2	2	2	2	4
7	4	4	2	4	4	3
8	4	4	4	2	2	2
9	2	2	3	2	2	3
10	3	3	3	2	3	2
11	3	3	3	3	3	2
12	3	2	3	3	3	3
13	3	4	3	2	4	2
14	2	1	1	2	2	1
15	2	1	1	1	1	1

16	2	1	3	2	3	2
17	1	1	2	1	1	1
18	1	1	1	1	2	1
19	3	2	2	2	2	2
20	2	2	1	1	2	1
21	2	2	3	3	3	3
22	3	2	2	2	2	3

Table 11 NASA-TLX Statistic description

	Mental	**Physical**	**Temporal**	**Effort**	**Frustration**	**Performance**
Mean	2.50	2.36	2.50	2.18	2.55	2.09
Median	2.00	2.00	3.00	2.00	2.00	2.00
Std. Deviation	.859	1.049	.964	.853	.912	.868

None of the participant rate the task load as 5 (heaviest), as per Table 6. Most tasks are rated as 2(easy) except for temporal demand, which rated by most participants as 3 (medium). A participant usually rate each task within range of 3. For example, if a participant rate mental demand as 4, they would rate other tasks around 2, 3, or 4, but would never jump their rating to 1.

From Table 7, the mean for all tasks range from 2 to 2.6, implying that most participants find task to be easy-medium. The task that has highest rating is Frustration at the mean rate of 2.55 with 4 participants rate this task with a 4. This makes frustration the most annoying task for the wearable device.

The task with lowest rating is Performance with mean rating of 2.09 as 6 participants rate themselves as 1 on this task. The shows that the participants feel they successfully perform the task with the wearable device.

From this result, we found that participants feel the device relatively easy to use, but still feel that it needs some effort to use.

4.8 NASA-TLX – Comparison

Independent Samples Test - Age >=40 vs Age <40

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mental	Equal variances assumed	1.379	.254	.997	20	.331	.367	.368
	Equal variances not assumed			.978	17.441	.341	.367	.375
Physical	Equal variances assumed	.037	.849	2.433	20	.024	.983	.404
	Equal variances not assumed			2.463	19.922	.023	.983	.399
Temporal	Equal variances assumed	.219	.645	1.360	20	.189	.550	.405
	Equal variances not assumed			1.337	17.673	.198	.550	.411
Effort	Equal variances assumed	1.311	.266	1.101	20	.284	.400	.363
	Equal variances not assumed			1.074	16.667	.298	.400	.373
Frustration	Equal variances assumed	.275	.606	.717	20	.481	.283	.395
	Equal variances not assumed			.714	18.879	.484	.283	.397
Performance	Equal variances assumed	.508	.484	1.033	20	.314	.383	.371
	Equal variances not assumed			1.016	17.639	.323	.383	.377

From comparing elderly NASA-TLX report to younger drivers’ one, we found that the only task that elder rate significantly different from younger drivers is physical task. With mean difference of 0.983, almost a full point different between 2 sides. The reason for this rating could be that for older drivers, having a big device on their arm just feel unnatural.

4.9 NASA TLX – Performance Correlation

To find out of NASA task load has any connection with performance, we conduct Pearson Correlation matrix accordingly.

Table 12 Correlations matrix of NASA-TLX vs brake time

		Average None	Average Sound	Average Haptic
Mental	Pearson Correlation	.075	.195	.117
	Sig. (2-tailed)	.741	.384	.606
Physical	Pearson Correlation	.037	.250	.190
	Sig. (2-tailed)	.868	.262	.396
Temporal	Pearson Correlation	.267	.360	.281
	Sig. (2-tailed)	.229	.099	.206
Effort	Pearson Correlation	-.217	-.122	-.091
	Sig. (2-tailed)	.331	.587	.688
Frustration	Pearson Correlation	-.343	-.072	.036
	Sig. (2-tailed)	.118	.750	.873
Performance	Pearson Correlation	-.022	-.128	.225
	Sig. (2-tailed)	.921	.571	.313

From the Pearson Correlation matrix in Table 8 above, there was no outstanding correlation between tasks and performance. This time, the highest correlation coefficient come from the Temporal task at 0.360 (sig. 0.099). The second correlation coefficient is for Frustration at -0.343 (sig. 0.188). And third highest correlation coefficient recorded from Physical at 0.250 (sig.0.262),

Other tasks have relatively lower correlation coefficient at 0.225 (sig.0.313), -0.217 (sig. 0.331), and 0.195 (sig. 0.384), from Performance, Effort, and Mental respectively.

It is very suiting that Temporal task would have the strongest connection to performance as the whole experiment is trying to notify participants of the red lights. This correlation explains the connection between the two as that, when the drivers feel the load from temporal task, they spend more time applying the brake.

Follow closely with Temporal task is Frustration. The negative correlation implies that the higher frustration the drivers have with the device, the less time the drivers will apply the brake. This is the other side of the coin that may actually make the situation less safe if the device is not properly studied and implemented.

4.10 Technology Acceptance Model (TAM)

Technology Acceptance Model is a model which propose factors that have potential to affect users' acceptance of the technology. As attitude is one the most important factor that has potential to change non-users to users, this study will use Attitude and Intended Use as the focus point of this TAM. The other popular factors such as Perceived Ease of Use and Perceived Usefulness are usually set as the factors that affect attitude. The factors are then arranged to form the following model:

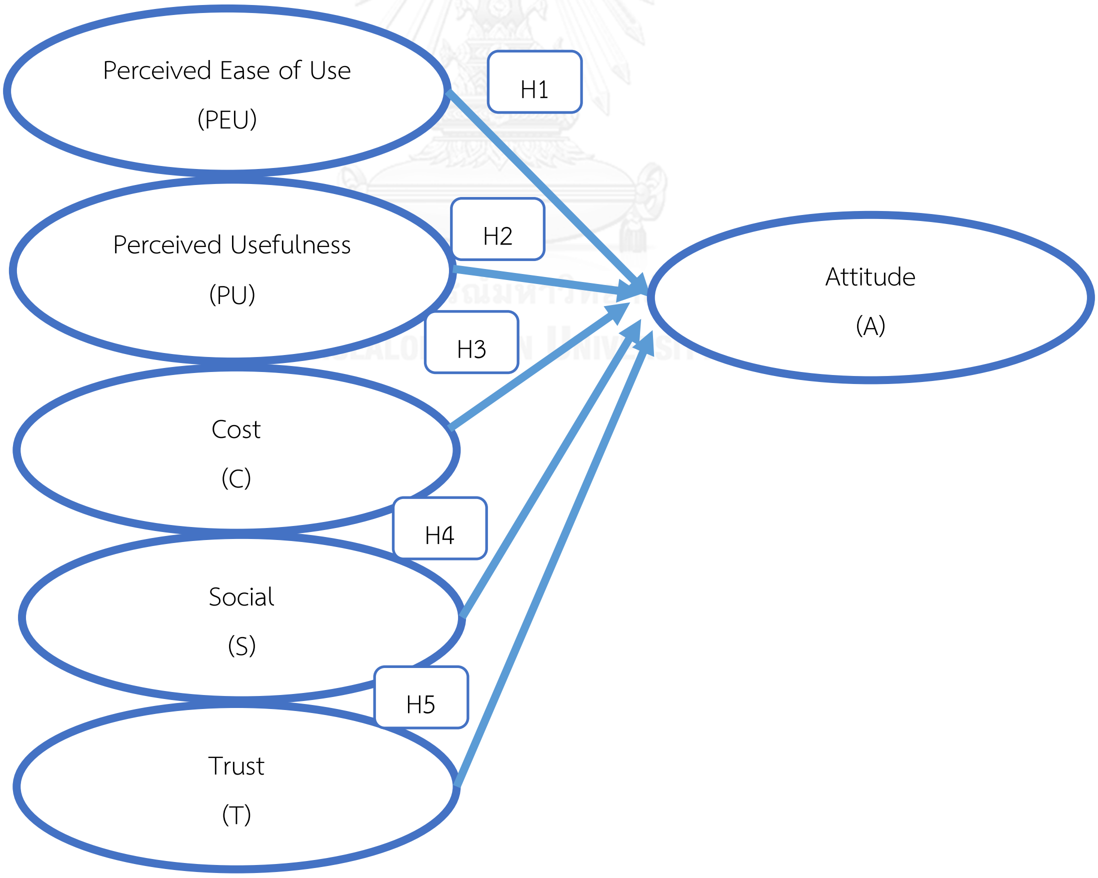

Figure 5 TAM for Attitude

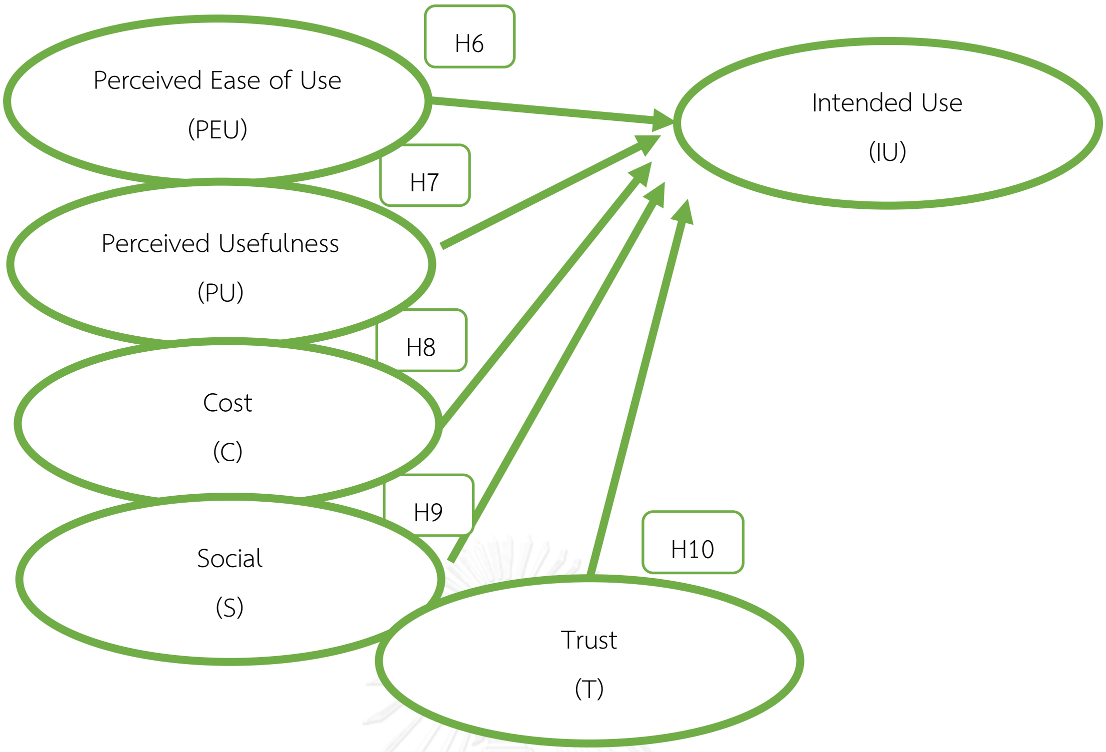

Figure 6 TAM for Intended Use

The model are based on figure 5 and 6 have following hypothesis:

H1: Perceived Ease of Use has positive influence on Attitude

H2: Perceived Usefulness has positive influence on Attitude

H3: Cost has negative influence on Attitude

H4: Social has positive influence on Attitude

H5: Trust has positive influence on Attitude

H6: Perceived Ease of Use has positive influence on Intended Use

H7: Perceived Usefulness has positive influence on Intended Use

H8: Cost has negative influence on Intended Use

H9: Social has positive influence on Intended Use

H10: Trust has positive influence on Intended Use

4.11 TAM Result

After the driving experiment was conducted, the surveys were given to participants to ask for their opinion on the questions regarding these factors. The survey asked participants to rate in Likert-scales style from 1 to 5: Lowest (1), Low (2), Medium (3), High (4), Highest (5). The questionnaire focuses on 7 factors: Perceived Ease of Use, Perceived Usefulness, Cost, Social, Trust, Attitude, and Intended Use.

4.11.1 Reliability test, Factor Analysis, Regression Test

4.11.1.1 Reliability Test

From the data collected, we start the digestion with Reliability test. This is to check the consistency of our data and to measure if any question has irregular effect on the data.

Table 13 Reliability Statistic

Cronbach's Alpha	N of Items
.887	21

Table 14 Item-Total Reliability Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
PU1	74.9091	72.944	.726	.875
PU2	74.7727	73.803	.749	.875
PU3	74.6364	74.147	.714	.876
PEU1	74.7727	75.517	.612	.879
PEU2	74.7727	75.232	.539	.881
PEU3	74.7727	76.851	.464	.883
S1	74.8182	70.632	.756	.873
S2	75.0909	75.706	.572	.880
S3	74.5000	74.452	.649	.878
C1	75.6364	88.623	-.308	.907
C2	75.4545	89.688	-.352	.910

C3	74.9091	85.706	-.141	.900
T1	74.8636	76.314	.654	.879
T2	74.5455	75.403	.665	.878
T3	74.9091	78.848	.483	.883
IU1	74.7273	76.494	.609	.880
IU2	74.5909	77.682	.577	.881
IU3	74.6818	80.037	.368	.886
A1	74.1818	71.870	.822	.872
A2	74.2727	71.922	.848	.871
A3	74.1818	72.156	.868	.871

We end up with Cronbach's Alpha of 0.887 for our data as shown in Table 13 Reliability Statistic. By standard, Cronbach's Alpha of greater than 0.7 is considered acceptable. While our Cronbach's Alpha does not reach the excellent interval of 0.9, we can claim that our collected data are very consistence.

With further inspection in Table 14 Item-Total Reliability Statistics, we also found that none of the question has significance negative effect on the consistency of the data.

4.11.1.2 Factor Analysis

After the Reliability test, we then consolidate our variables into factors by Principle Component Analysis.

Table 15 Rotated Component Matrix: Factors

	Component				
	1	2	3	4	5
PU1	.902				
PU2	.841				
PU3	.708			.540	
PEU1		.835			
PEU2		.956			

PEU3		.924			
S2				.830	
S3				.893	
C1			.870		
C2			.756		
C3			.791		
T1	.576				.544
T3					.748

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Rotated Component Matrix[a]

	Component	
	1	2
IU2		.673
IU3		.926
A1	.888	
A2	.897	
A3	.938	

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

A few questions was cut due to its inconsistency within the factors, namely one question in Trust factor, one in Social factor, and another in Intended Use factor. After the cut, the factors become a lot cleaner as they group together. We can then use this result in Table 11 in the next step.

4.11.1.3 Regression Test

Once we have the factors calculated, we can then conduct regression test to proceed with factor loading. In this case, we conduct the process twice, one for Attitude and the other for Intended Use.

4.11.1.3.1 Regression test for Attitude

Table 16 Model Summary : Attitude

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.877[a]	.769	.697	.55037492

a. Predictors: (Constant), T, S, C, PEU, PU

b. Dependent Variable: A

Table 17 Coefficient: Attitude

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-2.687E-016	.117		.000	1.000	-.249	.249
PU	.643	.120	.643	5.352	.000	.388	.897
PEU	.236	.120	.236	1.963	.067	-.019	.490
C	-.042	.120	-.042	-.353	.729	-.297	.212
S	.511	.120	.511	4.258	.001	.257	.766
T	.193	.120	.193	1.603	.128	-.062	.447

a. Dependent Variable: A (Attitude)

4.11.1.3.2 Regression test for Intended Use

Table 18 Model Summary: Intended Use

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.385[a]	.148	-.118	1.05730404

a. Predictors: (Constant), T, S, C, PEU, PU

b. Dependent Variable: IU

Table 19 Coefficients: Intended Use

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-1.480E-016	.225		.000	1.000	-.478	.478
PU	.098	.231	.098	.426	.675	-.391	.588
PEU	.136	.231	.136	.588	.565	-.354	.625
C	-.100	.231	-.100	-.432	.672	-.589	.390
S	.263	.231	.263	1.138	.272	-.226	.752
T	-.203	.231	-.203	-.881	.391	-.692	.286

a. Dependent Variable: IU

As seen on the result above in Table 12, 13, 14, 15. The value of R square is quite high for A, not so much for IU (by standard, >70 is high). Some of the standardize coefficient values for A are high as well as significant. With the data fully digested, we can move back to creating our model

4.11.1.3.3 TAM – conclusion

From the digested data, we can create our TAM for smart wearable device as below.

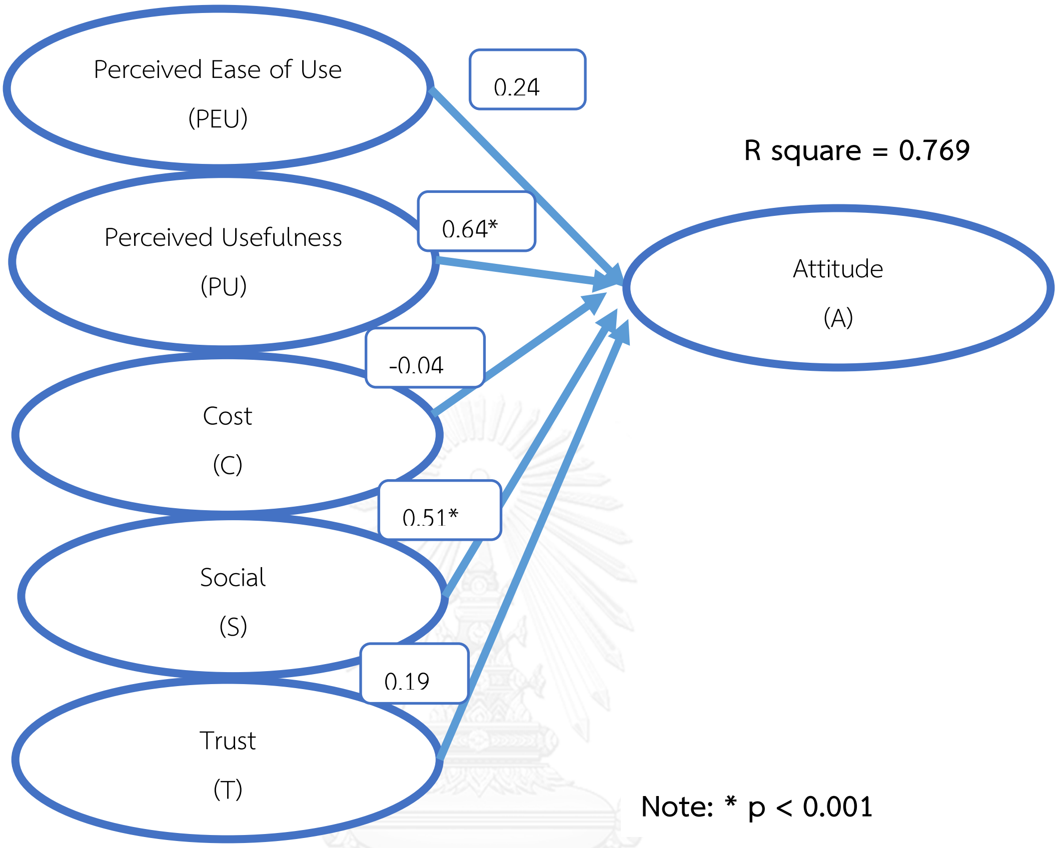

Figure 7 TAM result: Attitude

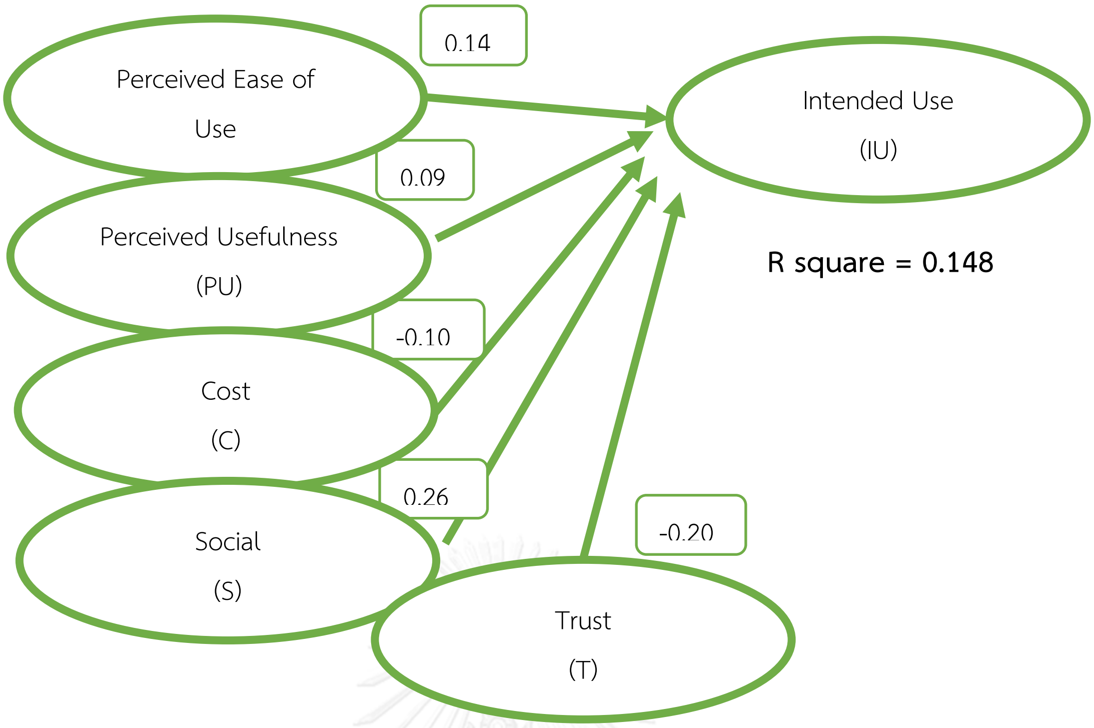

Figure 8 TAM result: Intended Use

From the model in Figure 7 TAM result: Attitude, we can deduct that the factor that affect Attitude the most and second most is Perceived Usefulness and Social at 0.64 and 0.51 respectively. The significance of both factors are also less than 0.001, which implies that both are very statistically significance.

However, other factors do not even reach the significance level of 0.05. The next closest one is Perceived Ease of Use with standardized coefficient of 0.24 at the significance of 0.067. These are the top 3 of factors affecting users' smart wearable device. The other 3 while they do not show statistical significance in this study, they all are still a very common factors when users decide to accept the technology or not.

R square = 0.148

Unfortunately, on Intended Use side, as seen on Figure 8 TAM result: Intended Use, there was no factor that that affect it significantly. The most influential factor is Social with standardized coefficient of 0.263 at significance level of 0.272. Coming close second is Trust at standardized coefficient of -0.203 and significance level of 0.391. Very strange result as it implies that the more trust users have, the less likely they intended to use the device. Other factors are very far from significant that the result seems very weak.

To finalized, we propose a Technology Acceptance Model for smart wearable device where Perceived Usefulness and Social have very significant effect on users Attitude, and Perceived Ease of Use are also a factor but to lesser degree. This study, however, could not conclude which factors could influent users’ Intended Use.

Chapter 5

Discussion

There were several discoveries and challenges that we found in this study. Many even came in a surprising fashions. We will discuss and try to uncover the possible reasons behind those.

5.1 Participants' demographic data

A total of 22 participants were involved in our experiment. One of the focused controlled attribute is the age of the participants as we believe it dictate other aspects of the participants. From this, we will take a closer look on how age may affect other background and choices of the participants.

5.1.1 Age and Type of car

From Table 1 Participant Demographic data, one surprising discovery that caught the author off-guard is type of car owned by younger participants (less than 40 years old). Out of 12 younger participants, 10 of them use sedan car, over 83%. Compare to older participants, 4 out of 10 or only 40% use sedan car. In other words, younger participants are very likely to be driving sedan car, even more than twice as likely compare to older participants.

These choices have a great potential to affect other attributes as being inside one type of a car can change driver's environment tremendously. Sedan type of cars tend to be smaller and have lower driver's seat. This may limit the drivers' visibility and limit what the drivers can put inside their cars. The horsepower characteristics and feature of sedan cars can also play a role in driving style and priority of the drivers.

The reason behind these choices from the author's casual discussion with the participants were the cost, the preferred driving experience, and necessity. First, many of the younger participants have just started their career and simply need personal transportation, cost is one of the most crucial limitation rather than choice. Not only the cost of the car, but the cost of maintenance and future resell were also included into consideration. Second reason is the driving experience, including the ability to tinker and customize their own cars. Some participants simply preferred sedan style cars and the flexibility that comes with it. Last reason is the necessity for the drivers. This is mostly the reason behind non-sedan drivers. These drivers may have family, need space inside their cars for activities, or simply need a higher cars so they and their passengers can get in and out of the cars easily.

5.1.2 Age and Eyewear usage while driving

Another surprising discovery the author found was that only a small portion of participants wear their glasses while driving cars. From Table 1 Participant Demographic data, out of 22 participants, only 7 participants conduct the experiment with glasses on. More surprising is that while most of the older participants have glasses for reading, only 2 out of 10 older participants wear glasses while driving. This leaves the other 5 glasses wearing participants to be in a younger group.

When asked what the reason was, the older participants stated 2 reasons. First, because they do not need glasses to read while driving. And second, closely related to the first one, that they are confident with the route they are taking. Seeing that older participants have been living in Chiang Mai for years, it is understandable that they already have a very good idea of the route in Chiang Mai.

Contrast with younger participants who wear glasses. The reason was that they wear glasses all the time, thus, they simply keep the glasses on while driving. While this might be related to familiarity with the route in Chiang Mai or their driving experience, the author feel that the choice to wear glasses (or contact lens) is mostly personal preference or personal limitation. Moreover, it is not as closely related to age as the hypothesis of the author.

5.1.3 Age and other backgrounds

Apart from the background discussed above, age does not seems to influences other backgrounds. Or it influence it in a very straightforward fashion, such as Driving

Experience. All of the older participants have at least 10 years of Driving Experience, and 8 out of 10 older participants have well over 20 years of Driving Experience.

Other backgrounds such as Preferred Feedback Type and Familiarity with Smart Device do not seems to be influenced by Age either. For Feedback Type, it is understandable as it relies heavily on personal preference. However, for the author, Familiarity with Smart Device is quite a surprise that it is not influenced by Age. The consumer market might have changed to the point that a textbook example of younger people belong in the group of early technology adopter is not as certain anymore.

5.2 Participants’ performance

From our experiment, majority of participants have their brake time increased when they wear our device. Although the increase is statistically significance, it could be explored further on why it help our participants, and why it does not for some participants.

One interesting thing to note is the consistency of some drivers. From Table 2 Raw brake time, the drivers who drive frequently or drive for business such as driver number 2 and 4 tend to have relatively consistence brake time, especially without the device. Those who do not drive as often may have a big swing in their brake time such as number 8 and 11. Even though it seems to relate to drivers experience, it seems to relate more to frequency-wise experience rather than the length-wise experience that we have collected. Since age does not imply any driving frequency, the consistency on both young and old drivers are quite similar.

Also, when we compare device-assisted performance between older and younger drivers, the pattern appears to be the same. Both younger and older participants have increase brake time when they wear the device, and both have relatively similar brake time length. This might mean that the device can provide additional information for both older and younger drivers.

There are, however, some factors that can influence the performance for both groups.

5.2.1 Performance of participants who wear glasses

The participants who wear glasses in the experiment has high correlation coefficient to performance. As seen in Table 3 Average brake time, the participants who wear glasses has an average brake time of 9.96, 10.89, 10.14 for none, sound, and haptic feedback respectively. Compare to the average of the whole group of 9.05, 10.17, and 9.97, the average of participants who wear glasses are roughly 10%, 7%, and 1% higher for none, sound, and haptic feedback respectively.

One explanation for this outcome is that participants who wear glasses drive more carefully compare to the one who do not wear glasses. This is due to the nature of the glasses that require the wearers to focus on their surroundings. Or it could be that the drivers who wear glasses keep their cars tidy, so they can focus on the road.

In the end, it is unclear what the cause of this higher average time is. However, it is still possible to claim that the introduced device in this experiment can help drivers to receive additional environmental feedback.

5.2.2 Performance relates to Age

Age plays a significance role as discussed previously. For performance, Age also have quite an influence on it significantly. According to Table 3 Average brake time, the participants who are older than 40 years has an average brake time of 9.07, 10.73, and 10.18 for none, sound, and haptic feedback respectively. This translates to an increase in brake time approximately 0.2%, 5%, and 2% higher for none, sound, and haptic feedback respectively.

The reason behind this seems to link to driving experience of the drivers, and how sensitive they are to the device. At first glance, this seems to relate to the type of car as it provide different environment and thus may offer better experience for drivers. However, as the correlation on type of car result suggest, type of car does not have as much influence compare to other background. Thus, the influence of Age become more definitive.

The bottom line might be just that, older participants have more experience or familiarity with their driving, so they have a better chance to notice the change when introducing new factor into their cars.

5.2.3 Performance relates to Driving Experience

Very similar to Age, participants who have more Driving Experience tend to have longer brake time. In Table 3 Average brake time, participants who have more than 20 years of Driving Experience recorded an average brake time of 9.14, 10.84, and 10.23 for none, sound, and haptic feedback respectively. Approximately 1% increase for none feedback trial, 6% in sound feedback trail, and 2% in haptic feedback trial, the result very close to that of Age.

This background suggest almost the same message as Age, the longer the experience is, the longer the brake time. This makes a straight forward logical sense that those who are older will spent more time in their lives driving, and thus developed a skill that keep themselves safer. Driving Experience add another point to the same conclusion that the experience can teach drivers to increase the brake time.

From the 3 background discussed above. It is safe to assume general trends that, the more experience one has with driving, the more likely one will drive carefully and take time to prepare to brake. It becomes even clearer as Gender and Familiarity with Smart Device has very low influence toward performance compare to other backgrounds. This is because they carry no indication of the experience of the drivers.

5.2.4 Participants' Improvement from device

When we compare the brake time before and after the device, we found that the brake time increase significantly. However, when we take a closer look and split into groups of older and younger drivers, we found that only the older drivers have their brake time increase significantly, as seen in Table 7 Paired Sample T-Test for sound and haptic against none feedback - Older drivers.

This implies that older drivers were influenced by the device more. The design of additional information channels through sound and haptic can improve elderly drivers' performance, and significantly improve only that group.

The result could come from the fact that older drivers indeed benefits more from additional feedback compare to younger ones as their sensory function starting to deteriorated. When introduced to additional information, they become more aware of the surrounding. Together with their driving experience, they manage to utilize the additional feedback better.

5.3 NASA-TLX

The result of NASA-TLX in this experiment came out relatively neutral. As shown in Table 11 NASA-TLX Statistic description, all of the tasks were rated from 2 to 2.6 in average. This implies that the task load for the device is on the scale of low to medium. In other words, the device introduced in this experiment has low, yet, still noticeable task load. Considering the unpolished design of the prototype, it is understandable that having a sizeable cell phone strap onto one's arm while driving can be quite distracting.

As it may suggest, Frustration is one of the highest rated task for this device. This shows that the participants find the device to be quite annoying at times. From the casual discussion with the participants, we found that the feedback type may feel too similar to cell phones. In other words, it can be said that using the device reminds the participants of their cell phone, and they feel annoyed by that.

On the opposite side, Performance is the lowest rated task. This implies the participants found the device to be easy to complete the task. As the participants only have to wear the device and receive feedback, it is predictable that this will be the result. And when the participants find the task to be easy with the device, we may conclude that the device has been helpful in the eyes of the drivers.

5.4 TAM – Regression Test

From the regression test as shown in Figure 7 TAM result: Attitude and Figure 8 TAM result: Intended Use, we found that two significant factors that influence users' attitude toward this smart wearable device are Perceived Usefulness and Social. This means that the more users learn about the device and its potential, the greater and better their attitude will be towards the device. As this survey was completed right after the concept and the hands-on test were conducted, the enthusiasms were shown in the participants' voice. However, the participants' doubt also soon followed via the question regarding accuracy and feasibility of the whole system. This reflected quite noticeably in Trust factor. But with enough hope, Perceived Usefulness can stand as the most important factor for Attitude.

The other significance factor is Social, or social norm. This means if a person have some concern regarding social norm, they will also have better attitude about the device. This is relatively common as Thailand culture tend to lead people to become group-oriented person. And since driving is an activity that require mutual agreement to share the road together, it is understandable that people who care about others would see the device in positive light.

5.5 Challenges

5.5.1 Environment inside cars

One of the challenge that was discovered during the experiment is that one car may have a very different environment from another. Not only does the type of cars affect driving experience, many other items also provide different feels. Some drivers drive with their windows and radio opened. Some drivers adjust their console very frequently. Some drivers have accessories that may fill the car or dangle around and make noise. Some drivers drive with manual stick. Some car shakes heavily when it is slowing down. All of these items may very likely affect the effectiveness of the smart wearable device. While this is one of the challenge that wearable devices have to overcome, the challenge is even more difficult for device that need installation.

5.5.2 Familiarity with smart device vs watches

In the survey, there is a question that ask if the participant is familiar with smart device. After the NASA-TLX comes in and frustration was rated the highest, the author realize that some participants already have wearable device, a watch. Watches have been a stable wearable device for a long time that everyone might have a chance to wear it at some point in their lives. But as smart device becomes more and more integrated part of the author's life, watches just faded away from the author's recall.

The fact is that, many participants wear watches and developed some familiarity with them. To understand and study on the device that serve very close or even identical purpose, watches should have been another focus on this study.

5.5.3 Time consuming and potentially unsafe experiment

The prototype device in this experiment is relatively primitive, most of the measuring and triggering were done manually, one experiment by one experiment. Along with the risk of conducting the experiment in real public road. These make the experiment to be pretty costly and frankly inefficient. The process to recruit volunteers was also done in groups of small acquaintances. This is to reduce the risk and simplify the information distribution and appointments process.

5.6 Future study

5.6.1 More sensor-based measurement

As discussed, the prototype device used in this experiment requires several manual triggers. If the experiment is set up to record brake time by sensor, the result can be much more accurate. To approach this, one option is to move the experiment from real road to a simulated one. Set up a virtual reality or a simulator so that the participants can test the device without actually driving their cars and risk the accident.

With the change, we may overcome several limitation and further the study into many risky situation such as sudden cut-in or tail gate, which are the leading cause according to the report.

5.6.2 More sophisticated feedback device

As suggested by the participants, the prototype device feel too close to the cell phone which caused some conflicting annoyance. To differentiate itself from cell phone, the smart wearable device must send out a feedback that is unique enough to not confuse it with cell phones. While there are several devices that provide unique feedback, the feedback itself should send clear signal to the drivers while avoid being too annoying in a long term. Customization might be the answer for different users, but at this point, more studies are needed before concluding.

5.6.3 Connect the device to the world

Another doubt and actual limitation of this concept depends heavily on how will the device detect red light or anything worth signaling the feedbacks. With current prototype, the one who decide which and when to send the feedback is the observer. Fortunately, there are many researches that focus on the status of a machine and its surrounding. One of the more popular field currently is a Self-driven car. With the same concept, the device could understand its surrounding and send the feedback to the driver accordingly. The device does not even have to detect the surrounding itself as long as they can fetch the data from a cell phone. To pursuit this, a further study has to be made.

Chapter 6
Conclusion

This study proposed a prototype of a smart wearable device to help increase the brake times at red lights. The device underwent an experimented with a group of 22 volunteers who drove with the device on a route in Chiang Mai to measure if their brake time is affected by the device.

The result is that, on average, participants spend 9.05 seconds to brake their car at red lights without any help from the device. When the device is introduced, the brake time increases to 10.17 seconds with sound feedback trial, and 9.97 seconds with haptic feedback trial. This increases the brake time by 12.39% and 10.19% for sound feedback and haptic feedback respectively. This increase in brake time by approximately one second translates into the distance of 13.89 meters, if the car is going at the speed of 50 kilometres per second.

However, when we split the results of older and younger participants, we found that only the older participants have significant improvement from using the device. From the average brake time of 9.07 seconds to 10.73 seconds for sound feedback trial and 10.19 seconds for haptic feedback trial, resulting in 18.30% and 12.30% increase for sound and haptic feedbacks respectively. We can conclude that the device has greater influence on elderly drivers, as hypothesized.

The participants also took a survey on their demographic data, NASA-TLX, and TAM. We learnt that glass wearing, age, and driving experience have the most influence on brake time. The reason behind them is unclear, but it seems that higher driving experience usually leads to a safer driving style. The NASA-TLX suggests that frustration puts the highest load onto the users. And lastly, perceived usefulness and social norm is the most influential factor on users’ attitude toward smart wearable device.

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APPENDIX

Appendix A: Questionnaire (next page)

แบบสอบถาม - goo.gl/RS1Akz

การใช้อุปกรณ์ Smart Wearable Device (SWD) ช่วยในการขับรถ

ส่วนที่ 1.1: ข้อมูลส่วนตัว

ชื่อ

อายุ

เพศ

○ ชาย
○ หญิง

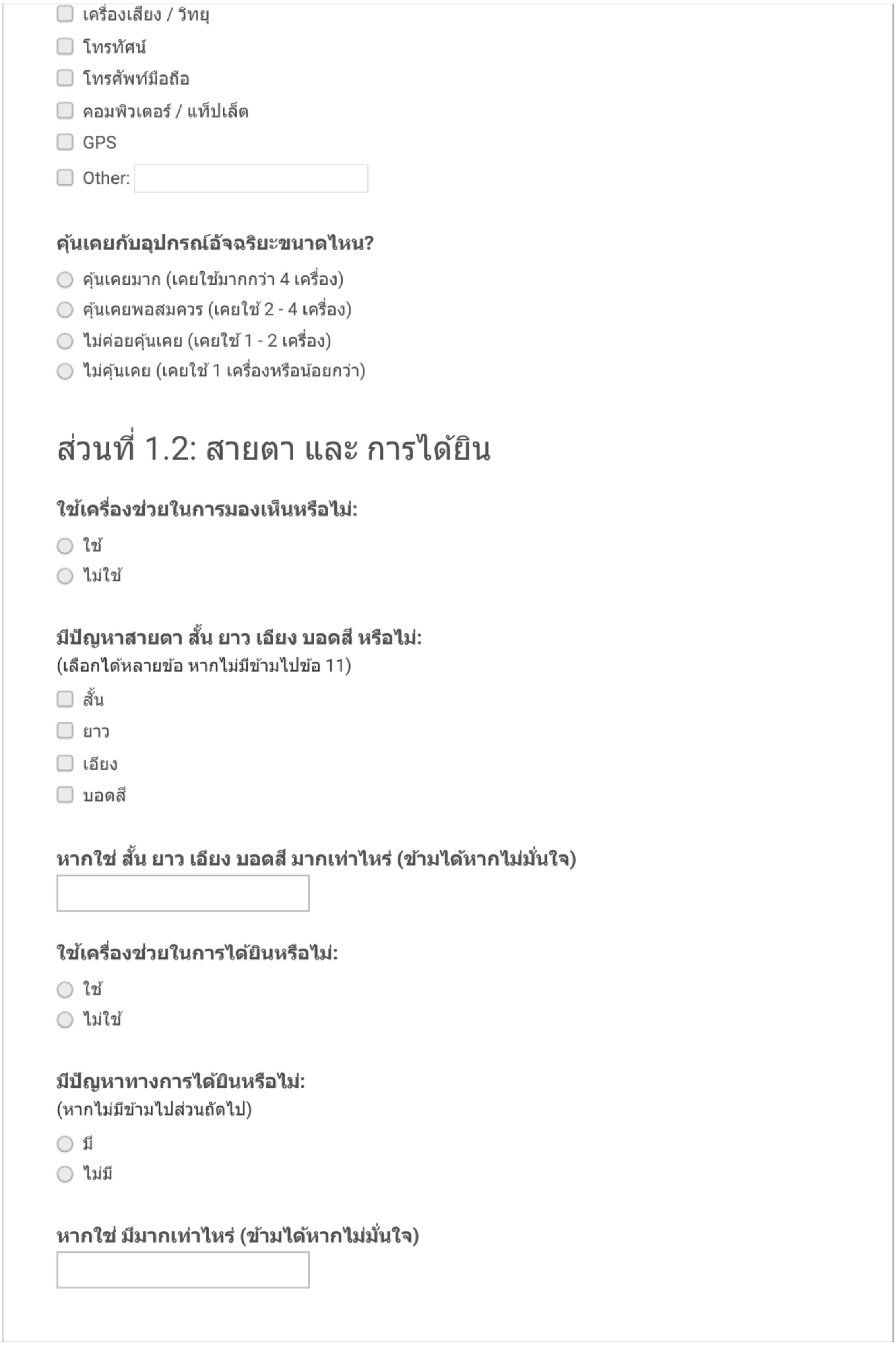
ประสบการ์ณการขับรถยนต์ (จำนวนปี หรือ เดือน)

ประสบการ์ณการขับรถยนต์คันปัจจุบัน (จำนวนปี หรือ เดือน)

ช่วงเวลาที่ขับรถโดยปกติ (เลือกได้มากกว่าหนึ่งข้อ)

☐ เช้า (05:00 - 10:00)
☐ กลางวัน (10:00 - 18:00)
☐ เย็น (18:00 - 05:00)

ระหว่างขับรถใช้อุปกรณ์ด้านล่างหรือไม่? (เลือกได้มากกว่าหนึ่งข้อ)



☐ เครื่องเสียง / วิทยุ

☐ โทรทัศน์

☐ โทรศัพท์มือถือ

☐ คอมพิวเตอร์ / แท็ปเล็ต

☐ GPS

☐ Other:

คุ้นเคยกับอุปกรณ์อัจฉริยะขนาดไหน?

○ คุ้นเคยมาก (เคยใช้มากกว่า 4 เครื่อง)

○ คุ้นเคยพอสมควร (เคยใช้ 2 - 4 เครื่อง)

○ ไม่ค่อยคุ้นเคย (เคยใช้ 1 - 2 เครื่อง)

○ ไม่คุ้นเคย (เคยใช้ 1 เครื่องหรือน้อยกว่า)

ส่วนที่ 1.2: สายตา และ การได้ยิน

ใช้เครื่องช่วยในการมองเห็นหรือไม่:

○ ใช้

○ ไม่ใช้

มีปัญหาสายตา สั้น ยาว เอียง บอดสี หรือไม่:
(เลือกได้หลายข้อ หากไม่มีข้ามไปข้อ 11)

☐ สั้น

☐ ยาว

☐ เอียง

☐ บอดสี

หากใช่ สั้น ยาว เอียง บอดสี มากเท่าไหร่ (ข้ามได้หากไม่มั่นใจ)

ใช้เครื่องช่วยในการได้ยินหรือไม่:

○ ใช้

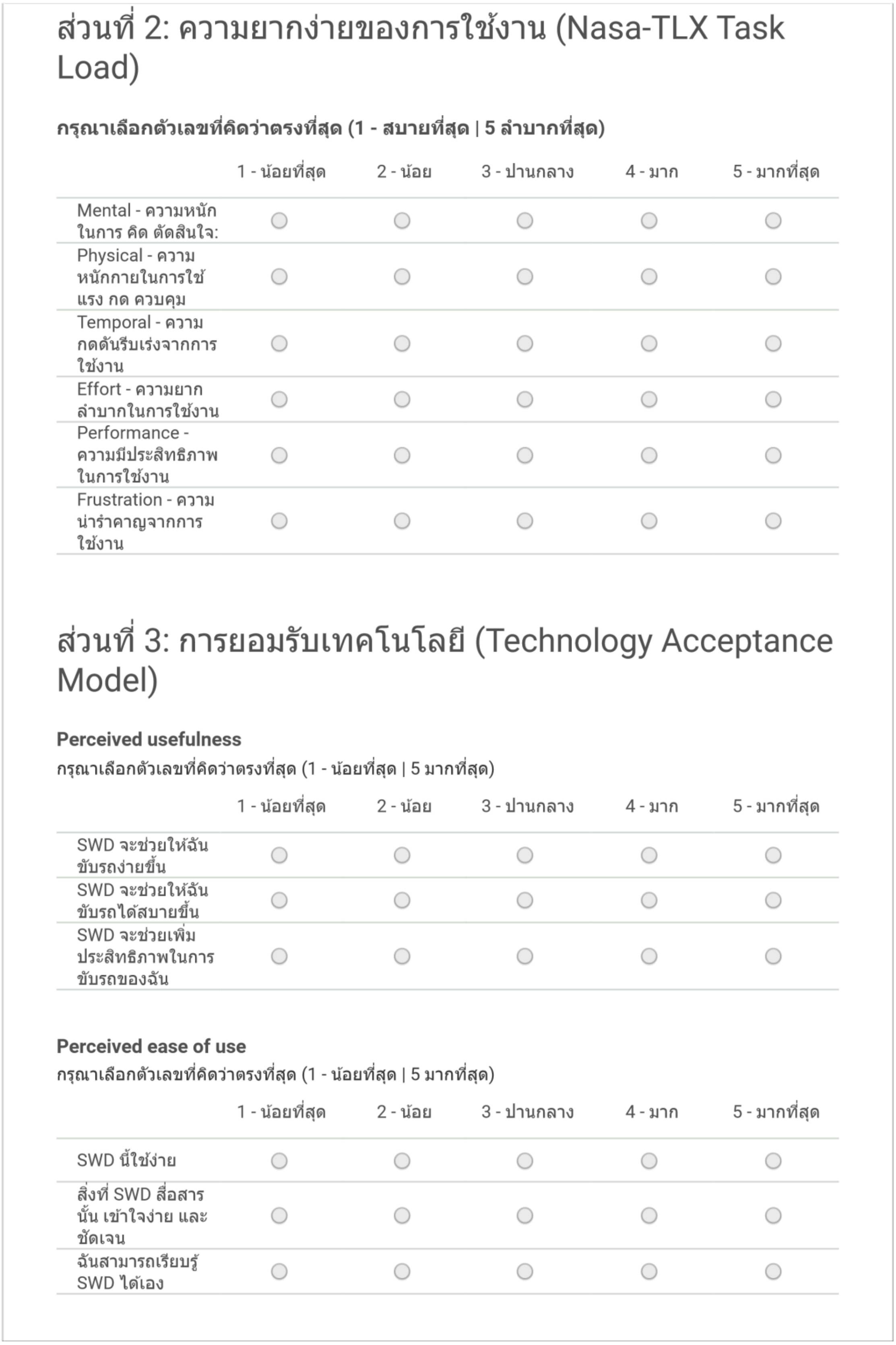
○ ไม่ใช้

มีปัญหาทางการได้ยินหรือไม่:
(หากไม่มีข้ามไปส่วนถัดไป)

○ มี

○ ไม่มี

หากใช่ มีมากเท่าไหร่ (ข้ามได้หากไม่มั่นใจ)



ส่วนที่ 2: ความยากง่ายของการใช้งาน (Nasa-TLX Task Load)

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - สบายที่สุด | 5 ลำบากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
Mental - ความหนักในการ คิด ตัดสินใจ:	○	○	○	○	○
Physical - ความหนักกายในการใช้แรง กด ควบคุม	○	○	○	○	○
Temporal - ความกดดันรีบเร่งจากการใช้งาน	○	○	○	○	○
Effort - ความยากลำบากในการใช้งาน	○	○	○	○	○
Performance - ความมีประสิทธิภาพในการใช้งาน	○	○	○	○	○
Frustration - ความน่ารำคาญจากการใช้งาน	○	○	○	○	○

ส่วนที่ 3: การยอมรับเทคโนโลยี (Technology Acceptance Model)

Perceived usefulness

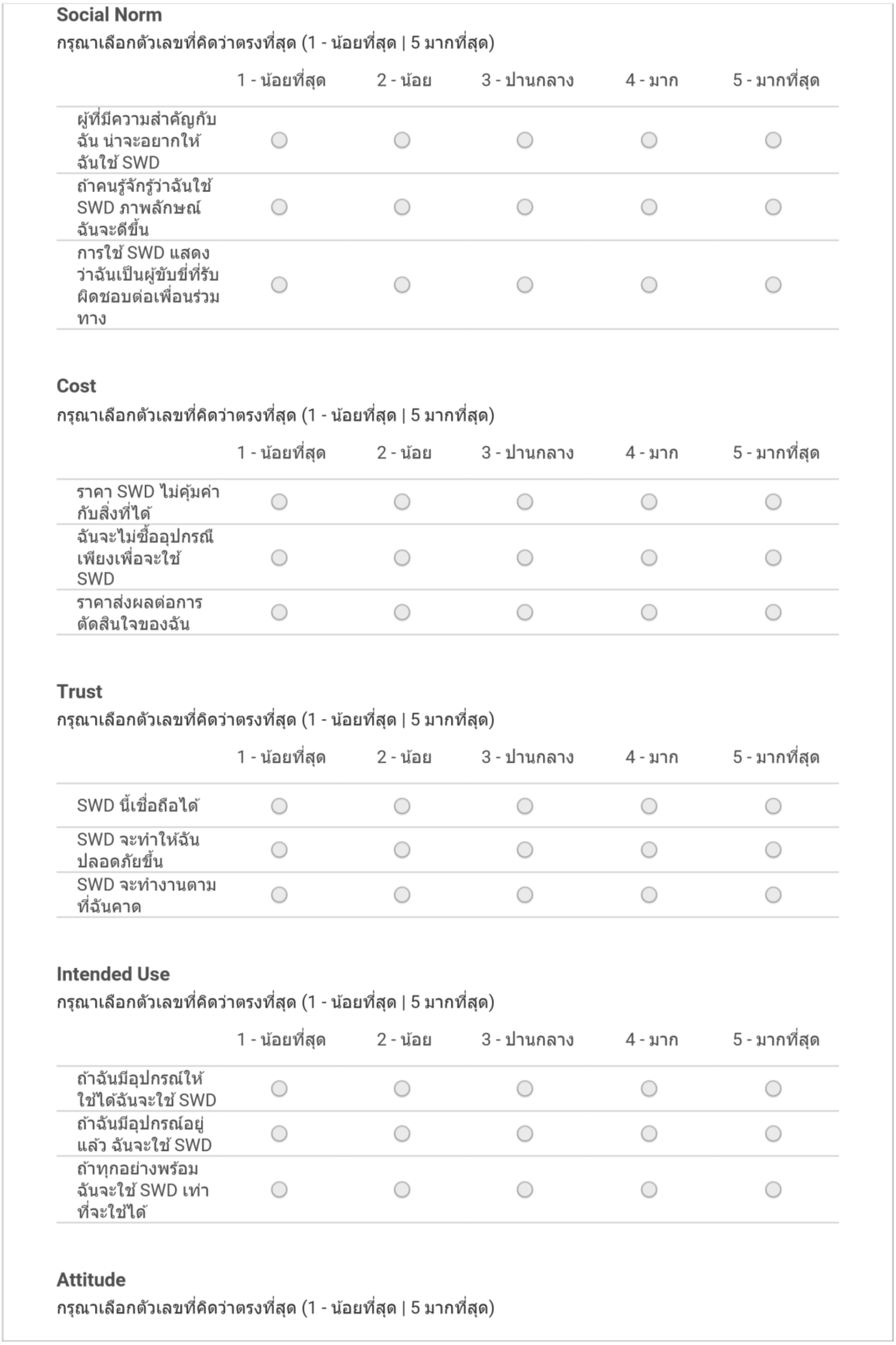
กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
SWD จะช่วยให้ฉันขับรถง่ายขึ้น	○	○	○	○	○
SWD จะช่วยให้ฉันขับรถได้สบายขึ้น	○	○	○	○	○
SWD จะช่วยเพิ่มประสิทธิภาพในการขับรถของฉัน	○	○	○	○	○

Perceived ease of use

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
SWD นี้ใช้ง่าย	○	○	○	○	○
สิ่งที่ SWD สื่อสารนั้น เข้าใจง่าย และชัดเจน	○	○	○	○	○
ฉันสามารถเรียนรู้ SWD ได้เอง	○	○	○	○	○



Social Norm

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
ผู้ที่มีความสำคัญกับฉัน น่าจะอยากให้ฉันใช้ SWD	○	○	○	○	○
ถ้าคนรู้จักรู้ว่าฉันใช้ SWD ภาพลักษณ์ฉันจะดีขึ้น	○	○	○	○	○
การใช้ SWD แสดงว่าฉันเป็นผู้ขับขี่ที่รับผิดชอบต่อเพื่อนร่วมทาง	○	○	○	○	○

Cost

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
ราคา SWD ไม่คุ้มค่ากับสิ่งที่ได้	○	○	○	○	○
ฉันจะไม่ซื้ออุปกรณ์เพียงเพื่อจะใช้ SWD	○	○	○	○	○
ราคาส่งผลต่อการตัดสินใจของฉัน	○	○	○	○	○

Trust

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
SWD นี้เชื่อถือได้	○	○	○	○	○
SWD จะทำให้ฉันปลอดภัยขึ้น	○	○	○	○	○
SWD จะทำงานตามที่ฉันคาด	○	○	○	○	○

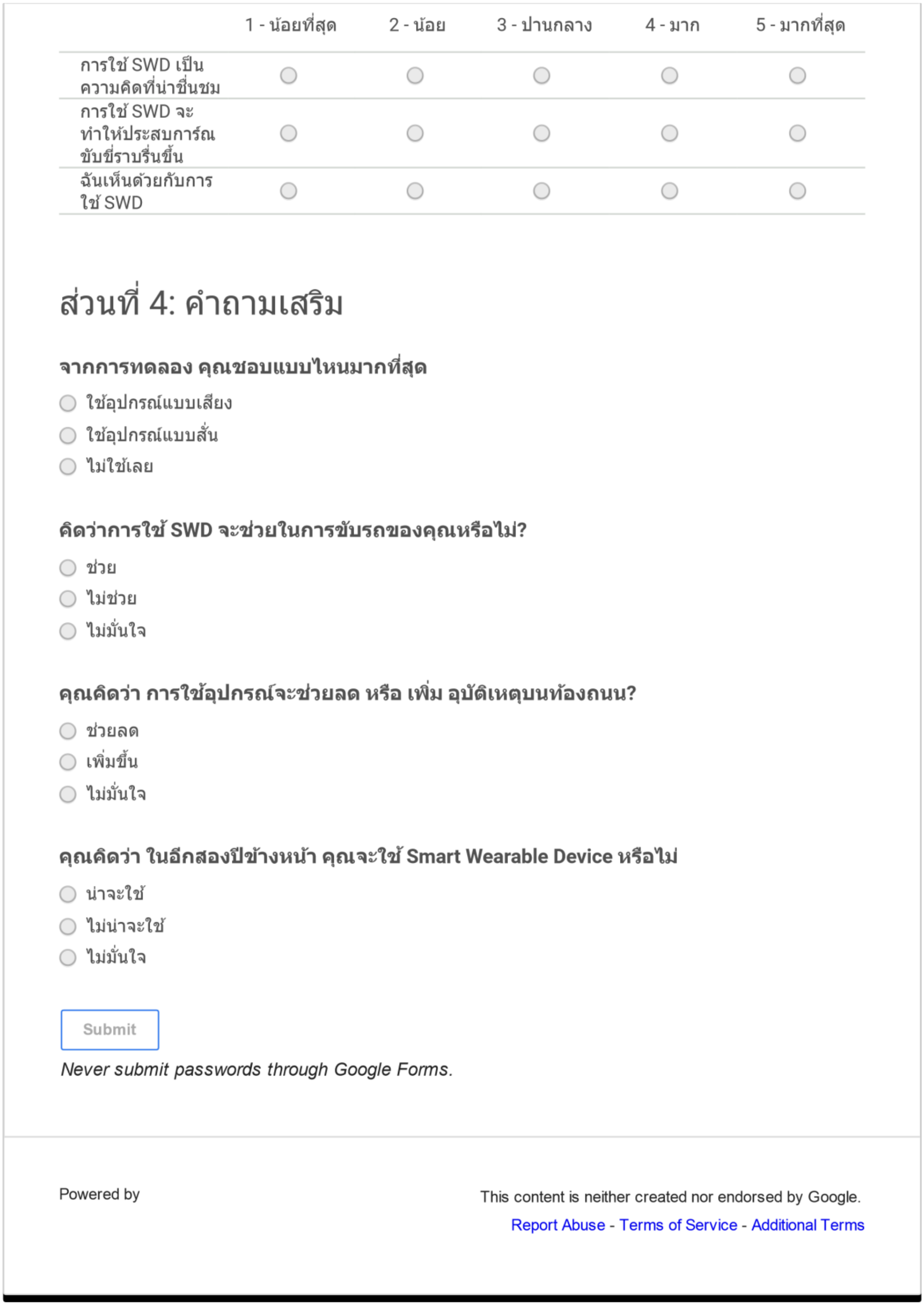
Intended Use

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)

	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
ถ้าฉันมีอุปกรณ์ให้ใช้ได้ฉันจะใช้ SWD	○	○	○	○	○
ถ้าฉันมีอุปกรณ์อยู่แล้ว ฉันจะใช้ SWD	○	○	○	○	○
ถ้าทุกอย่างพร้อม ฉันจะใช้ SWD เท่าที่จะใช้ได้	○	○	○	○	○

Attitude

กรุณาเลือกตัวเลขที่คิดว่าตรงที่สุด (1 - น้อยที่สุด | 5 มากที่สุด)



	1 - น้อยที่สุด	2 - น้อย	3 - ปานกลาง	4 - มาก	5 - มากที่สุด
การใช้ SWD เป็นความคิดที่น่าชื่นชม	○	○	○	○	○
การใช้ SWD จะทำให้ประสบการณ์ขับขี่ราบรื่นขึ้น	○	○	○	○	○
ฉันเห็นด้วยกับการใช้ SWD	○	○	○	○	○

ส่วนที่ 4: คำถามเสริม

จากการทดลอง คุณชอบแบบไหนมากที่สุด

○ ใช้อุปกรณ์แบบเสียง
○ ใช้อุปกรณ์แบบสั่น
○ ไม่ใช้เลย

คิดว่าการใช้ SWD จะช่วยในการขับรถของคุณหรือไม่?

○ ช่วย
○ ไม่ช่วย
○ ไม่มั่นใจ

คุณคิดว่า การใช้อุปกรณ์จะช่วยลด หรือ เพิ่ม อุบัติเหตุบนท้องถนน?

○ ช่วยลด
○ เพิ่มขึ้น
○ ไม่มั่นใจ

คุณคิดว่า ในอีกสองปีข้างหน้า คุณจะใช้ Smart Wearable Device หรือไม่

○ น่าจะใช้
○ ไม่น่าจะใช้
○ ไม่มั่นใจ

Never submit passwords through Google Forms.

VITA

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