Affective Antenna for Screen Quality: A Comparative Autoethnographic Study

Brandon Ables María López-Delgado

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ABSTRACT

The Affective Antenna is a new interaction method connecting heart rate to the brightness of a laptop screen. The user's heart rate acts as an antenna, but instead of adjusting the position of a rabbit ears-style antenna, the user uses breathing techniques to raise or lower their heart rate to achieve the ideal screen brightness for the activity. In this comparative autoethnograpahic study, two researchers tested the Affective Antenna while using their laptop computers for the routine activities of reading or listening to research papers and viewing media on YouTube. One researcher was experienced in mindfulness techniques and more interoceptively aware, the other researcher had little experience with mindfulness techniques and was less interoceptively aware. The researchers were interested in discovering how heart rate represented as screen quality (brightness) in their everyday lives can promote the development/practice of interoceptive awareness through peripheral interaction. The researchers conducted 10 20-minute trials each with the Affective Antenna and wrote notes about their experience in pre- and post-intervention questionnaires. The Affective Antenna was found to help focus and lessen multitasking for the interoceptively experienced researcher and was found to lessen the focus of the less interoceptively experienced researcher.

1 INTRODUCTION

This project was motivated by our experience using technology in the evenings. When watching media or using our phones in the evenings, both researchers found it difficult to relax. Much of our engagement with the media or technology was not mindful as it was filled with multitasking and low self-awareness. Bad habits can form when interacting with media and technology that are tough to break. Some of these habits may be innate to technology use as evidenced by the failure of 3D televisions to become popular. Users of 3D televisions found they were unable to view media on other devices such as tablets or smartphones while wearing the 3D glasses required for the 3D television [1]. The human drive to focus on multiple things at once while trying to relax can be addressed by the Affective Antenna.

Previous studies have been conducted using biofeedback to promote stress and relaxation assistance. Many of these studies used embedded biofeedback where the display of physiological information was attached to an environment. The DeLight system by Yu et al. (2018) used an LED immersive lighting environment that can also be embedded in homes, offices, or hospitals to facilitate biofeedback experiences [2]. Biofeedback has also been embedded in the environment through the controls of a computer game [3]. Frachi et al. (2023) investigated using skin resistance to change the speed of the character in a video game to influence player stress and relaxation levels. Biofeedback has also been embedded in cars for interventions for guided breathing techniques [4]. Paredes et al. (2018) investigated the effectiveness of haptic and voice interventions for guided breathing to reduce stress levels in drivers during commutes. Embedding systems in everyday environments helps users get biofeedback data without interrupting their natural routines. Users don't spend all their time in everyday environments, so non-embedded (portable) options for biofeedback must exist as well to provide mobile biofeedback options.

A non-embedded biofeedback option is using a smartphone-based audio-biofeedback system to improve the balance of users [5]. Franco et al. (2013) created the iBalance system which uses audio-biofeedback (ABF) to provide cues to users about physiological processes, body movements, and postures. Another option for non-embedded biofeedback is EEG sensors, many of which have become available to the consumer market. Rahman et

al. (2020) used portable EEG sensing to diagnose Parkinson's disease in-the-wild. The researchers combined the NeuroSky Mindwave EEG sensing headset with machine learning to investigate the differences between Parkinson's patients and healthy individuals in different emotional states [6]. Choi and Ishii (2020) used a portable biofeedback system worn on the wrist to help regulate heartrate through tactile stimulation. The wearable was called ambienBeat and used tactile beats to lead the user's heart rate into a synchronizing pattern while operating peripherally to a user's primary task and focus [7].

A paper by Al Osman et al. (2014) coined the term Ubiquitous Biofeedback or U-Biofeedback. But Al Osman et al. (2014) do not address the mobility or portability of ubiquitous systems, as their case study is presented in an office environment. To achieve true ubiquity, a user must not be confined to one location within the home or office but should be able to move freely between rooms and other locations, easily access the biofeedback system, and peripherally engage in self-monitoring while focusing elsewhere on a primary task. Many of the non-embedded biofeedback options reviewed above interrupt a user's natural routine too much for true ubiquity to be achieved. The Affective Antenna addresses this gap in the research by attaching biofeedback to a portable device used every day, the laptop computer.

Our research question was: How can heart rate represented as screen quality (brightness) in our everyday lives promote the development/practice of interoceptive awareness through peripheral interaction? Interoceptive Awareness is noticing what one is feeling by tuning into the internal sensations of the body. Peripheral interaction is engaging with interactive systems in the periphery of our attention that are embedded into our routines and environment.

The Affective Antenna will benefit both beginners and more experienced users in their development and practice of interoceptive awareness. As stated above, there is a need for users to be able to develop skills to be aware of their body and mind, particularly when using technology. The Affective Antenna allows for ubiquitous non-emdedded biofeedback through an everyday device to help promote interoceptive awareness, relaxation, and focus. As part of our thematic analysis we identified patterns of contrasting experiences concerning heart rate control, concentration, breathing control, and body awareness. Overall for both the novice and experienced researchers, the Affective Antenna promoted an opportunity to improve and practice interoceptive awareness in relation to heart rate.

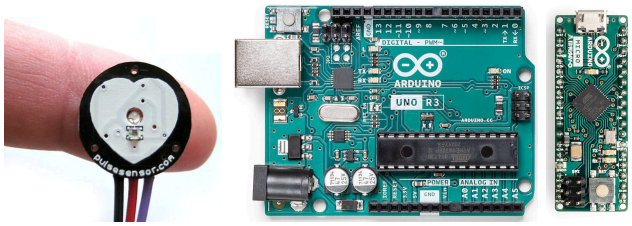

Figure 1: Pulse Sensor, Arduino Uno, and Arduino Micro

2 METHODS

The Affective Antenna consists of a pulse sensor, a 3D printed case with velcro strap, an Arduino Uno, an Ardunio Micro, wires, a secondary computer running the Arduino IDE Software application, and a primary computer an Apple Macbook running macOS High Sierra 10.13 (see Figure 1). The programming of the brightness controls of the laptop screen was done using Max. An external Max object called aka.booklight was found through searching online Max forums and was connected to the heart rate sensors through the Arduinos. The Arduino Uno was directly connected to the pulse sensor and Arduino Software application. The Uno was programmed to output a signal on pin 13 to the Arduino Micro each time the heart rate passed a threshold on the serial plotter. The Arduino Micro was connected to the primary computer and was programmed as a midi instrument, so any input signal would be read as a midi note in Max. Max recognized the midi note input and calculated the space between each input in milliseconds and sorted them into six heart rate zones: 45-59, 60-66, 67-75, 76-85, 86-100, and 101-120 (see Figure 2). A change in the heart rate zone would cause the screen to brighten or dim depending on the task.

To begin each test, researchers sat with their primary laptops and a secondary laptop to change the

threshold of the pulse sensor through editing the programming code in the Arduino IDE Software application (see Appendix B). The researchers first filled out the pre-intervention questionnaire. Some of the questions of the pre-test focused on recording the time of day, starting heart rate, media that was going to be engaged within the test, and computer use time prior to the test. Other pre-intervention questions recorded in this section explored current moods and attitudes towards completing the task (see Figure 3). Then researchers attached a pulse sensor in a 3D printed mount with a velcro strap around their thumb on their non-dominant (left) hands. Researchers then pulled up the serial plotter in the Arduino Software application to gauge the threshold of each heart beat. Thresholds would vary between 500-800 depending on time of day, body temperature, temperature of room, and other unknown factors (see Figure 4).

Heart Rate Zones	Milliseconds Between Heart Beats	Brightness Level of Screen (increase)	Brightness Level of Screen (decrease)
101-120	500-599	10%	100%
86-100	600-699	30%	90%
76-85	700-789	50%	70%
67-75	800-909	70%	50%
60-66	910-1,000	90%	30%
45-59	1,001-1,333	100%	10%

Figure 2: Heart Rate Zone and related Brightness Level Table

Once a steady heart rate was achieved and the threshold was set, the researchers would begin a 20 minute test of the Affective Antenna while reading a research paper, listening to a research paper, or watching media on YouTube. While engaging with different types of media, researchers could tell when there were shifts in heart rate as the screen would brighten or darken depending on the task. The screen would brighten when lower heart rates were achieved when engaging in the reading or listening to research paper tasks to keep the alertness of the researcher while still allowing for relaxation. The screen would darken when lower heart rates were achieved when watching media on YouTube to aid the researchers in feeling more relaxed but still maintaining focus. If the researcher was not successful achieving the desired brightness or dimness level, they would employ deep breathing techniques to lower their heart rates. The deep breathing technique involves slowly inhaling through the nose for three or more seconds, holding your breath for 3 or more seconds, and then exhaling through the mouth for three or more seconds. Deep breathing techniques were also employed if heart rates were too inconsistent and jumping between multiple zones causing rapid changes in brightness levels that were distracting to the task.

Pre-Intervention Questions	Post-Intervention Questions
1. Time of Day: 2. Length of time using computer before test: 3. Type of media engaged with (reading/watching): 4. Describe how you feel about the media being engaged with (e.g. Do you want to be reading this article now?): 5. Describe your current mood: 6. Starting heartrate: 7. Anything else of note:	1. Time of Day: 2. Length of time using computer during test: 3. Did you engage with any other media while testing ?: 4. Did you interact with any people while testing?: 5. How was the experience different from how you usually read/watch? 6. Did you feel you were able to control your HR? Why/How? 7. Did the breathing exercise help you attain the target HR? 8. How aware were you of your heartrate? 9. Describe your current mood: 10. Ending heartrate: 11. Anything else of note:

Figure 3: List of Pre- and Post-Intervention Questions

After each 20-minute trial, the researchers removed the pulse sensors and answered the

post-intervention questionnaires about their experience using the Affective Antenna. The post-test questions centered around multitasking, comparison of interaction with the antenna versus usual consumption of the media, and current mood. Other questions completed in this section were related to heart rate control, the use of breathing exercises, and heart rate awareness. In addition to the qualitative data, the researchers gathered a tally of the amount of times the heart rate hit a zone (see Appendix).

To compare and contrast levels of interoceptive awareness, the researchers conducted a comparative autoethnography. The researchers were interested in how high and low self-reported interoceptively aware people might experience the Affective Antenna. The researchers collected quantitative data such as the tally of heart beats in each heart rate zone, the time of day, type of media consumed, and the brightness mode (low heart rate relating to brightness, or low heart rate related to dimness). The researcher also collected qualitative data in the form of the written responses to the pre and post-test questionnaires. To analyze these experiences, the researchers created inductively coded written responses to generate themes. For each theme, the researchers identified the responses of the interoceptively experienced versus that of the interoceptive novice.

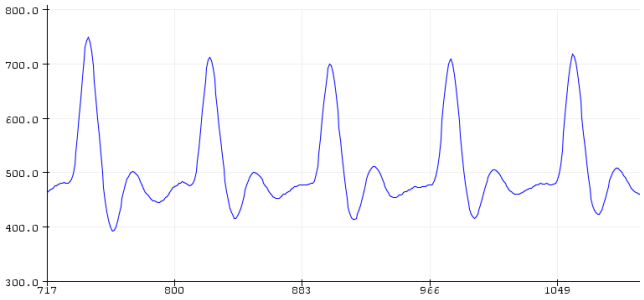

Figure 4: Heart rate from Pulse Sensor through Arduino Uno to Arduino IDE Application's Serial Plotter. For this heart rate signal the threshold would be set at 600, so each time the signal passes above 600, a signal would be sent to the Arduino Micro into Max and sorted into a heart rate zone changing the brightness of the primary laptop screen.

3 RESULTS

The themes identified as part of the inductive analysis help answer the research question proposed for this study. As part of the analysis we also share other interesting findings for this comparative autoethnography. For each theme, a quote from each of the researchers, novice and experienced, is shared. Below the major themes are identified:

Heart Rate Awareness

A major element of this project was interoceptive awareness, in particular heart rate awareness. The journal data was rich in description and allowed us to find pieces of data that show the Affective Antenna allowing the novice researcher to develop a consciousness with regard to the changes in heart rate.

As they stated:
"The variability in brightness helped me be aware of the changes in my heart rate, something I usually do not feel any shifts [in]." (test #5, watching)

The more experienced researcher stated:
"Very aware. Definitely more than usual when using a computer. It is putting my feelings first, like I'm keeping pace with my body rather than rocketing ahead in my mind trying to follow a thought and leaving my body behind. " (test #2, watching)

As shown in the quotes, both the novice and experienced researchers felt that the Affective Antenna helped in being aware of their heart rate thanks to the change in screen brightness.

Heart Rate Control

Another theme that arose from the data regarded control of heart rate. As will be evident from the two quotes, the researchers had contrasting experiences. The novice researcher found it extremely difficult to control the heart rate, mostly because the breathing exercises were not effective.

"It was frustrating that the light was so dark and I do not know how to control my heart rate to make it brighter. Breathing doesn't really help, it just makes very subtle shifts and it doesn't last long." (test #6, listening to paper)

Factors that could produce this outcome were the lack of experience with breathing techniques, and the researcher's wanting to focus on the tasks.

As for the experienced researcher, they had moments of difficulty with the breathing exercises during the first tests or in moments early morning or late at night, but mostly were able to control their heart rate.

“Yes, breathing in through the nose and out through the mouth helped keep my heart rate low.” (test #4, watching)

As mentioned in the experienced researcher’s journal, it felt similar to meditation sessions, they leveraged experience with different techniques from their meditation practices to help become more interceptively aware. Post-use Affective Antenna feelings were said to be similar to post-meditation feelings by the more interoceptively experienced researcher. This was a level of calmness and tranquility not usually associated with reading/listening tasks or media viewing tasks.

Breathing Control

The data also reflected contrasting results regarding experiences with breathing exercises. As demonstrated by the journal quotes the novice researcher could not effectively use the breathing exercises to control the screen brightness, much less be able to control their breathing.

“Tried breathing in deeply, but it made the opposite response, it made the screen darker not brighter.” (test #5, watch)

In contrast, the experienced researcher was able to use their meditation knowledge to practice mindfulness and control their breathing.

“Yes, the deep breathing really helped. I found a good rhythm inhaling through my nose and exhaling through my mouth that was able to maintain lower heart rate levels.” (test # 9, reading)

Once again this theme reflects how the Affective Antenna with breathing exercises can help in the promotion of interaceptive awareness. This enhanced interoceptive awareness occurred only when the proper breathing skills were used as reflected in the data.

Body Movement Awareness

In the journal, the researchers also made notes regarding their bodies. An interesting finding was that although target awareness was related to the heart rate, researchers reported awareness of their body movements. For example, the novice researcher explained that she usually fidgets when listening to a reading, but because fidgeting changes the reading of the sensor…

“[I am] Moving [my] body in order to pay more attention to the screen, also, seeing if this would help increase the brightness, but it is still low.” (test # 4, listening to paper)

In opposition, the experienced researcher mentioned that the Affective Antenna helped with concentration in their body.

“Really more centered in the body on the chair rather than only in the head. ” (test #1, watching)

Again, it is interesting to see how the use of the Affective Antenna helped in not only the awareness of researchers' heart rate but also of general body movements.

Concentration

Another theme that emerged from the findings was concentration. Both researchers had major differences regarding how the Affective Antenna helped or hindered levels of concentration. For the novice, it was complicated to follow the reading when waiting to use breathing exercises to change the screen brightness.

“If I do breathing exercises, my focus shifts too much to the breathing, and [I] cannot concentrate on the task at hand.” (test #6, listening to paper)

In contrast, the experienced researcher found the Affective Antenna to be an excellent tool to concentrate on the task at hand.

"Much more focused. My mind is not flying around to other topics or thinking about what I'm going to do after I watch the video." (test #3, watching)

This contrasting perspective concerning concentration reinforces the idea that the Affective Antenna could be a tool that helps build concentration once the user has developed the right heart rate control and more interoceptive awareness experience.

Reflection

In the researchers' notes, there was also evidence of reflection regarding the tasks and the system. For example, the novice expressed concern in relation to the pulse sensor or health issues.

"The brightness changes so much, I wonder if there is something wrong with my heart or with the sensor." (test #5, watching)

The experienced researcher also shared reflections throughout the journal regarding their experience considering how the changes in screen brightness contributed to interoceptive awareness using the antenna. This quote reflects the latter.

"When the brightness level of the screens would change I take a second to focus on my breathing and consider why the jump in HR occurred." (test # 1, watching)

The data echoed the reflective nature of the Affective Antenna. This type of intervention prompted and allowed both researchers to ponder about the process, contributions, and experience.

Multitasking

One of the key questions and elements the researchers wanted to explore was whether the use of the Affective Antenna also prompted less multitasking. As with most of the other themes, the findings also reflect a contrast of experiences. The novice researcher mentioned in an early day session that they were totally consumed in the media, but regarding a reading, it was the opposite as shown in the following quote.

"Got distracted looked at email, and around the room. I felt the urge to multitask, use phone, fidget and so got distracted answering text message and checking email." (test #7, listening to paper)

The experienced researcher shared in many journal entries how the Affective Antenna system aided in avoiding multitasking. However, in some instances, depending on the time of day, they did multitask. The following quote reflects the first mentioned experience.

"This time I was struck by how this process is stopping my drive to multitask. It is making me focus on just the video and my breath" (test #4, watch)

The findings regarding multitasking are very interesting, and surprising how the time of day and the tasks at hand influenced the practice of multitasking.

Stress Level

As graduate students, the researchers have different levels of stress. As part of the journal prompts, researchers were asked to share their mood before and after each test, to see if the Affective Antenna intervention had any effect. The novice researcher expressed concerns in most of the tests with stress and overwhelming thoughts. An important note regarding the novice researcher was that they were going through a personal loss, and this affected their personal emotional state and academic work. Throughout all the darkness, the Affective Antenna gave the novice researcher a chance to destress and engage in media they enjoyed.

"Stress, hopeless, overwhelmed, but at the same time a bit less stress because while engaging in watching something I enjoy, I was able to think of what I was going to do next." (test #6, watching)

The experienced researcher also shared in a journal entry how the use of the Affective Antenna helped in feeling less stressed.

"It really restricted my multitasking and fluttery thoughts because it gave me something to focus on through the activity. In this way, it might be very beneficial to use when you are trying to focus attention on one task because it limits peripheral distractions and unnecessary movements and does seem to calm me. "(test # 6, listening)

Again, it is interesting to see how the Affective Antenna was able to help prompt a sense of relief in the stress of the participants.

Mental State

Similar to the previous theme, the journal data reflected the mental state of the researchers. With this theme, we want to acknowledge how the use of the Affective Antenna influenced the researchers' mood. The novice researcher shared a sense of anxiety because they could not use their coping mechanism because it would affect the reading of the pulse sensor.

“Reading makes me very anxious, to combat this [I] usually listen to the reading while knitting while listening to a reading, but while completing the test, knitting affected the reading of the sensor. This made me feel very anxious and affected my concentration. ” (test #4, listening to paper)

In contrast, the experienced researcher through most of the journal expressed feeling a sense of relaxation when using the Affective Antenna.

“Very relaxed, like post-meditation. Clear-headed. Want to continue using it. Still very focused and feeling less all over the place mentally. ” (test # 2, watch)

This theme reflects again a contrasting result between novice and experienced. It would be interesting to see in future iterations how using more robust hardware could help with the anxious feeling of the novice researcher, as they would be able to use their coping mechanisms while using the Affective Antenna.

Time of Day

Another interesting theme was how the time of day changed the experience of using the Affective Antenna. The novice researcher shared in their journal how they felt so immersed in the media that they didn’t even take many notes during the test.

“Wanted to keep watching the show, didn’t think about taking notes, fully immersed in watching. I think it is because of the time of day [early morning] and wanting to watch the media. ” (test #3, watching)

The experienced researcher also made a note as to how the time of day may have affected their ability to control their heartbeat.

“Because it is so late at night and I am tired I think my HR is naturally slower. It was easier to keep in the lower regions and trended toward those categories naturally.” (test # 3, watching)

Again, it is interesting to see how the use of the Affective Antenna can be influenced by so many factors including the time of day. Also, how your level of interaceptive awareness does not matter, how it is just part of human nature and each person's habits and disposition.

Quantitative Findings

Our quantitative results are listed in the Appendix of this document. There were too few trials to run statistics on the testing data. Overall trends can be observed that show a general lowering of heart rate while engaging with different media. But as mentioned above, time of day and task-specific baselines need to be documented in order for true quantitative results to be uncovered. We plan to continue documenting our use of the Affective Antenna throughout the summer for this purpose.

4 DISCUSSION

Our results show that the use of the Affective Antenna produced more benefits for the interoceptively experienced researcher, but also benefitted the less intercoceptively experienced researcher as well. Both researchers benefitted from increased heart rate awareness, body movement awareness, reflection, stress level reduction, and time of day. This shows that even a novice at mindfulness techniques can use the Affective Antenna to bring attention to heart rate regulation through breathing exercises while engaging in everyday tasks on a computer. Our research question: How can heart rate represented as screen quality (brightness) in our everyday lives promote the development/practice of interoceptive awareness through peripheral interaction can be answered by the five categories listed below for novices and for all ten categories for users more experienced with mindfulness and interoceptive awareness techniques.

	Interoceptively Experienced Researcher Benefitted	Both Researchers Benefitted	Interoceptive Novice Researcher Benefitted
Heart Rate Awareness	X	X	X
Heart Rate Control	X		
Breathing Control	X		
Body Movement Awareness	X	X	X
Concentration	X		
Reflection	X	X	X
Multitasking	X		
Stress Level	X	X	X
Mental State	X		
Time of Day	X	X	X

Figure 5: Table of qualitative findings.

With any research project, there are limitations. For this research project, a limitation was the robustness of the prototype, in particular that of the heart sensor. Given the limited time and resources, the system used a hardware called Pulse Sensor available on Amazon. The sensor gave the perception to the novice researcher that something was wrong, sometimes even considering if it was broken. The Pulse Sensor was also very sensitive to movement and temperature changes of the body and room throughout the day. As will be discussed in the following section, for future work other hardware will be explored to replace the Pulse Sensor.

Another limitation was not giving the novice researcher scaffolding for learning breathing exercises. Their lack of experience in this regard affected their experience using the device, causing at moments stress and affecting their level of concentration. Another limitation involves varying heart rate levels throughout the day. The researchers only took one baseline test to compare with data from the Affective Antenna collected throughout different hours of the day. For more reliable data to be collected for comparison, baseline heart rates should be collected from every hour to find actual changes from the Affective Antenna. In addition, type of physical activity directly engaged in before using the Affective Antenna could be noted as this might determine a change in ability to control heart rate, for example, if a test was run right after walking from the parking lot to a building on campus.

5 FUTURE WORK AND CONCLUSIONS

For future work, more trials will be carried out incorporating more tasks other than reading/listening and watching media. More locations will also be considered in pursuit of a true non-embedded (portable) Ubiquitous Biofeedback experience. An upgraded sensor, possibly with Bluetooth technology and less invasive body placement, will be helpful to make the interaction more natural and ubiquitous. Standardizing the deep breathing exercises for each user is also of interest in future work.

We also have plans to develop the programming so that if the brightness level is jumping between heart rate zones too often, the screen brightness will be used as a breathing guide to steady the heart and relax the user. In this way, the user could still focus on the task but be peripherally exposed to a breathing guide operating on the screen with increasing brightness as the inhale and decreasing brightness as the exhale. Other programming additions will include tabulating how long users stay in certain heart rate zones, encouraging steady streaks in the user that promote relaxing interactions, and an easy way to track improvement over long-term use of the Affective Antenna. Other potential programming updates might include task-specific features, such as a user being only able to highlight a research article if they are in a certain heart rate zone.

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APPENDIX A - Qualitative Results

Table of Interoceptively Experienced Researcher Results

#	Media	**Time**	**Location**	**45-59**	**60-66**	**67-75**	**76-85**	**86-100**	**101-120**	**Total**	**Threshold**
1	watching	3:52 PM	Home Office	10	10	93	480	610	108	1802	700, 800, 750
2	watching	7:40 PM	Home Office	67	250	601	170	99	85	1653	700, 800
3	watching	9:36 PM	Home Office	271	512	223	63	41	15	1314	650, 600, 750
4	watching	10:42 PM	Home Office	494	490	160	34	35	11	1331	650
5	reading	7:11 AM	Home Office	211	528	416	31	9	8	1266	650, 700
6	Listening to podcast	9:14 AM	Home Office	36	285	830	103	47	23	1464	550, 650
7	Listening to paper	3:31 PM	Home Office	6	23	461	622	115	52	1564	650, 750
8	Listening to paper	6:02 PM	Home Office	19	277	833	144	23	11	1404	550, 650, 600
9	reading	6:34 PM	Home Office	65	303	778	134	38	30	1446	600
10	watching video	8:05 PM	Home Office	26	326	602	113	69	5	1237	600

Table of Interoceptive Novice Researcher Results

#	Media	**Time**	**Location**	**45-59**	**60-66**	**67-75**	**76-85**	**86-100**	**101-120**	**Total**	**Threshold**
1	watching	10:20 pm	home	16	73	273	155	74	29	620	600
2	watching	6:35 am	home	16	51	102	135	229	502	1035	550
3	Listening to paper	7:30 am	home	60	67	181	181	169	289	947	500
4	reading and writing	8:00 am	home	71	131	184	156	176	317	1035	500
5	watching	10:50 am	office	17	56	206	373	290	357	1299	500
6	Listening to paper	11:30 am	office	1	3	10	81	214	55	364	500
7	Listening to paper	3:00 pm	office	6	15	157	753	588	50	1569	550
8	watching	4:20 pm	office	6	15	157	753	588	50	1569	500
9	watching	3:30 pm	home	3	1	1	10	1365	1188	2568	600
10	watching	4:50 pm	home	6	5	27	113	1362	454	1967	600

APPENDIX B - Primary and Secondary Computer Setup