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Master's Thesis

Academic Year 2016

The Kopia Light: Designing for Occupational Stress Coping through Biofeedback Visualization

Keio University Graduate School of Media Design

Jimi Okelana

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

Jimi Okelana

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Abstract of Master's Thesis of Academic Year 2016

The Kopia Light: Designing for Occupational Stress Coping through Biofeedback Visualization

Category: Design

Abstract

Managing occupational stress is a prominent and necessary factor in navigating through the cognitive and emotional challenges of completing a variety of tasks. The Kopia Light is a device that exists in neutral areas of a work environment and offers a supporting coping strategy for stress recovery. It accomplishes this through reading the user's heart rate (HR) and creating a personalized light pattern using rhythmic patterns to assist in maintaining a lowered HR state. This research aims to highlight the importance of dedicated spaces in the working environment for stress intervention and create a positive social norm surrounding the idea of stress recovery using personalized biofeedback interactions.

Keywords:

Visual Entrainment, Heart Rate, Occupational Stress, Stress Recovery, Coping Mechanisms, Biofeedback

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Jimi Okelana

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Chapter 1
Introduction

1.1 Motivation and Background

The awareness of stress in the modern working environment is an apparent factor in the majority of personal experiences.In Japan alone, where this research was conducted, 60 percent of office employees have reported experiencing high to severe stress during work. [19] As a result, many employees tend to seek stress relief throughout their workday as a means of recuperation. The methods of emotional recovery vary between individuals, but are often based around forming negative health habits such as over-consumption of coffee or tobacco use. [4] The Kopia Light (hereafter also referred to as Kopia) is an interactive tabletop device that encourages personalized stress recovery though biometric feedback. The device features a heart rate monitor and an array of light emitting diodes (LEDS) that pulse in a decreasing rhythmic pattern in order to take advantage of the biometric human response that reduces HR in some individuals.

The goal of Kopia is to introduce a new social norm surrounding emotional recovery in the workplace in order to increase positive interactions and work productivity. The following research and evaluation builds an argument for the implementation of interactive environmental objects in order to positively affect emotional behavior change. The final prototype presented in this thesis was created as a variant of the Social Things (ST) concept developed at Keio Media Design in collaboration with the Ericsson User Experience group.The concept of ST represents a shift from Internet of Things (IoT) into more socially and emotionally intelligent devices. One of the key characteristics of ST applied to the Kopia concept is the ability to perform affective computing through simple, light based interactions.

Young employees or higher education students often find themselves working under high-stress conditions without the social support of their peers. The majority of who are often influenced through unhealthy coping habits or activities that do not correlate with emotional recovery as a method of self-induced therapy. These often result in redundant trips to the office kitchen or neutral areas that not curated for emotional refreshment. Besides the obvious escapism issues regarding establishment of such habits, organizations are also faced with challenges to manage a productive workforce. In Japan, young employees are particularly susceptible to being unable to sustain extended working hours and the continually mounting pressures from senior staff. This has resulted in a dwindling full-time workforce and an apprehension to pursuing the salaryman, or company employee, lifestyle. [3] In the most extreme cases, these continually high stress situations have been known to cause fatal physiological conditions resulting in the Japan-specific condition *karoshi* (premature death by heart failure due to stress or overwork). [1]

The goal of this research is to create a dedicated space that builds a new social norm for maintaining stress levels within a manageable range. If the design concept proves applicable, it may help open the conversation for addressing physiological issues to improve workplace conditions.The research conducted in this study hopes to offer evidence of the benefits that come with dedicating space and time within a work place environment for stress recovery. The ultimate goal is to prove that through shaping social norms in an environment, we can decrease stress quantitatively through reduction of elevated heart rate, and qualitatively through positive emotional feedback.

Many people find themselves understanding their need for a break or brief change of surroundings to reset their minds and bodies in order to return to the task at hand with greater efficiency. This is often referred to in projects that address repetitive strain injuries (RSI) and the benefits of building interruptions into interactive design [20]. However, corporations struggle to cater to emotional needs of their employees. This is a common situation in Japan in particular as the concerns for emotional health are rarely taken as the responsibility for the employer.

A clear example of this is the recent implementation of mandatory "Stress

Checks" that were initiated by the Japanese government in December of 2015 [18]. Although a step in the right direction, the culture and social norms that surround the idea of stress do not always translate into positive interactions when using peer based stress analyzation or survey based stress tests. However, both of these methods are often utilized in Japan and abroad with mixed results and can cause the user additional stress due to act of testing.

Many alternative culture companies have taken an unorthodox approach into investing in the workplace environment to offer a variety of working spaces as a means of stress recovery through working style freedoms. One of the most famous examples is that of the Google offices which pride themselves on their individuality in expressing the offices' interior design spaces around the world [28]. In any of these eccentrically designed offices, one is bound to find a table tennis area, bean bags, or an assortment of purposefully-odd furniture arrangements. All of these elements are meant to inspire creativity and individuality, but their direct effects on stress recovery often purposefully avoid a quantitative approach. Many of these companies also utilize their playful image and office perks as a more strategic method of enticing new hires [5]. This angle may provide an initial positive response, but might not give a more holistic view of the emotional atmosphere of an office space at any given time.

As individuals increasingly understand that their mental and physical health is ultimately a personal responsibility, many users have gravitated towards the quantified self approach through fitness tracking devices and wearables. These generally wrist mounted products, offer the user a daily summary of their activity based on motion, steps, and sleep such as the FitBit.[1] This connection between physical activity and management of mental well being is the basis in understanding the physiological impact our workplace has on our overall health. Because users now understand this link, there is an increasing trend of adopting these new technologies. Although these devices are accepted as being able to provide a benchmark towards self-betterment, there has yet to be a product that has broken through the market to initiate the infamous "Tipping Point" [13] effect in

1 http://www.Fitbit.com

self regulated health.

The flatlining trend of activity tracking wearables, and their current waining success, might suggest that solution that users are seeking is not something that should be self deriving. Instead, perhaps more focus should be put on the potential of tapping into a more community driven device or activity. Although future implementation might also incorporate personal activity trackers inputing data, the Kopia Light aims to allow users to experience the benefits of individually catered interactions without additional devices.

1.2 Stress in the Workplace Environment

It is important to understand that stress is a physiological reaction that has its roots in the fight or flight response. The nature of " high-stress " situations are connected to biological responses that are meant to assist people as a survival tool. [8] Unfortunately, modern society may be evolving at a pace that our bodies and minds are still catching up to. This artificial and natural gap in social and work related interactions may be part of understanding the complexities of designing workplaces to maximize positive experiences. Although it is difficult to measure individual responses on a subjective, emotional response level, there has been great headway made through scientific testing advancement on a biological measurement level.

The key components that trigger commands to the adrenal gland to change physiological chemistry are the release of cortisol, oxytocin, and adrenaline that result in various biological changes including an increased heart rate as a reaction to the adrenal hormones. [10] Many other chemical reactions and factors take place in a reaction to stress, however, these represent a consistently tested grouping of stress hormonal changes.

Cortisol acts at the hormone with the most long term impact on recovering from a stressor. Long after an encounter with a stressful situation, many people might feel a reemergence of emotions that come with all of the same physiological feelings that were present at the time of the actual event. The cortisol hormone can be described as the reminder of a close call encounter that creates a chemical chain reaction that causes flashbacks to previous moments. This can result in a chemical and emotional replay of a stressful situation complete with adrenaline surges, increased heart rate, and negative effects on physical recovery through weakening of the immune system.

Research has also shown an interesting application of utilizing cortisol in treating post traumatic stress disorder. It was found that the increased levels injected into patients after facing a traumatic injury greatly reduced the chances of developing negative physiological conditions later on. Patients were also found to recover more quickly and have more positive outlooks on the event, in contrast to those who were not given additional cortisol. Research has also been conducted with similar results when the hormone was administered before a potentially dramatic event.

In the complex reactions that occur during exposure to a stressor, the oxytocin hormone plays the role in direct response to the physiological response the individual has to a situation. In the presence of a situation where a person feels a social connection, the hormone rewards them positive feelings that encourage extension of the interaction. However, in the opposite situation where an individual finds themselves in a critical or negatively impacting situation, the same hormone modulates emotions to trigger the flight response [15].This biological-driven, growing body of research suggests that the perception of stress as positive or negative plays an important role in the balance and response to stress triggered hormones [12].

1.3 Occupational Stress Coping Behavior

A growing body of work in understanding our emotional response to how our bodies and minds react to stress put an increasing amount of focus on how stressors are perceived. Ideas rooted in positive psychology have suggest that the negative impacts of stress are greatly subjective in regards to their effect on physiological conditions.In the case illustrated by Crum, [9] two groups exposed to the same stressor showed vastly different levels of hormonal response depending on whether or not they were primed with positive or negative mindsets. In Crum's test, the group that was told about stress being a naturally positive reaction to a challenge performed better during testing and felt better afterward. While the contrasting group went into the experiment primed with the idea of stress as unhealthy and hamper of performance came out with negatively reflecting results.

1.3.1 Social Entrainment

The basis of social entrainment reflects that the space and social community that an individual occupies can unconsciously alter their cognitive and social functions affecting their ability to thrive in a group setting. Therefore going on to suggest that the impressions of people around us as a group have a great impact on our emotional thermometer in regards to how to react. Simply put, it is the difference between a boss saying , " We have to make sure this is absolutely flawless by tomorrow, no mistakes! " or the similar message of, " Take your time to complete the task the first time so we have less to do tomorrow " .

Social entrainment is a phenomenon within groups of people that causes them to react to each other on a physiological level in order to establish a peer connection. This is argued to be derived from hunter-gather societies where the strength of the pack depended greatly on their ability to adapt to the group's strengths and weakness. The modern version of this can be seen in its negative form in the spontaneous creation of the mob mentality, or its positive counterpart as the empathy-driven emotional surge that makes ordinary people lift a car off of someone. [14] These survivalist situations illustrate the extreme nature of group driven actions, however, they require an individually derived catalyst that sets off the chain of events. This is best described through the environmental impact of a person's psyche over both short and long term periods.

1.3.2 Social Embodiment

In office environments, social embodiment can account for a multitude of stress coping social norms with that are triggered by both positive and negative interactions. This theoretical approach states that the decision making process for thought, feeling, and emotional inclination is directly influence by the physical space of occupation. [17] In a typical office environment, the effects of negative social embodiment can be identified through occupational stress that results from lack of control of a personal space, or poor lighting conditions that may lead to eye strain and physical discomfort.

The challenge in encouraging positive coping behavior in stressed individuals is creating the motivation to positively self-regulate their emotional states. Even if opportunities to engage in social or emotionally positive interactions are presented, their effectiveness in enticing the user to action is often varied in results. One of the leading causes of this, as suggested by Dan Ariely in his writings on irrational behavior studies, is the fact that in order to participate with full cognitive reasoning, a person needs to be in a stable emotional state [2].

An additional area of discussion with extensive research surrounds the area of spacial design in order to optimize productive social interventions. Interior designs of collaborative workspaces such as Pixar studio pride themselves in a workspace, initiated by Steve Jobs, that creates "inadvertent encounters" as a method of fostering chance encounters that are noted to be a crucial element to creative freedom. [6] A similar discussion of the importance of utilizing space to encourage socially based interruptions to positively manipulate emotional atmosphere can also be found in the study of proxemics. Led in the late 1960s by anthropologist Edward Hall, these studies of interaction boundaries as they relate to emotional states [11] offer insight into the instinctive nature of people and their surroundings.Through the incorporation of research supporting socially driven behavioral change, and the methodology of the design driven approach, Kopia combines proven results with accessible technology to provide a unique solution to stress recovery.

Chapter 2
Related Works

In the pursuit of proposing a solution to stress recovery in the workplace, this research looks at the benefits of affective computing as a means of creating new social norms in self-regulated and serendipitous interactions. Through the psychological understanding of coping with stress, it has been stated that individuals are more likely to communicate their personal information with computers as opposed to traditional human-based therapy. A simple example of this in modern society can be drawn to the thriving medical website WebMD.com[1]. This is largely due to the fact that scheduling for such professional counseling and an aversion to peer judgment is an undesirable option in dealing with stress. It can also be argued that stressful situations may need to be defused in the immediate vicinity without making a prearrangement. The anonymity and self-initiated interaction of affective computing systems offers a convenient and neutral positioning for approaching assisted emotional change. As discussed in Picard's presentation in machine learning, the better the environment understands you, the more it can display emotional intelligence in adapting to your needs [23].

2.1 Regulating Stress Through Affective Computing

Technology has continued to provide generations with new opportunities to utilize methods of communication as a source of social connection. In the current age

1 http://webmd.com

of IoT, it is now easier than ever to connect via low cost, high quality hardware and software. These trends can be seen from social media applications running on smart devices, to open source hardware allowing for unprecedented levels of user customization. However, the next iteration of interaction is hinting towards models that reflect conversations and exchange-based experiences, in contrast to command prompt input/output and information curation.

This research and the design of the Kopia Light encourages redefining the interpretation of a connected object. Instead of the idea of connected devices being associated with access to the internet, Kopia proposes that the idea of a connected object means that it can communicate on a biometric level to its user. In order to create a human experience that is built upon a certain level of dependency between user and object, a blend of visual triggers are incorporated.

Over the last few years, collection of biometric data in order to build personal snapshots of individual activity has created a new arena for interactive experiences. Most of these solutions focus on health and wellness in relation to physical movement, such as steps or movement during sleep. However, recent research suggests that data retrieved from HR may provide insight into emotional activity patterns which can be used to affect environmental stressors. The appeal of utilizing HR as a measure of emotional state stems from the variety of cheap and accessible technologies that are able to retrieve the data.

The COGCAM, [16] an abbreviation of Cognitive Stress Camera, proposes a unique take on capturing biometric data in the form of heart and breathing rate through utilization of a digital camera. The motivation for this research arose from the need for non-intrusive monitoring of physiological states in order to capture data that gives insight into the stress state of the subject. One of the key drivers in the potential usage of this technology is the lack of any sensors connected to the individual. The goal of this system is to allow for uninterrupted activity without the need for the user to adapt to attached sensors or be actively aware of data capture. The researchers also noted that through utilization of this system, the subject is less likely to distort data with false stress readings that may be associated with smile detection or other manipulations of stress free activity. Through capturing the subtle fluctuations in images that correlate with breathing and heart rate, a more definitive understanding of cognitive stressors can be identified. Through understanding of these points, the researchers then utilized their live readings to alter tasks given to the subjects to induce or reduce stress appropriately.

It is also stated within the research that the ten participants in the study where of lighter skin pigmentation in controlled lighting conditions. Variations in skin tone and environmental lighting may also prove to be a challenge for image based technology. The utilization of a camera which compares images and has the ability to store this data may deter some users and stakeholders depending on the environment of intergration. Skepticism to camera based recording may infringe on feelings of personal privacy between users, creating additional stress or hamper adoption of the technology due to liability concerns.

Another unique approach to using biometric patterns is through direct manipulation of stress response through known affective means. The Doppel Watch[2] uses a self-induced method that takes advantage of the HR rhythmic syncing phenomenon by replicating a slow or fast HR pulse through vibration on the user's wrists. This novel approach to haptic based feedback creates an on-demand option for mood alternating behavior on a personal level. In contrast to the activity tracker based wearables, the Doppel Watch proposes another level above simply recording biometric data by offering the possibility to change mood or mental states. This intimate interaction has the potential to create positive reactions to stress and cognitive results pending that the interaction is rich enough to sustain long term use. It is clear that the subtlety of the stimulation is an attractive part of the experience, and may entice social interaction through common interest. However the challenge of manual initiation may be counterproductive as the anticipation before use could create a usage pattern that is reflective of an addictive stimulus response and may become desensitizing. In designing repetitive interactions, variation of stimuli and haptic input might be advantageous in creating consistent responses.

2 http://www.doppel.london/

2.2 Integration of Personal Data Logging

The rise in IoT and affordable technologies in recent years have contributed to the increased interest in products that offer a sense of quantified self (QS) and a customizable interface. This accessibility and social norm shift of logging and comparing personal data sets such as steps taken, or average HR allows for more involved interactive experiences. Through demystification of the idea of data gathering devices, individuals are now able to grasp the concepts of responsive environments and make the appropriate adjustments whether internally or externally. How this information is attained is still part of a larger discussion that faces many social and technological barriers.

The Medical Mirror [24] (also referred to as the CardioCam) is a system that has taken these issues into account through its unique execution. The CardioCam allows for data logging and monitoring of heart rate through its concealed mounting behind a mirrored display installed in the home. The driving factor behind this project is to suggest a method of daily interaction with a familiar artifact through casual encounters, all within the routine of home living. The core element of this tracking research is to make the practice of recording personal biometric information seamless and convenient. The mirror captures multiple images of the user and filters out specific wave lengths of color which it measures the fluctuations of to determine a user's HR.

The hidden camera element adds to its value through a high quality finish of the display without the uncomfortable sight of a camera. This attention to detail in the final form of the object helps convey to the user a sense of quality and refinement that eases the interaction. The data is also gathered in a private setting which reinforces the notion that the information is being used for personal use. Although not specified, the system seems to be focusing on a local network without internet connectivity. Having the system function offline allows for greater assurance of personal data security, greatly reducing the risk of data theft or manipulation. Through the power of information, the Medical Mirror aims to induce change in the user by allowing them to become more aware of their HR values. Therefore shifting the responsibility for action onto the individual to make their own interpretation.

2.3 Qualitative Self for Behavioral Intervention

Finding the most appropriate way to process and deliver large amounts of personal data over a long period of time poses a unique challenge for researchers as well as participants in studies. Perceived insight into activities such as sleep quality and social activity do not always translate into positive experiences or changes in behavior. Research conducted in 2015 at the Keio University Graduate School of Media Design (KMD), with fellow colleagues A. Salikova, X. Lang, and Z. Chen, showed feedback from current commercial QS products (See Figure 2.1) proved to support this fact through user feedback showing lack of comprehension of data sets. Another example can be found through the research of The HealthAware [25] system. Through the application of this advice based affective computing application, the researchers found that simply informing users of their activity was not enough to cause an immediate change in daily routine in relation to stress management.

Figure 2.1: App interfaces of Fitbit, Jawbone, and Sony Lifelog

In the case of stress management, calculating the quantitative success of triggers for behavioral interventions can also be challenging to validate. This can be said to be the result of limits in the evaluation process, that are generally achieved through qualitative means via feedback based data without utilization of heart rate or other biometric tracking.The HealthAware system provides and outlines a series of calculated interventions during the actual cognitive stress tasks in order to promote a better understanding of personal health and wellness in relation to sleep, diet, and physical activity. The aim of this project was to monitor each of these areas of health through a wearable device and application in order to encourage positive behavioral change. This triangulation of multiple data sets has the potential to create more detailed insight into qualitative change through quantitative measurement.The scheduled interventions were based on performance over the testing period and were delivered as alerts or notifications on a desktop application during work periods. This approach follows findings of planned periodical interruptions in order to promote a change of mental state and improve cognitive stress levels.

2.4 Building Positive Emotional Atmospheres

Examples of the curation of emotion triggering environments are often found in the rooted in discipline of interactive art and design. Due to the often subjective interpretations of altered spaces, and the necessity for full immersion, it is difficult to reproduce viable results in a lab setting. However, a growing body of research that has expanded into the commercial world shows great potential in the arena of emotional space design. One such interactive experience is the work ”Waveforming: Distillery” by artist George Poonhkin Khut. [22] The installation piece touches on many important points in the user focused process of interpreting and manipulating personal biometric data in a visual form. The transfer of the user's own heart rate into an app based interactive display directly initiates the sense of concentrated embodiment that is at the core of the QS experience.

In contrast to the individual experience, the research based analyzation conducted by the Philips Corporation through the Centre for Performance at Work [26] focuses on a more objective approach for catering to a generalized population experience. The work reviewed in this study helps to prove an increasing interest by large companies to invest in creating working environments catered to employee well-being. Through the study, the lighting of a workplace is stated to be a crucial step in a holistic approach to creating an atmosphere better suited for encouraging positive interaction within a space that has the potential to be high stress. The Philips Corporation also reflects on the motivations of individuals from various levels of responsibility in a tiered working environment and how mental states and perceptions of personal and public environments actively influence perceived levels of stress.

Because of the scalability of introducing catered lighting experiences on multiple scales, the article suggest the benefits of allowing for individually adjustable lighting spaces that cater to the needs of a specific user. This practice has been shown to not only increase productivity, but also relieve perceived stressors through allowing users to reclaim control of their environment.

Although the research takes a wide-angle view of the implications of lighting as an important factor of affecting emotional atmosphere, the details of space curation specifically for relaxation or replenishment of ego depletion were yet to be explored. This persistence of space design to increase productivity is clearly an underlying motive of corporate interest which may fundamentally detract from offering more qualitative experiences that are important to establishing lasting affects in company culture.

Another approach to manipulating environmental space for initiating emotional temperature change is to create an ad-hoc solution to integrating interventional experiences into standard work flow. The implementation of the Happiness Counter [27] research into the occupational environment explored a both affective and intriguing system to directly influence human and human computer interaction through a method of social entrainment. This novel application encouraged the forced interaction of smiling to trigger a physiological response in users through a simple, scalable system. The trigger was designed to build up a habitual response through interface design in the hopes of leading to a more wholesome social experience.

2.5 Contribution of this Research

The goal of this research is to create a qualitative experience for occupational stress recovery utilizing affective computing to provide a personalized experience. This will be successfully accomplished through passively suggesting workplace interventions through positive, personal interactions integrating both visual and focus-inducing triggers. In order to offer an attractive solution for both individual and corporate stakeholders, the project's aim is to provide solutions for identifying trends and usage patterns to better understand emotional atmosphere.

A key factor in accomplishing this is to offer multiple levels of inclusion through stress recovery interactions in order to reduce the negative feedback of forced interaction. The concept will focus on initiating human to device communication, through transfer and affective computation of biometric data in the form of heart rate. Success will be measured through the user based feedback of its viability for establishment of new social norms for personal stress recovery in the workplace on a personal and commercial level.

Chapter 3
The Kopia Light

The Kopia Light is an interactive heart rate visualization device that creates an enriching experience for occupational stress recovery within social norms. The design concept aims to prove the value addition of creating personally curated environments for stress coping behaviors can positively add to workplace experience. The prototype developed, as well as research through user focused ethnography, led to the discovery of the necessity to establish new coping social norms within the modern workplace. In this research, stress level is directly correlated with comparative measurements in HR as they relate to resting and agitated states. The final prototype was used to gauge the effectiveness of multiple light patterns as they relate to the user's perceived stress levels and those reflected quantitatively through actually HR count.

The application of personal biometric data in the interactive process also aims to better understand the degree of personal information people are willing to contribute in exchange for a catered experience. The HR measurements are also recorded in the experimentation process to compare perceived and actual stress levels to aid in the design process. The setting of a high-stress, semi-public environment was decided with the intention to take advantage of a community ecosystem with pre-established social norms around stress coping habits. Research and testing of the prototype was completed with participants from Keio University Graduate School of Media Design (KMD) during the 2016 thesis submission period. The core group of participants were made up of ten students (five male and five female) who were shadowed, interviewed, and used during development and experimentation of the final prototype. The results of the research and concept design are covered in the evaluation chapter.

The design challenges discussed in this chapter will highlight the considerations made in utilizing Kopia as an effective solution in behavioral triggers in stress recovery through environmental manipulation. The discussion will cover the ideation process and resulting prototype used in the evaluation of the concept.

3.1 Design Concept

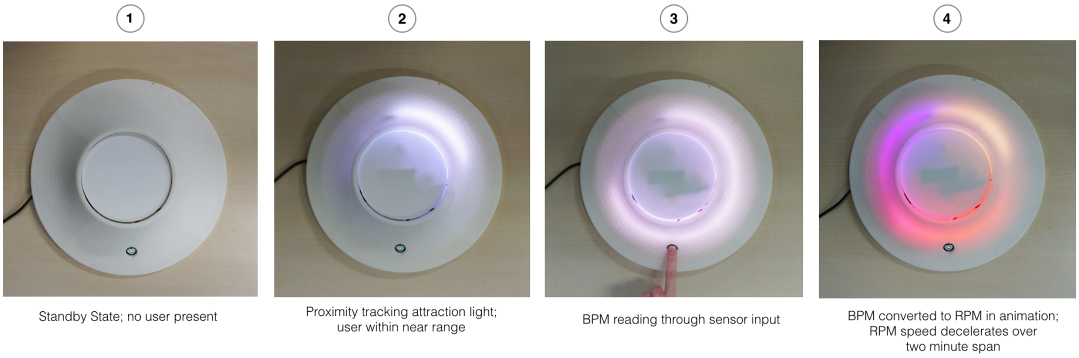

Figure 3.1: Kopia Light user interaction flow

The Kopia concept uses personalized interactions based on rotating, rhythmic light patterns that focus on assisting the deceleration of HR. The goal of the interactive experience is to engage users in a self initiated intervention that is supplemented through provision of a curated space. The intimacy of the interaction aims to allow for a meditative-like focus for a limited period of time. The appeal of a personalized experience through HR at the moment of interaction aims to incite repeat engagement through offering a different experience every time. The rhythmic light patterns purposefully vary in color and movement depending on the HR input. The goal is to offer the most appropriate experience for affecting a positive emotional response and allow the user to enjoy the randomness of the visual interaction without dwelling on previous stressors.

The expectation of this interaction is a more stable and lower HR than what is normally attainable through traditional coping methods. Therefore giving the user a feeling of calmness after or before a stressful encounter. Through providing a space for users to feel comfortable to engage in this practice within the workspace, it is also expected that the social norms around interval "stress breaks" could become more socially acceptable should the prototype be installed in that area. After engaging in the interaction, the rhythmic pattern will last approximately three minutes after reading the initial input.

As a person approaches the Kopia Interactive Light mounted on a standing table, proximity sensors indicate that someone is within interactive rage. At that point, Kopia entices the user interaction by pulsing a neutral warm white light in the direction of their location. Once the person decides to input their own HR data to initiate the light animation sequence, their HR calculation process is displayed through the completion of a white illuminated ring. Upon completion of the HR reading, they are provided with a customized rhythmic light display to visually interact with throughout the session. The initial pace of the sequence depends on the HR value. A higher HR would require a quicker deceleration with shorter transitional intervals to reach an HR resting state slight below the average resting state. A lower initial HR input also lasts for the complete three minutes with slower transitions of deceleration speed.

The thought process behind providing an experience of stress recovery is based on a combination of multiple concepts in regaining cognitive efficiency and initiating biological triggers for hormonal based emotional change.

Over repeated use of the Kopia Light over a span of time, shifts in behavior response and social norms are expected to change in the following ways.

- Healthier attitude towards stress coping behaviors
- Decrease in resting HR through rhythmic visual entrainment
- Positive perception of emotional intervention
- Reduced anxiety during stress recovery session

In creating a curated experience that is able to satisfy the previous points, a comprehensive analysis of individuals in the working community of the Kopia Light was crucial to the success rate. Although some generalizations may be applied across multiple workspaces, unique time schedules and people traffic flow will have an influence on the effectiveness of the installation.

3.2 Understanding the User

The initial the implementation of the Kopia concept was to create an object that increased social emotional awareness, while offering a personalize experience for stress recovery. The decision for testing in an academic environment was made after consideration of working with a diverse group of people who are open to utilization of technology in the context of affective computing. In order to better understand the social norms and stress coping habits of this group, multiple observations and direct conversations where held to build ideal personas discussed later in this chapter.

Current coping practices for stress in the workplace such as drink or snack breaks, and socialization during lunch periods are well understood and accepted standards in most workplaces. During this study, the experimentation and user testing was conducted at Keio University Graduate School of Media Design (hereafter referred to as KMD) in Yokohama, Japan.[1] This location was chosen for the unique situation of international graduate students in a new cultural setting undergoing the stressors of both work based deadlines and socially related interaction. Additionally, the similar work flow patterns between students in a shared space often resulted in grouping of coping habits leading to greater insight into behavioral change and adaptation.

3.3 Observational Research

Observational research was conducted during the 2016 spring semester at KMD, an internationally focused private graduate school based in Yokohama, Japan at Keio University Hiyoshi Campus. The school's two main areas of shared student workspace were identified as the areas of greatest student concentration. The

1 Keio University Graduate School of Media Design http://www.kmd.keio.ac.jp/

workspaces were commonly referred to as the Hacking Studio (HS) and the Project Room (PR) and separated by key entry doors dividing the space by north and south wings. Due to the unique facilities and limited space of each room, a natural social segregation of students was observed and used to identify two characteristic groups within the school. Through analyzation of the movement patterns of over sixty students, it was discovered that first year students tended to utilize the PR while second year students predominantly worked in the HS or off-campus. In order to get a better understanding of the motivations and daily schedules of the two groups, two students (described as students A and B) were shadowed throughout a period of three hours each on an active weekday.

3.3.1 Motivators for Coping Actions

In order to better understand the focus group within the KMD work place, two students were observed with permission during group meeting sessions and interviewed later in the day. In the following paragraphs they are addressed as Student A and B.

Student A had been enrolled at KMD for two semesters, and it was noted that their preferred workspace was the PR, reflecting accurately on the previous observations made on group activity. They were more subjected to social stressors due to working in a new environment with unfamiliar peers, as well as forced interaction from team based assignments. Although the majority of encounters that they deemed stressful arose from working within the group, they rarely took breaks alone. Instead, the group would often interrupt their workflow to mentally reset themselves in pairs of at least two people.

Besides getting lunch, student A would engage in trips to the convenient store located within the KMD facility and smoke cigarettes. During the time of observation of over four hours, the student made one trip to the convenient store to buy coffee and smoked three cigarettes. The initiation to go to the convenient store was made by the student, however in three out of four cases regarding smoking, the interruption was triggered by a peer.

The most insightful behavior noticed during the observation of Student A was the socially driven stress coping mechanism of smoking cigarettes. Through analyzing the activity, many key points were noted in the usage of time, verbal socialization, and non-verbal communication surrounding the artifact of the cigarette itself, as well as the usage of the smoking room. The utilization of the multiple tools to engage in the coping behavior empowered the student to both socially initiate the activity by verbally offering companionship, as well as give them a sense of reward based purpose in interrupting their own stress elevating work. In later interview-based feedback it was also noted that the borrowing of lighters and cigarettes helped to bridge social interactions with like-minded users.

Student B in the HS preferred a balance of working off and on campus was comfortable with their social interactions and felt that deadlines and presentations were a stronger stressor due to thesis submission deadlines. Because the student had spent over a year in the KMD program, they were confident in their working patterns and socially adept within their support group of peers. Due to the nature of their work being predominately independent, the majority of the time that they spent in the shared space was without social interaction. During small break periods, Student B was just as likely to leave the space on their own as they were to invite another peer. However, during lunch and dinner periods, the group was observed to travel together.

Although Students A and B worked in separate rooms, all of the coping behavior spaces, including the convenient store and smoking room, were shared facilities. Both groups were more likely to spend their break periods outside of their workspace, while time to return to work would vary between ten to twenty minutes. Regardless of the main trigger of their stressor, it was clear to see that social inclusion and a shared, familiar activity was a great motivating factor in response to stress recovery.

3.3.2 Identifying Stress Coping Norms

Although the predictions made around typical stress recovery social norms tend to be true across workplace environments, for the purpose of this research it was important to establish those among KMD students. In addition to the previous observationally based research, a survey of over 100 students and professionals was conducted in order to understand both actual and perceived occupational stress

1. Person begins feeling frustration during work
2. Contemplates coping options, but all have been used to the limits of social norms
3. Notices colleagues going for a social smoke break together
4. Upset because he is unable to participate

Figure 3.2: Sketch of observed user pain points in occupational stress recovery social norms

recovery coping mechanisms. The data supported the observations made during the KMD ethnographic research.

As reflected in the previous descriptions of students A and B, the area most related to stress coping norms within the KMD space was the convenient store. The ideal time for spending on coping activities between work was deemed by a majority of survey respondents to be within ten to fifteen minutes away from work. Almost all of the participants in the study confessed to making a small purchase as part of this stress relieving pattern. Purchases tended to be small, lower than JPY 500, and largely consumables such as a drink or snack. Enjoying the food or snack was often taken as an extension of the recovery process that initiated social interaction. Students who had traveled alone or in a pair were also more likely to purchase additional goods to share if they were returning to their group afterwards.

Emotional Event	Cognition	Action
Feels pressure to perform	I work best in a research focused environment	Go to shared work space to work with peers
Comfort in companionship	Everyone is working hard, so I will too	Works on individual assignment
Anxious about progress	I wonder how everyone else is doing	Initiate conversation with peer
Empathetic relief	We are all having a hard time working	Suggest a short break
Escape from work environment	I want to think about something other than work	Leave workspace for short walk to convenience store
Companionship	It is nice to talk outside of the work environment	Maximize time outside of convenience store
Responsibility	I need to get back to work and complete my goal	Return to workspace

Figure 3.3: Cognitive model for emotional events

After comparison of all sets of observational and interview based primary research, patterns between emotional awareness and cognitive process became clearer. Among a large group of students working in the same area, smaller support groups emerged as a social enabler in coping with work related stress in the academic environment. Not only were these bonds strengthened by the intensity of the project, but also by the amount of time spent together. While newer students tended to find coping mechanisms that involved exploring new habits (such as coffee or cigarettes), second year students were more likely to stick with efficient practices in regards to time spent and positive experience gained. Although the timing factor tended to be the biggest divider of the two groups, ultimately their coping mechanisms remained largely similar in regards to short term breaks.

In order to better understand the correlation between stressors and the activities that trigger and follow them, a logic flow was drafted in the example of a cognitive mental model for emotional events (See Figure 3.3).

3.4 Creating the Target Persona

Utilizing the mental model of stress coping actions among graduate students, an ideal target persona was created in order to guide the prototype design process. Through the ideation process, this ideal user was used to help justify reasoning for addition or subtraction of features. Their potential pain points were also addressed in order to satisfy as many needs as possible while addressing their internal motivations.

Target persona "student X" is a 25 year old Japanese male student enrolled in his first year at KMD after working for about two years at a magazine company in Japan. He decided to pursue his graduate degree in Japan after realizing he was not compatible with his previous company's working style that involved excessive unpaid overtime and little vacation. During his first semester he decided to try and quit smoking in order to better his overall health. On an impulse purchase to start taking better care of himself, he bought a Fitbit activity tracker with a HR tracking function. He was excited to get better incite into his daily routine and make better decisions for his physical and mental health.

However, due to the pressures of making new friends and dealing with intensive research assignments, he struggles not to revert to his negative coping habit of smoking. In place of cigarettes, he drinks coffee much more often, but still misses the camaraderie of the smoking lifestyle. He wishes there was a place at the university like the smoking room where he could spend time to take short, refreshing breaks alone or with a few of his peers. Although he is still wears his Fitbit tracker, he no longer follows his progress through the application and mostly uses it as a watch.

3.5 Prototype Ideation

The basis of designing the Kopia prototype was ideated around using it to gathering supporting evidence that it can deliver its value through functioning within the social norms of a working environment, while offering users a unique and engaging, but not over exciting, interactive experience. Additionally, an understanding of emotional atmosphere and an empathetic approach to interaction were noted as being crucial parts to creating this experience. In regards to the physical form of the object, it would need to fit within the acceptable parameters of the social norms surrounding it regardless of whether or not it was actively being used. This approach helped to form the iconic representation of each of the artifact's functions as driving factors in the haptic interactions.

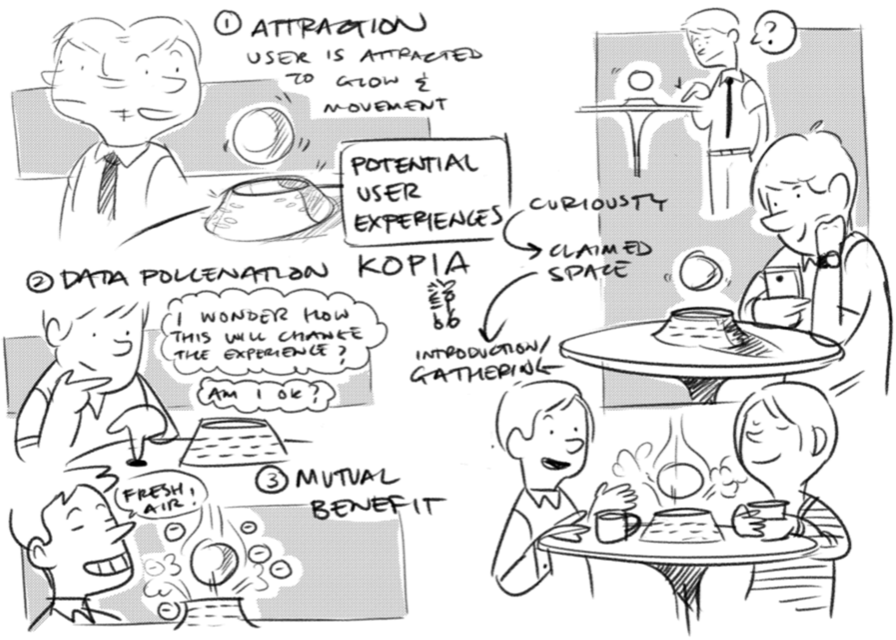

Figure 3.4: Ideation Sketch

The ideation process focused on using the target persona of student X to predict possible outcomes for user experience flow. These user interactions covered social patterns that were discovered during the observational period, as well as those addressed during interview sessions.

In order to best predict possible pain points in user interaction, thorough experimentation was conducted in a controlled setting prior to a potential field demo. This included further testing of interface design led by visual response features produced from lighting and color cues.

3.6 Product Design

The original concept for the Kopia Light was based on the integration of personal wearable devices (such as the Fitbit) to offer additional value through an environmentally interactive object. As the target persona identified, their main motivations of health and wellness were found as the leading driver in their wearable purchase motivation. Further inquiry produced negative feedback for requiring a separate wearable device to be used for interaction. Additionally, these personal activity tracking devices did not offer any feedback in terms of environmentally influenced data in relation to physiological monitoring.

UX Logic Flow
User walks passed Kopia Table
Kopia detects motion and triggers heart rate pulse
User is intrigued and enters personal space of table
User interacts with heart rate interface as prompted by lighting
User enjoys lighting interaction and is calmed through rhythmic movement
After 1-3 minute interval the interaction ends and loop is continued

Figure 3.5: UX Logic Flow

A large user experience gap was identified in value perception of QS data presentation between home an office spaces. At home, users could receive better feedback from data sets at the end of the day. However, in the office there is no artifact or environmental interaction that allows for utilization of personal biometric data in a comparative or personal setting. This led to the development of the concept in order to positively affect the act of destressing and understanding emotional temperature.

As a product, the Kopia Light houses a small but robust set of interactive input and output devices that run on a micro-controller known as the Arduino UNO R3 board[2]. The platform is open source and programming in the Arduino IDE is optimized for sensor based data reading. The elements that create the interactive experience work together to (1) detect HR through the pulse sensor based on infrared light variation detection; (2) trigger a unique light pattern rhythm that is based on the range of the HR; (3) then store the average HR data as a means of providing a more affective experience over time.

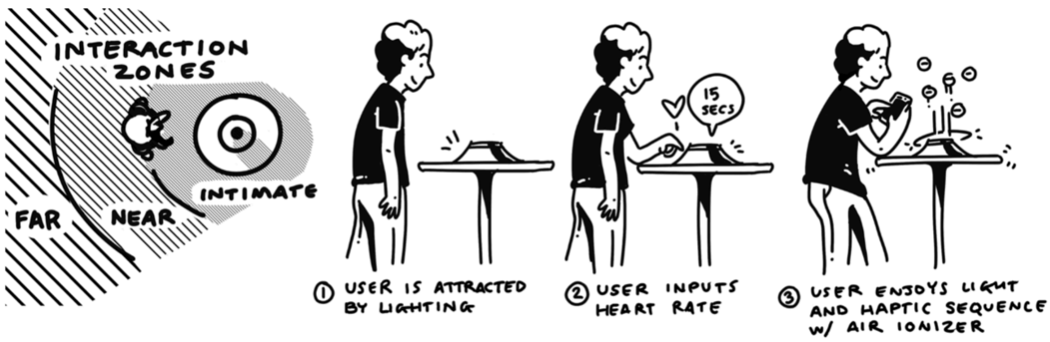

Figure 3.6: Early ideation for interaction area & usage

The extruded circular shape is purposefully designed to replicate the form of a clock in order to support the animated motion of the passage of time. The shape is also representative as an organic object that is meant to give off the feeling of familiarity and softness through its rounded contours. In the setting of a table top, there is also an elusion to the centralized campfire that is intended to trigger a positive social response to communication. Early observations of smoking rooms greatly influenced the shape as an object to congregate around similar to an ashtray or table ventilation fan.

2 http://www.arduino.cc

3.6.1 Experimentation with Audio Sensory Input

Figure 3.7: Experimentation with affecting heart rate through auditory sensory input

Through research conducted with colleague I. Knives under the supervision of KMD Associate Professor K. Kunze, audio was explored as a sensory biometric trigger to affect HR in subjected users. The goal of this short experiment was to gain incite into the feasibility of utilizing sound clips of various genres to predictably alter the HR of each subject. Through multiple user tests, it was found that the subjective nature of the audio listening experience created too much variation in comparison between users. Although over time and consistent monitoring, individual trends could be isolated, the applications were not suited for further development of the Kopia concept in its current iteration. Regardless of the lack of immediately applicable use, the study did prove fluctuations in HR could be recorded with accuracy and consistency with accessible equipment.

3.6.2 Hardware Design

The visual development of the interaction was created in order to reach a broad range of users without taking away from the surrounding environment. It also needed to be quickly customizable to suit different needs that were discovered through testing.

Figure 3.8: Early light testing with 3D print materials and patterns

The core element of displaying information is the circular array of programmable RGB LEDs sold as NeoPixels[3]. These were chosen for their simplicity in programming through utilization of one input source. This feature greatly reduced the chance of hardware failure due to complex wiring configurations. The LEDs also offer a wide range of flexibility in producing animated sequences with controlled brightness and color range while only taking up a small surface area. A variety of open source LED animation programs were customized and tested to increase the efficiency of ideation time.

The outer shell that containing all of the interactive elements serves to both mask the distracting internal components and provide an aesthetically pleasing appearance. The shell was created through production of four separate but iden-

3 https://www.adafruit.com/category/168

Figure 3.9: Hardware outer shell and internal mounting system prototypes and final (top left)

tical pieces created with the 3D rendering software application SketchUp [4]. The material consists of acrylonitrile butadiene styrene (ABS) plastic used in creation of the 3D print of the shell. This material was chosen because of its flexible and finishing properties.

All pieces were creating using a Makerbot Replicator 2X 3D printer [5]. Each section consists of one-fourth of the complete circular shape in order to allow for rapid ideation and customization. Print time and errors are also cut down considerably and the parts join together almost seamlessly with a glue solvent after light sanding. Once assembled, the entire unit runs as a semi-portable solution and can be placed on any flat surface. A steady five volt current via USB cable is needed in order to power all of the components managed through the micro controller.

4 http://www.sketchup.com

5 http://www.makerbot.com

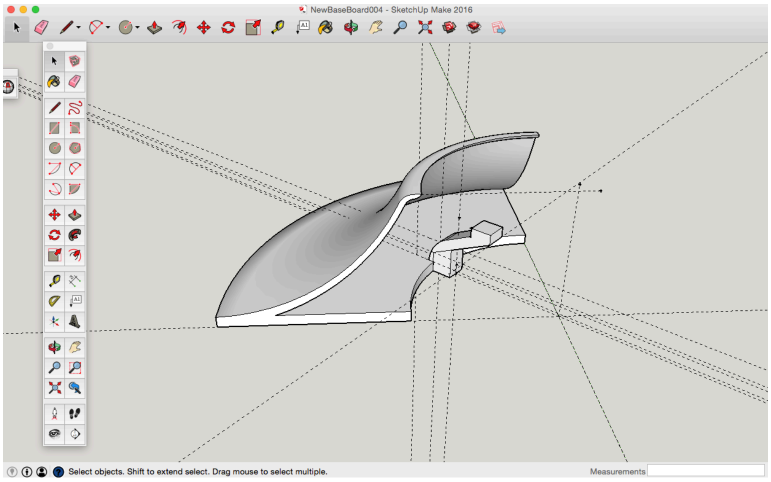

Figure 3.10: Rapid 3D model prototyping with SketchUp application

3.7 Visual Representation of Pulse

An engaging simulation of the human pulse in the Kopia Light is an important part of the device as it pertains to believability and effectiveness of the entrainment theory. HR is visualized with the circular LED pattern through variations in speed, rotation, and color. Multiple iterations were created in order to achieve a simple display to provide the user with a passively entertaining object of fixation. The animation samples were originally created to match common visualizations of heart rate as closely as possible. The first iteration featured a pulsing red light that faded in real time with the input pulse BPM from the user. Feedback received from this visualization was wholly negative as it was perceived as a negative emotion similar to an emergency signal or warning notice. Various colors were tested outside of the warm color range with equally negative results. The constant repetition of one color was said by users to be "monotonous", "uninteresting", and "distracting" over a three minute interaction. The rainbow color palette rotating in a circular pattern proved the most effective and neutral in qualitative experience feedback sessions. This pattern was further refined and integrated into the interaction sequence.

On initial physical interaction, the user inputs their HR using the pulse sensor, and the Kopia Light responds with a timer style display that is visualized by incremental LEDS. These increments eventually fill in the circle in its entirety over a span of ten seconds. During this time, the microprocessor averages the individual's beats per minute (BPM) in order to get the best representation through taking multiple data readings. This average BPM is then used to set the rotations per minute (RPM) of the light animation. Once the RPM is defined, it is entered into the resting HR formula which calculates the appropriate deceleration speed within the given time frame. When the animation is completed, a warm range color is brightly pulsed to signify the end of the interaction.

3.7.1 Lighting Sequence Design

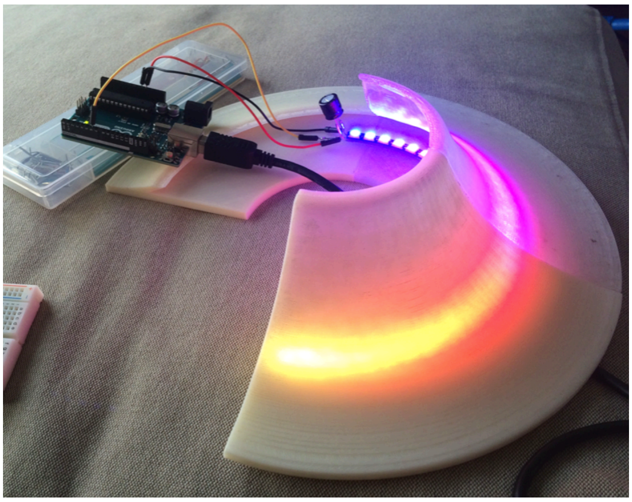

Figure 3.11: Light animation prototyping

The lighting sequence that follows the input of the user's HR is meant to feel as though their HR has been transferred into the device. The translation of the pulse traveling in a circular pattern gives the user a visualization of their current state of stress in relation to HR which they can track in real time. As the intensity of the speed reduces, the high HR of the initial interaction is also represented as slowing over the duration of the sequence. This visual reduction of energy is meant to induce a more calmed state of the user through entrainment. The time frame of the sequence is also designed to limit the interaction in order maximize the stress recovery sessions effects, while suggesting a resting period that does not exceed that expected of a social norm.

3.8 Application in Live Space

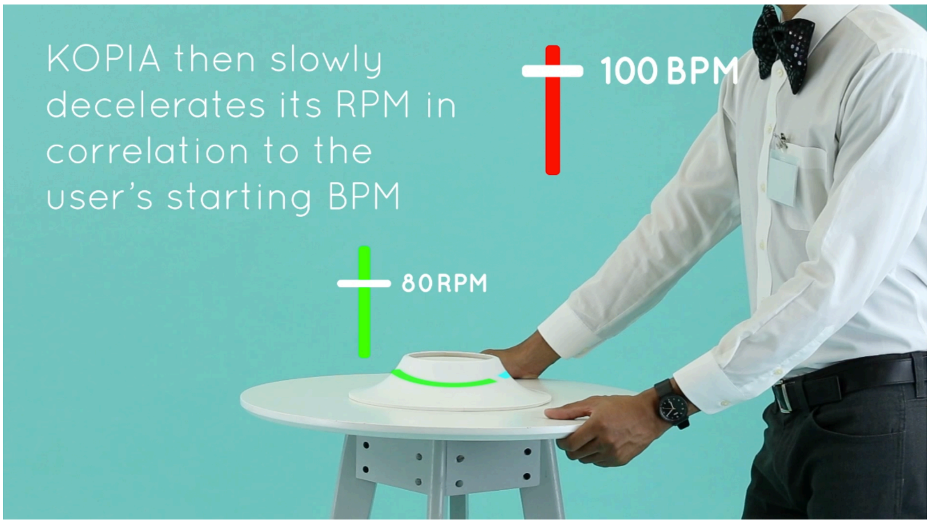

Figure 3.12: User interaction sequence from concept movie

The installation area of the Kopia Light requires a number of considerations for deployment into a workplace environment with multiple stakeholders. Even in the experimental nature of the research in an academic setting, guidelines need to adhere to local safety protocols, the flow of human traffic, and ethical issues regarding the storage and manipulation of personal HR data.

In regards to physical location, great care in positioning the interactive light needs to be taken in order to assure proper visualization to attract and engage users. Although the lighting experience can be enjoyed from multiple angles, the attractiveness of the idle animation should not distract from people currently engaged in work. Therefore, visibility should be limited to neutral areas out of the line of sight of any work space. Feedback from users also suggests at least partial blocking of the user's identity through partitions or installed architecture.

The Kopia Light is mounted at the center of a round, standing height table with a diameter of no more than eighty centimeters. The table is placed in a position away from walls and without chairs in order to limit prolonged interaction which may negatively affect the user's work efficiency and the example of stress recovery as a social norm. In relation to the area surrounding the table, enough space must be given in order to distinctly define interaction zones referred to as intimate (within one meter of table), near (within three meters), and far (more than four meters).

3.9 Design Summary

The Kopia Light is a tabletop device that supports the reduction of occupational stress through a personalized, heart rate based light visualizations. It involves placement in an area within a neutral location and functions as an emotional intervention tool to those seeking stress recovery. The user engages with the device through direct input of their biometric data, and are given a customized interactive experience that shapes the immediate area around them.

- Users can have their heart rate calculated in under ten seconds
- Visualization and haptic feedback sequence is adjusted for heart rate range
- No numerical information is displayed
- Tabletop space is available for fixated or passive mediation
- Sequence and physicality of standing table nudge users to limit interaction time

Through implementation of Kopia, users can expect the following results.

- Better understanding of social stress recovery engagement at work
- Establishment of a curated space allocated to taking short work breaks
- Development of Kopia interaction as a social norm

The design process for the Kopia Table focused on the following aspects of designing for user based interactions.

1. Research the needs of stress recovery in the workplace
2. Observe stress-coping behavior within planned installation environment
3. Create target persona based on primary and secondary data
4. Ideation of interaction concepts to trigger stress coping interventions
5. Create prototypes to test in controlled environment
6. Reiterate for effectiveness and stability
7. Evaluate results

Chapter 4
Evaluation

This research aims to prove that utilization of biofeedback displays in working environments can guide stress recovery with a qualitatively positive interaction through customized experiences in curated spaces. The Kopia concept approaches this goal through (1) applying accumulative research of physiological responses to stress as they relate to sensory input; (2) exploring the feasibility of current heart rate monitoring technology; and (3) creating an artifact that fits within the social norms of coping mechanisms for stress in working environments. These three areas of focus were tested and appropriately revised in order to create the final prototype used for user testing and feedback to gauge both qualitative value and quantitative support through analysis of data.

The final prototype for experimentation used light based animations that were displayed after exposure to a series of activities created in a controlled environment in order to purposefully induce social stress and raise resting heart rate. Each participant's HR was monitored in real time prior to the procedure in order to adjust the animation to match their HR readings. On completion of the testing, the users completed a follow-up survey that reflected on their experience for relating to the stressful encounter both with and without the use of the Kopia prototype. Further analysis for correlation between perceived stress levels and actual HR data sets was conducted post-experiment for additional incite into creating the most valuable interactive experience.

The experiment was designed in order to (1) evaluate the effectiveness of the light based HR visualizations to induce an entrainment effect without drastically effecting resting HR levels and (2) prove the value proposition of introducing the Kopia concept as a viable social norm in coping with occupational stress. Users who experience the Kopia interaction are expected to feel as though their recovery after a stressful encounter is improved through focused relaxation, and therefore respond positively. This should also correlate directly with HR data supporting their biofeedback response. The experiment was conducted at the Keio University Graduate School of Media Design under controlled conditions in a research lab environment with permission granted from all participants.

4.1 Methodology

Through user testing using the final Kopia Light prototype, the evaluation process involved experimentation with participants in a controlled setting through stress testing, recovery sessions, and follow up interviews. The goals of which were to confirm that (1) the Kopia prototype was not adding additional stress to the users (2) recovery time did not differ substantially when comparing multiple occupational stressors (3) participants found the form and interaction experience positive and beneficial. The scenarios were designed using survey feedback from over hundred responses regarding occupation stress and coping mechanisms. A total of ten users were tested over a period of two days.

4.2 Experiment Setting

The Kopia Light was tested in a controlled environment within an isolated room in order to reduce the amount of error variables. Lighting, room temperature and positioning of furniture were maintained at similar levels throughout the tests. The room consisted of the following items: a single meeting table, the Kopia Light prototype, two personal computers for recording data and running software, a tablet app based timer, a heart rate monitor, and two chairs for the experimenter and user.

All of the items are in plain sight on the table throughout testing, however the Kopia Light is only activated during select recovery sessions. The user is fitted with an ear-mounted heart rate monitor running through a micro-controller that remains on throughout the experiment. All HR data is monitored in real time as

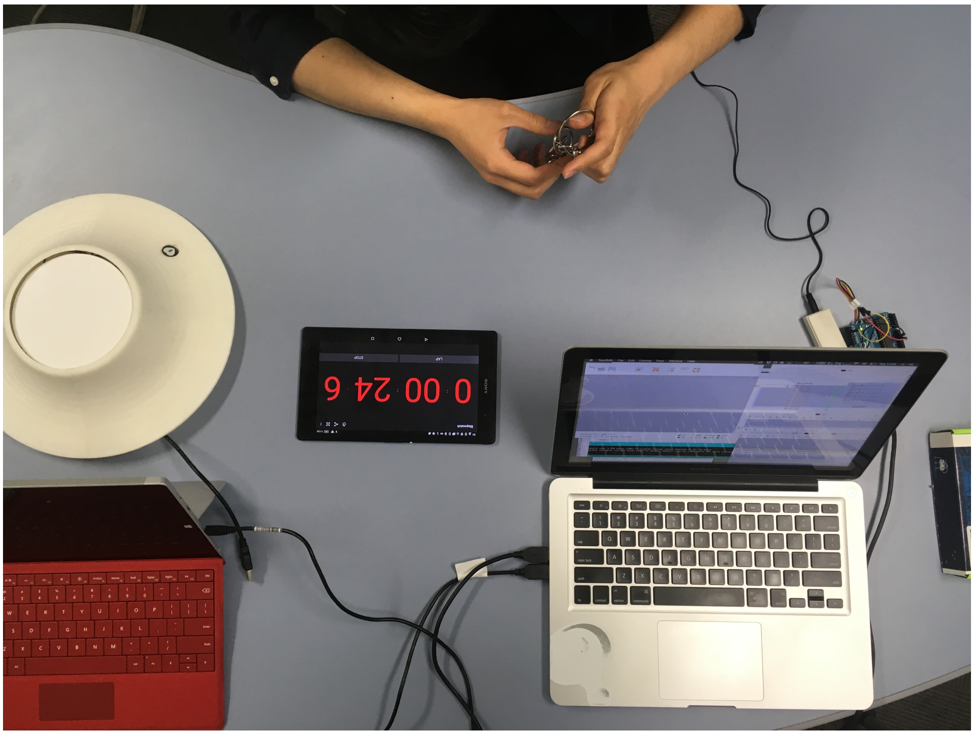

Figure 4.1: Cognitive stress test with participant while recording heart rate

well as stored on the computer for later analyzation. The only time the heart rate monitor is removed is during the user initiated break described later in session three.

4.2.1 The Social Stress Test

In order to initiate a high emotional response to simulate work place stress, a variation of the Trier Social Stress Test[1] was given to each user. Two versions of the three minute stress tests were created to incite stress in regards to performance based activity and social criticism of personal work ethic. Throughout the experiment, the participant was aware of their HR being monitored and recorded via the ear lobe attached HR sensor. A large digital stopwatch application on a tablet device was placed in front of the user and started at the beginning of each

1 http://iniastress.org/tssp

stress test session. The Kopia light was also placed on the table, but deactivated. Directions were given via a text-to-speech computer application to prevent personal association with the examiner. All participant's consent to engage in the activity was received prior to the beginning of the test. Participants were also allowed to leave the test at anytime should they feel uncomfortable, although no one chose to do so.

The performance based test was presented to the user as a cognitive problem solving test in the form of an advanced brain teaser puzzle with a completion time limit of one minute. No participants were able to complete the puzzle within that time period. The examiner would periodically remind the user of the time remaining in order to simulate the feeling of an impending deadline. Immediately following the one minute session, the participants were purposefully, heavily criticized for their poor performance resulting in a successful raise in HR and negative emotional feedback.

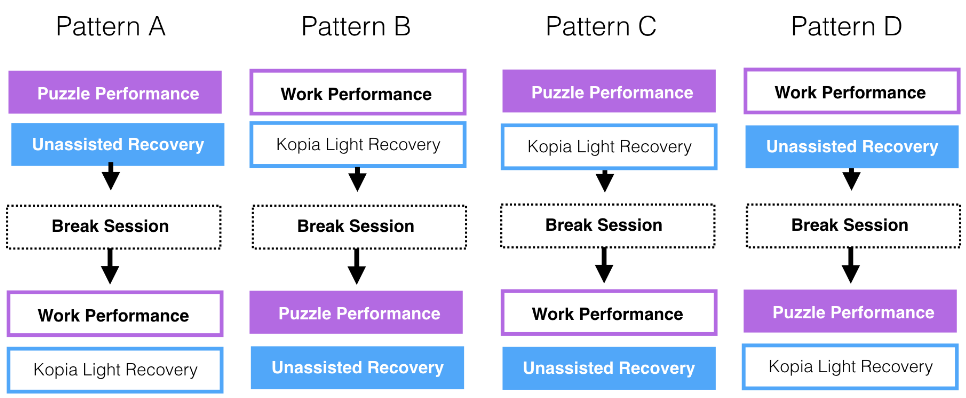

Figure 4.2: Crossover study for inducing stress and recovery

The social criticism stress test was presented as a personality test and focused on presenting negative feedback in response to questions related to their field of work. The replies of the participants were often cut short in order to cause an abrupt change in subject and feeling of disinterest from the interviewer. Seven out of ten participants found this test more emotionally stressful because of feelings of their personal decisions being attacked, rather than an arbitrary puzzle. HR data supported this fact for the majority of users who made this claim.

This anxiety of judgment, impeding deadline, and unpreparedness in both stress tests purposefully was recreated to simulate work place related stressors identified through previous survey results. Participants also confirmed these stressors as being present in the testing.

4.2.2 Controlled Variable Stress Recovery Session

Each stress session was followed immediately by a stress recovery session lasting an equal three minutes. During this time HR was continuously monitored in order to measure the contrast between stress induced periods and resting periods. The examiner left the room for the entirety of the session in order to minimize influence variables. HR data sets clearly show the distinction between the elevated HR state and a clear drop once the recovery session began.

Two types of stress recovery sessions were conducted in order to create comparative quantitative data sets with a controlled and independent variable. In order to measure the impact of the Kopia Light in regards to HR, the controlled variable was set as three minutes with no Kopia Light interaction. The independent variable was defined with the activation and user HR input with the Kopia Light.

After analyzation of the effects on HR using the Kopia light, the device managed to successfully stay within quantitative limits of resting BPM.

4.2.3 User Initiated Stress Recovery Session

Although the Kopia Light is designed to create additional value to the stress recovery process, as an experimental device, it may not be able to completely replace the user's current coping activities. In order to allow room within the experiment to gauge the effectiveness of the light, a brief open period between tests was allotted for each user. After the first test, conducted within the graduate school facility, the users were given free choice within a five minute period to recover from the experiment's stress inducing activity. The five minute period was selected as a representation of an acceptible time expected within work place social norms for a self initiated break period within working hours. Through the follow up interview conducted post experiment, insight into the activities and motivations chosen by the users during this period gave further insight into the validity of the Kopia Light.

4.3 Effectiveness of Heart Rate Visualization

Rhythmic light based patterns were used to mimic the HR of users through matching RPM to BPM. The correlation of the revolving visualization was designed as a cue to the relation of time and the elevated HR experienced by the user after the stress test. In order to further reinforce the connection, the user was instructed to place their finger on the heart rate sensor positioned on the Kopia prototype. Within ten seconds of touching the device, the light animation would begin. The RPM of the animation started at one-hundred RPM and decreased gradually to resting a rhythm of forty-five RPM over a duration of approximately one hundred one seconds.

Throughout the evaluation HR was monitored and recorded separately via an earlobe sensor to ensure that the participants did not have any large variations in HR. If the interaction with Kopia caused a considerable increase in BPM in contrast to the controlled variable data, it would hint at a state of agitation.

After reviewing the BPM recorded during the initial test group of users (ten participants in total), the curated recovery period HR value stayed within or below the same expected measurements as the control group. The values recorded confirmed the effectiveness of the product as being non-agitating in relation to HR. Follow-up interviews immediately after the testing reflected in positive feedback in regards to the animation sequence speed, color, and rhythm. Participants were also able to understand the correlation to their HR and the RPM of the animation without being prompted. However, the subject of the stress testing was given to the participant before the experiment and the presence of the ear mounted HR

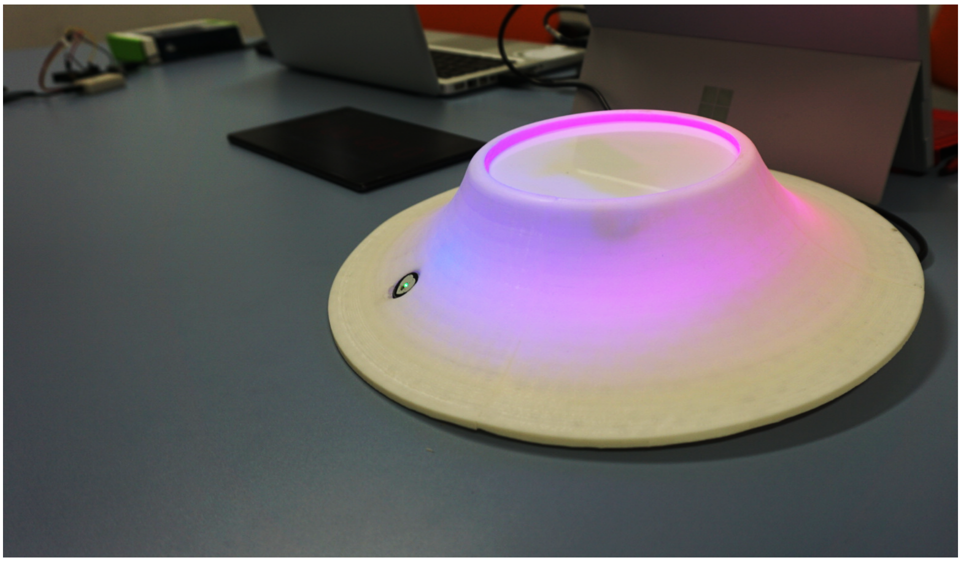

Figure 4.3: View of heart rate visualization animation

sensor may have primed their preconception of the Kopia Light's function.

4.4 Assessment of Entrainment Effect

The rate of deceleration of HR in the controlled variable group in comparison to the programmed timing sequence of the animation program did not reveal any stark differences.

The light based animation was intended to trigger an entrainment response within the three minutes following the stressful encounter. This was hoped to be observed through matching patterns of deceleration in the HR data collected throughout the experiment. However, when compared with the controlled variable of HR deceleration with and without the Kopia Light, no notable differences were observed between the two experiments.

Although cardiac entrainment was not clearly identifiable within the three minute session, nine out of ten participants experienced complete visual entrainment. Over the period of three minutes, the deceleration of the pattern dropped by over half of the original RPM from one hundred to forty-five BPM. The affected participants were not able to discern the difference in speed over the course

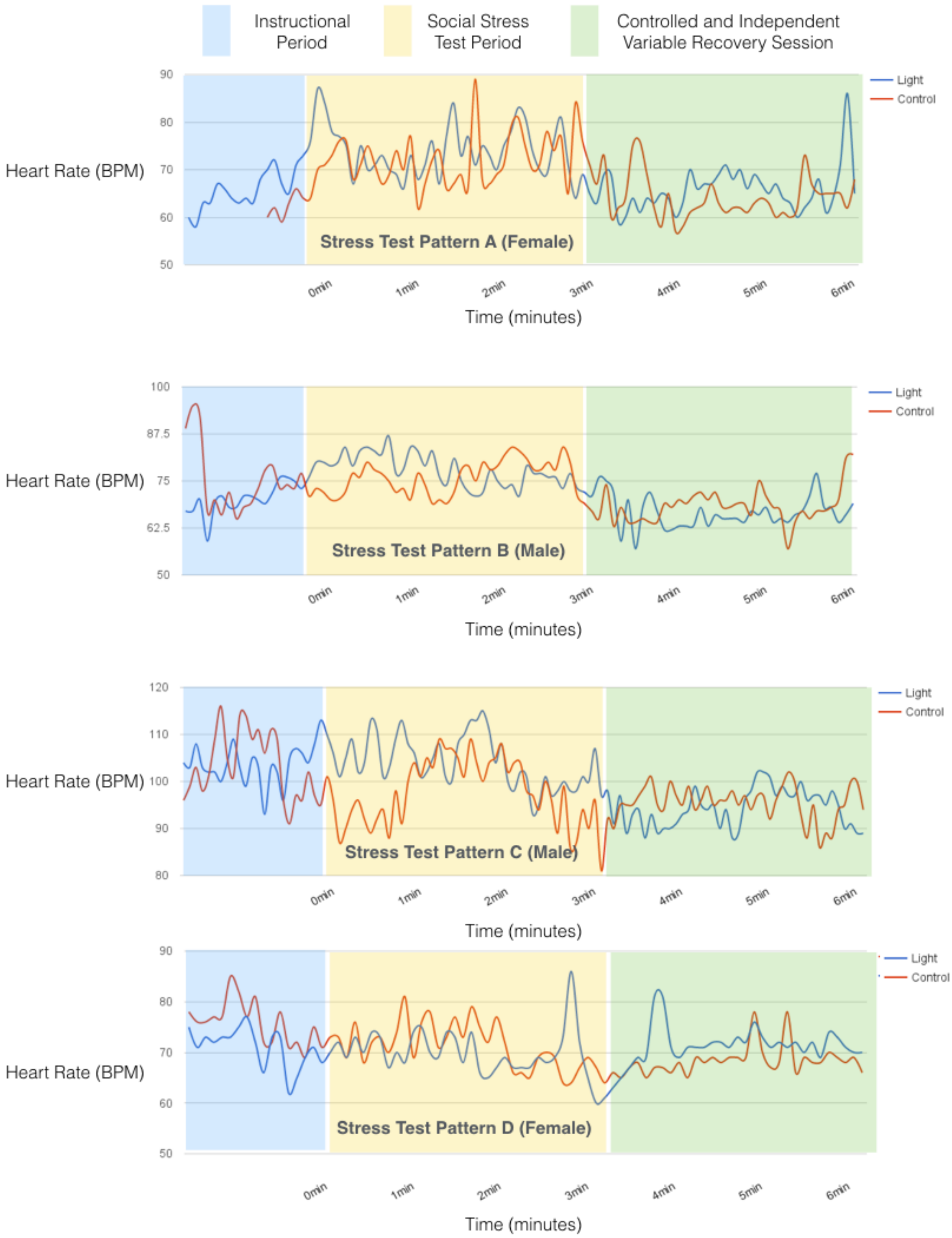

Figure 4.4: Samples of BPM measurements taken during instruction, stress testing, and recovery sessions

of the session and state feeling much more relaxed through use of the Kopia Light. Even though they did not actively engage in the visual experience throughout the entire session, all participants preferred having the Kopia Light activated during the session. Reasoning for this reaction stemmed largely from the ability to focus on the light interactions as opposed to the previous negative feedback experienced in the stress test. A few participants also responded in support of the light as relating to it as a friend-like presence when left in the room alone.

In contrast, the experience of being left in the room alone was described as being more stressful due to lack of an object to focus on. This led participants to reflect on their previous failings in the stress test session which was confirmed in periodical spikes of heart rate identified after the experiment (See Figure 4.5).

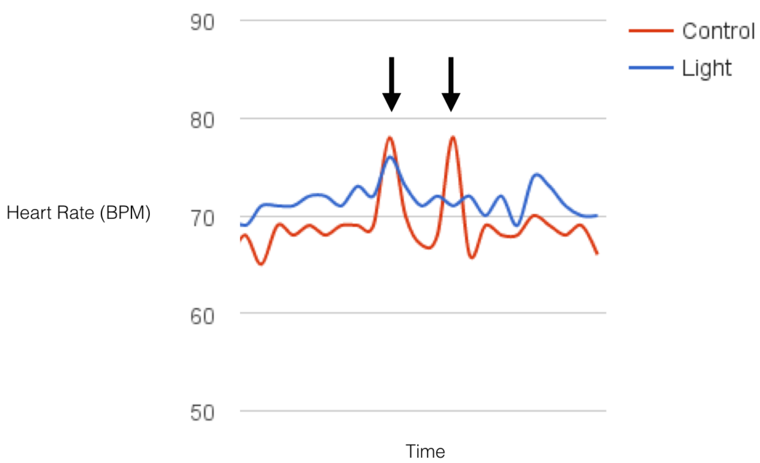

Figure 4.5: BPM variations in controlled variable identified as flashbacks to previous stressors

4.5 Viability of Social Norm Implementation

In the majority of user experience cases (over ninety percent), participants favored their post-stress recovery time with the Kopia Light. The interaction process from inputting their heart rate, to viewing the lighting animation also proved to be positive and produce a value-adding experience. Participants also found the shape of the object non-threatening, and in the testing environment, rarely commented on the presence of the prototype before being instructed as to what its function was or how they would interact with it. This neutral to positive response to the physical design of the artifact was a supported finding that matched expectations set during the iteration process.

Upon the beginning of the visual entrainment process, the activation of the light animation triggered an excited state in some users as identified in the quantitative data represented by a rapid increase in HR. This was later confirmed to be a positive experience when discussed post-experiment which was usually followed by a calm state of resting HR that fell below the average control group in some cases.

During the post-experiment interview, users also accurately identified the correlation between the light patterns and their own heart rate. The decreasing rate of the animation speed was only detected by one participant in the test.

Through the follow-up questioning regarding user assumptions for the implementation of the prototype's light based patterns in current real world working environments, responses correlated with feedback gathered through survey response (See Figure 4.6). All participants could imagine coming in contact with a similar lighting interaction in the near future. The majority of environments where they imagined the device being placed were connected with areas and interactions associated with coping habits for occupational stress. The majority of responses placed the Kopia Light physically outside of the work place environment in areas of moderate seclusion including coffee rooms, lounge areas, and restrooms. This finding supported the placement guidelines set in the concept creation for placing the light away from active occupational zones. A few responses also mentioned inclusion of the lighting interaction in current work place artifacts associated with stress inducing interaction such as customer service telephones and meeting rooms.

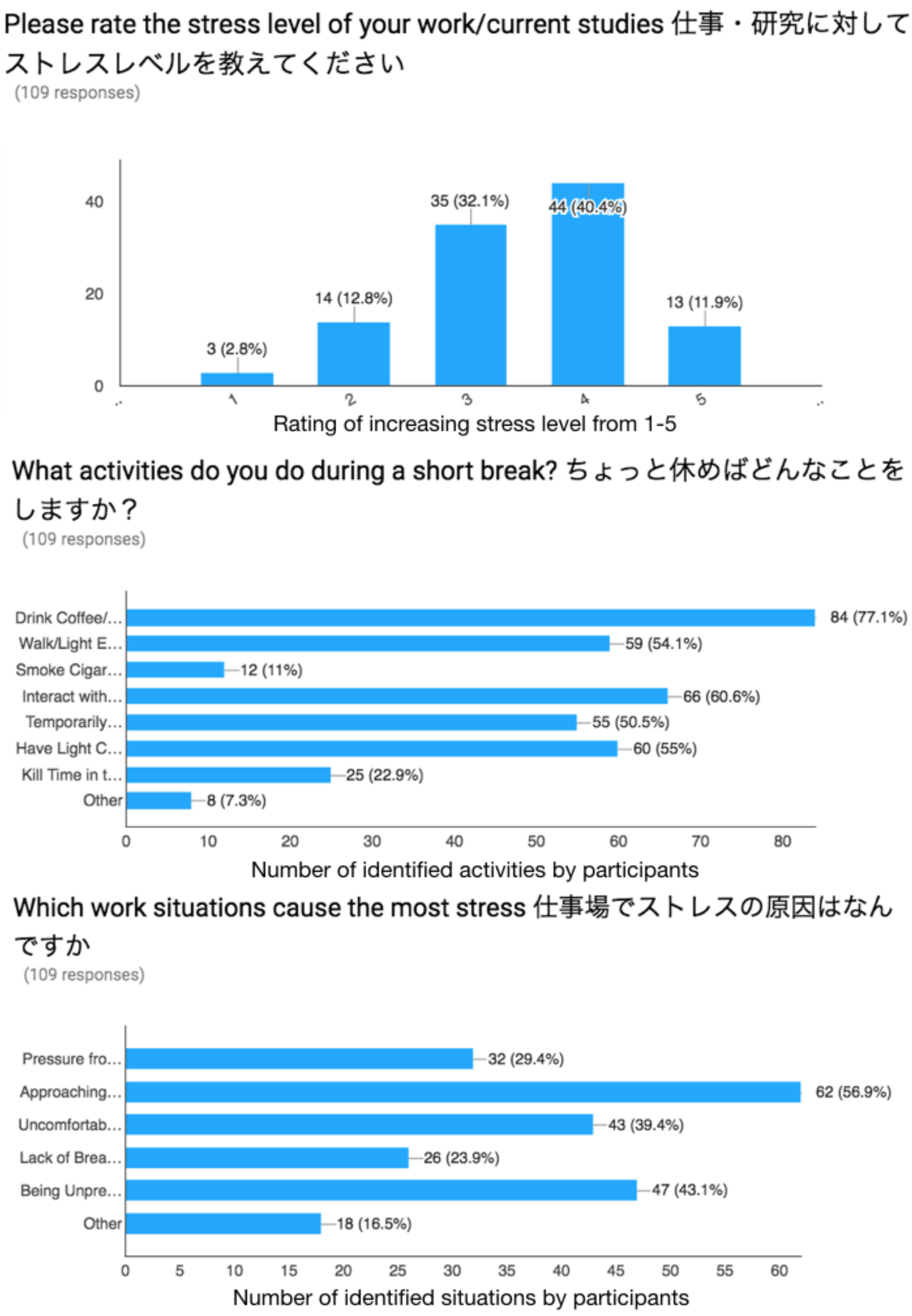

Figure 4.6: Results from occupational stress survey

4.6 Concept Revision

In reflection of the data gathered through ethnographical research, survey response, and user testing, opportunity for improvements in the interaction design were discovered through value co-creation and discovery of pain points in the product experience. In regards to utilization of sensory stimulus in order to affect HR change through deceleration, it was determined that additional haptic or sensory feedback should be explored as a method of inducing a more rapid deceleration in HR. In order to create the amount of affective response necessary to clearly distinguish the influence of the device, a more engaging experience may prove successful. Although great headway was made in the design of a neutral to positive light-based pattern, previous research completed in inclusion of audio stimulus for affecting HR may provide positive results for both qualitative and quantitative data sets.

Chapter 5
Conclusion

5.1 Kopia Light Coping Experience

The Kopia Light experience enhances the quality of occupational life in its application throughout strategic spaces in the work place environment. Not only does the device encourage individuals to spend their stress recovery time in curated spaces, but it give employers and facilities the opportunity to enrich the emotional environment of their communities through non-intrusive, scaleable solutions. Through offering a space dedicated to stress induced persons who are seeking healthier coping habits, the Kopia Light assists in self-management of time away from stressors without breaking any social norms. Users are able to take part in an attractive interaction that is as involved or passive as they see fit.

Management staff and employers are also empowered to provide a better environmental experience for the community by being able to better read the emotional temperature of the organization. Because the Kopia Light has the ability to store anonymous HR data and categorize it by location, time, and use, it is easier to predict fluctuations in stress levels. Appropriate actions can now be taken to use the power of quantitative data to add to the qualitative nature of a healthy work place environment. Cues for social stress recovery intervention are also more easily distinguished because users have become enabled to suggest sessions around the Kopia Light as a newly established social norm. In essence, the positive aspects of the community previously built around smoking rooms, now has a healthier and more community enriching outlet.

In regards to its introduction into the biofeedback and affective computing domains, the Kopia Light successfully provides and interactive platform for QS data exchange in a community setting without breaking social norms. Therefore making the step towards standardizing the betterment of self through personal big data a more realizable feat in the near future.

5.2 Design Approach

The design approach for developing the Kopia Light was established through utilization of elements of the design thinking process in combination with research analysis as a driving factor for implementation. In contrast to more engineering focused research that occupies the field of affective computing, the Kopia Light looked at the opportunities for innovative design available through accessible means for simple but robust systems that can be quickly deployed. This process placed great focus on understanding the user within their environment to create a solution that was driven by the needs of the individual and their community.

The access to rapid prototyping software and hardware was fully taken advantage of in order to communicate ideas through physical form for instant, and valid feedback. This style of constant reiteration not only helped shape the direction and story of the Kopia Light, but also made it more malleable through the ideation and experimentation phase to allow for the appropriate pivots in direction to meet the expectations of all stakeholders.

The decision to rely on open source communities provided the basis of which the concept was created on and allowed for collaborative efforts and easier access to source material. These values and strategic decisions helped guide the concept into a form that was quickly identifiable to the end user's experience in providing a supplementary offering to a personal and emotional subject.

5.2.1 Limitations

The design of the Kopia Light highlights its ability to aid in stress recovery coping habits, however it cannot be consider a full replacement for every user's needs. The complexity of distress and eustress in occupational environments requires a dedicated localized support system that Kopia can function as a part of but not an ultimate solution. Through tracking only one form of biofeedback data through heart rate, the best estimation that the Kopia Light can do is calculate stress in relation to BPM which may not reflect the actual emotional state of the user. Although in its current form, the potential for a false reading to cause physiological harm to a user is low, it is important to recognize the seriousness of the impact of biofeedback representation and affective computational interactions as a whole.

5.3 Prototype Development and Future Discussion

Through the feedback received from interviews and quantitative tracking of HR reactions to the Kopia Light interaction, many opportunities were discovered for further exploration in the occupational environment. The immediate next step would be to refine the prototype into its next iteration to offer a more stable experience outside of the controlled experimental space. Implementation into live space interactions would give greater insight into how the Kopia Light managed the unpredictable nature of real world testing.

In addition to refining the prototype, development of the Kopia Light as a platform for multiple biofeedback input would allow for explorations into more novel applications. Modulation of breathing and rhythmic entrainment from piezo based vibrations could be explored to produce more embodied experiences. Through an enriching multi-sensory experience, the Kopia Light has the potential to shift from a supplemental device into a fully immersive stress coping device.

Notes

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Appendix

A Dialogue for Stress Test Pattern C

Welcome to the Social Stress test.

In this test you will be given two stress inducing examinations that will last for a period of three minutes each. After each stress test, you will be given an additional three minutes of stress recovery time under the restrictions given by the examiner. At the end of the first session, you will be allotted a five minute break period. Upon returning from the nine minute break you will promptly begin the second stress test.

Please follow all directions given without error. Please refrain from asking questions during the examination. If at any time you feel uncomfortable, you are free to end the examination and leave the room as you see fit.

In a moment, you will be given a cognitive test by your examiner to judge your problem solving abilities. You will be given exactly sixty seconds to complete the test. Regardless of whether or not you complete the test, you must stop all activity and place the test back on the table by the end of the sixty second period. You will only get one opportunity to complete the test. Testing will begin at the end of the countdown. 5. 4. 3. 2. 1. Please begin···

This ends the stress test session. Please remain in the seated position with the heart rate sensor on your ear. The examiner will leave the room for exactly three minutes. During that time please do not move from your chair. Before leaving the room the examiner will activate the lighting device. Please place your finger on the device's heart rate monitor now. You may release your finger once the animation begins.

When the animation begins the examiner will leave the room for three minutes. After the three minutes are complete, they will return with further instructions. The examiner will now leave the room.

In a moment, you will be given a personality test by your examiner to judge your confidence level. The interview session will last for approximately three minutes. Please answer the questions given by the examiner clearly in your own words. These questions were gathered by your colleagues to be asked to you in regards to your current research status. The questioning will begin at the end of the countdown. 5. 4. 3. 2. 1.

This ends the stress test session. Please remain in the seated position with the heart rate sensor on your ear. The examiner will leave the room for exactly three minutes. During that time, please do not move from your chair or engage in any interaction. Upon completion of the three minute period the examiner will re-enter the room and give you further instructions. The examiner will now leave the room.

B Arduino Example Code

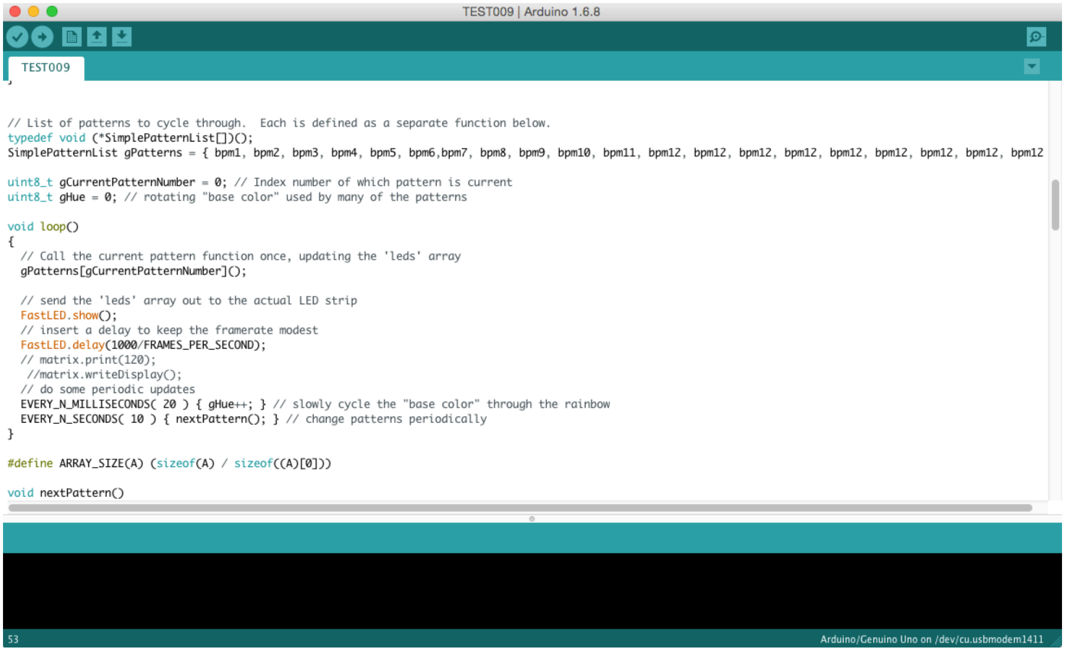

Figure B.1: Arduino IDE; FastLED library code based on original by Mark Kriegsman, December 2014

C Design Iterations and Sketches

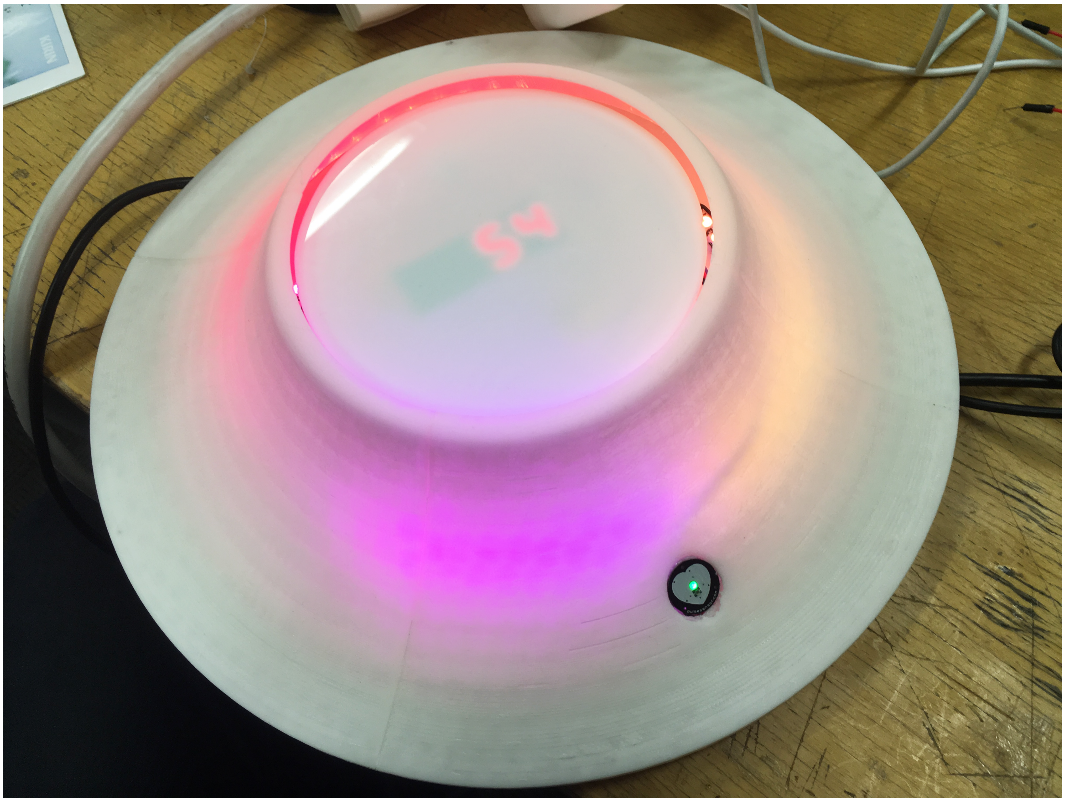

Figure C.1: Prototyping user interface with real time BPM monitor

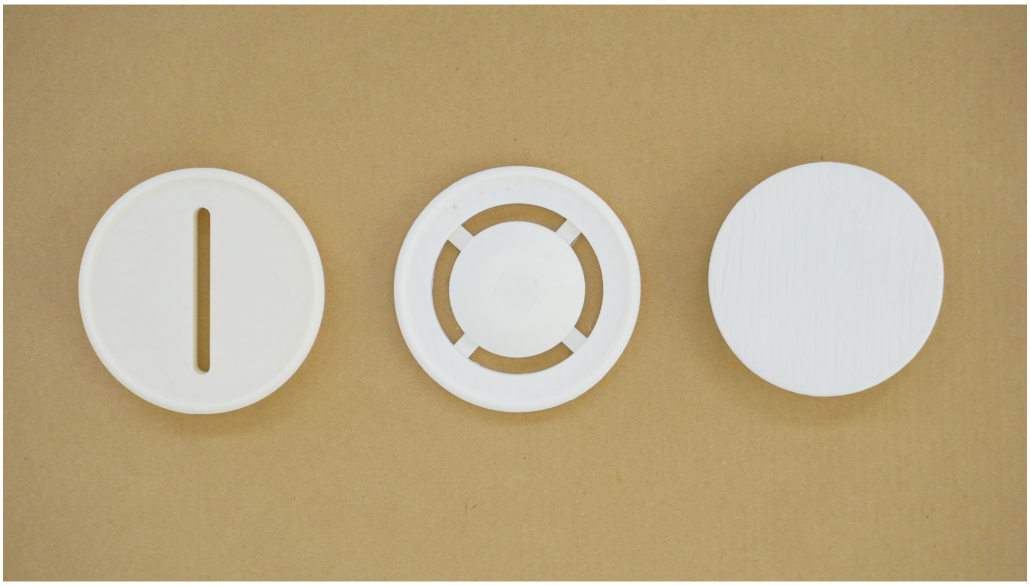

Figure C.2: Cap ideation for center piece

Figure C.3: UX Ideation sketch

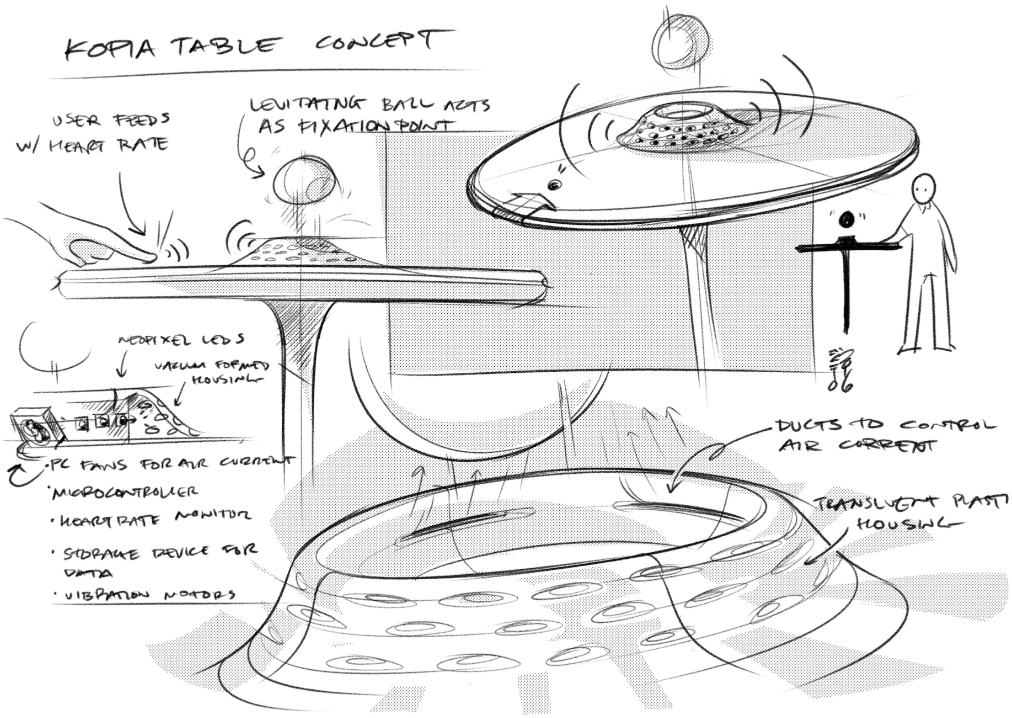

Figure C.4: Product design sketch

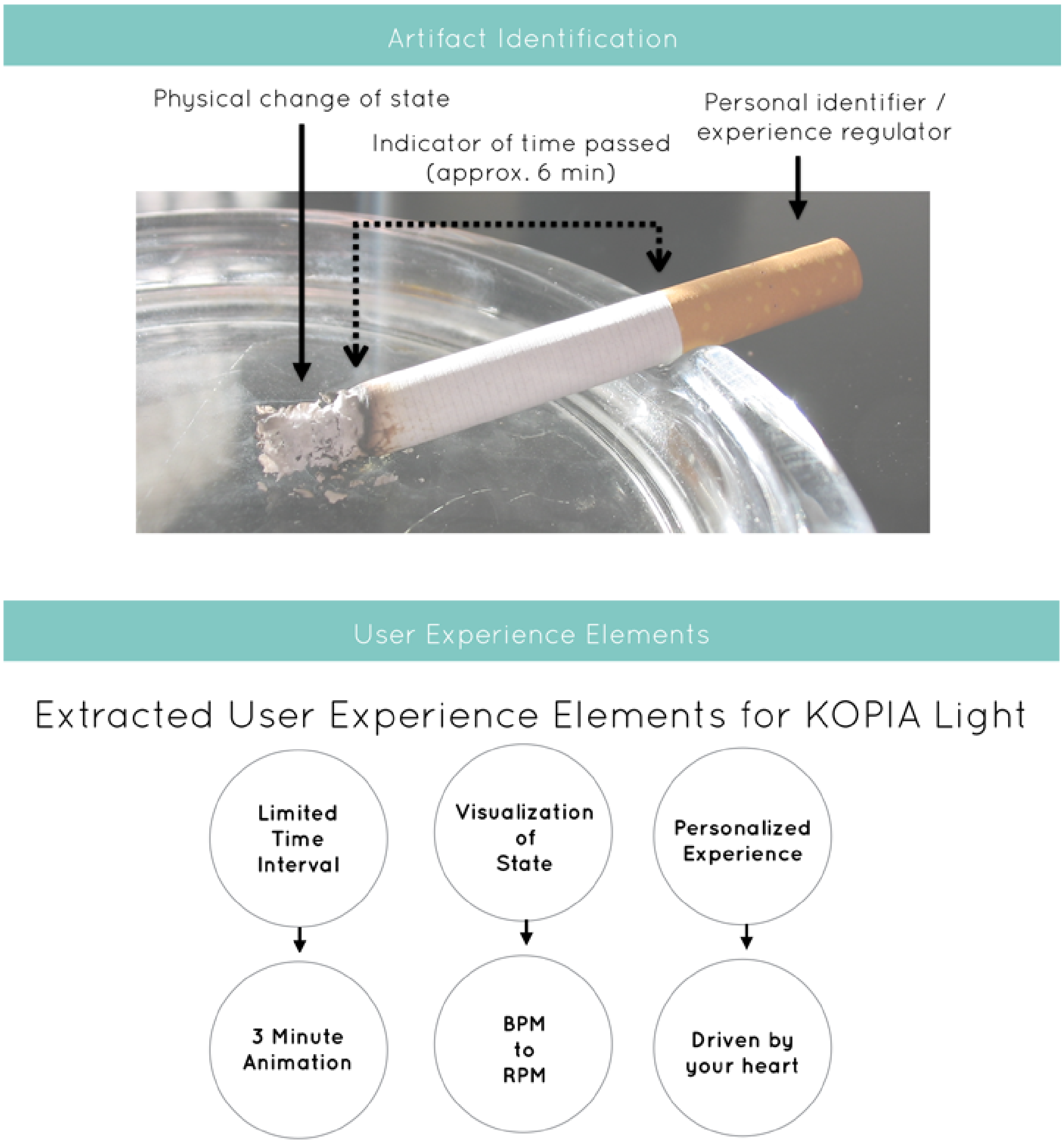

Figure C.5: Fieldwork artifact breakdown