YOUR ENVIRONMENT AND YOU: INVESTIGATING STRESS TRIGGERS AND CHARACTERISTICS OF THE BUILT ENVIRONMENT

by

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A REPORT

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Abstract

The physical environment influences mental health and inevitably well-being. While exposure to natural environments shows salubrious health benefits among those who maintain a consistent connection, little is known about how urban environments impact mental health. As urbanization increases worldwide, it is essential to understand the linkages between urbanized environments and public health. This project is guided by the research question: How do different environmental characteristics affect stress-related responses in users?

The study will guide individual subjects (*n > 30*) to walk a designated route, exposing them to different architectural and environmental elements in downtown Manhattan, Kansas. Physiological biofeedback sensors, including electrodermal activity (EDA) and heart rate sensors, will be used monitor physiological behavioral changes; GPS will provide spatial location; and a GoPro camera will provide real-time first-person experience. Data from these sensors will be integrated into a temporal-spatial analysis to ascertain correlations between architectural and environmental elements in space and associated stress responses. Upon completing the walk, participants will take a brief survey asking for their perceptions, both quantitatively and qualitatively, of the different environments they encounter on the walk.

Raw data collected from the biofeedback devices will be refined and analyzed spatially using GIS mapping software. This will allow us to visualize any associations between design characteristics and the elicited behavioral responses in order to determine the environmental characteristics that may illicit heightened stress responses. Analysis of the survey data will seek to identify any correlations between physiological and perception-based responses.

The intent of the research is to provide a foundation for further studies into how public policy can be better informed and augmented to mitigate potential public health issues caused by urban design. Results will also inform architectural and engineering decision-making processes to further improve urban design by identifying characteristics that may improve or decrease mental health of those living and/or frequenting urban environments.

YOUR ENVIRONMENT AND YOU

INVESTIGATING PSYCHOPHYSIOLOGICAL RELATIONSHIPS BETWEEN HUMAN BEHAVIOR AND DESIGN CHARACTER

YOUR ENVIRONMENT AND YOU

Investigating Psychophysiological Relationships Between
Human Behavior and Design Character

A report submitted in partial fulfillment of the requirements for a
Master's Degree in Landscape Architecture

Department of Landscape Architecture and Regional & Community Planning
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ABSTRACT

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ACKNOWLEDGMENTS

To my family, for their unwaivering support in all aspects of my life and instilling an ethic of "no half-assing, only whole-assing" expectations in me.

To all the friends I had the pleasure of making during my tenure at this university, for keeping me grounded and prying me away from my computer when it was time to play as hard as we had worked.

To all the faculty and staff in the LARCP Department, for putting up with me for four years and never giving up on me, even when I thought I was a lost cause.

In summation, this report represents a landmark moment in my life, the beginning of the rest of it.

"Well, I don't know how many years on this Earth I got left. I'm going to get really weird with it."
- Frank Reynolds

BACKGROUND 1

In an indirect manner, one's physical environment may influence mental health (Evans, 1982). As people have begun to gravitate towards more densely populated cities and away from rural and more isolated lifestyles (WHO, 2015), an issue of mental health instability has begun to creep up in the public's health, and the new urbanized environments people are moving into may have something to do with it (Ulrich, 1981; Ulrich, 1984; Ulrich, et. al, 1991; Parsons, 1991; Parsons, et. al, 1998).

Over the past 55 years, data have shown a 20 percent increase in urban populations and a projected growth of over one-and-a-half percent annually for the next 10 years (WHO, 2015). This has led to an increase in development aimed at urban renewal and city center revitalization, with primary goals of increasing developmental density (Faulk, 2006). While many of these revitalization and new urban design projects put a focus on expanding both potential business and housing development, there are many issues cities and developers are not considering and often overlook. When pursuing these endeavors, it seems that those in charge are often not concerned with the types of environments they are creating for their end users, at least from a social and behavioral perspective.

A number of these large development undertakings, such as downtown revitalization projects, drive up demand for developable land, in turn placing pressure on the availability of outdoor amenity and recreational spaces in these urbanized areas (Groenewegen, et. al, 2006; Maas, et. al, 2006). However, the populace of highly urbanized areas may be affected negatively by the built environments that surround them (Ulrich, et. al, 1991; Parsons, 1991; Parsons, et. al, 1998; Jackson, 2003), and may find themselves at a greater risk of suffering from conditions such as stress and mental fatigue (Ulrich, et. al, 1991, Ulrich, 1981; Ulrich, 1984; Kaplan and Kaplan, 1989; Kaplan, 1995; Parsons, 1991; Parsons, et. al, 1998).

This notion of beneficial effects of green space is present throughout history, dating all the way back to early humans and the "prospect and refuge" theory (Appleton, 1975; Wilson, 1984; Groenewegen, et. al, 2006). During the picturesque movement and debates of the eighteenth century, one prominent theme of the landscape design style was the idea of improving health by achieving a therapeutic effect for end users (Olmsted, 1865; Thompson, 2011). The idea of incorporating healing elements into landscapes carried over into nineteenth century urban park movements throughout the United States, with Olmsted even advertising the plans for the Greensward in Central Park as "the antithesis of the confined spaces of the town" (Schuyler, 1986) and providing an antidote for those living in urban areas by "affording the most agreeable contrast to the confinement, bustle and monotonous street-division of the city" (Schuyler, 1986).

Studies have shown the importance of having access to and maintaining a connection with the natural environment (Ulrich, 1981; Ulrich, 1984; Maas, et. al, 2006; Abraham, et. al, 2010), meaning those environments with no or minimal human influence, and the benefits offered by natural settings in regard to reducing stress and mental fatigue among users. Dr. Roger Ulrich, a health design expert, has shown through his research that individuals experiencing stress tend to recover faster when encountering "unthreatening natural environments" and that "many urban environments will hamper recuperation" (Ulrich, et. al, 1991). Stephen and Rachel Kaplan, psychology professors, have postulated that characteristics such as noise, crowding, and disorientation, all factors commonly associated with busy urban environments, may play a role in increased mental fatigue (Kaplan and Kaplan, 1989; Kaplan, 1995). "Restorative environments" (natural environments that offer restoration properties to users), on the other hand, can play a role in the reduction of day-to-day mental fatigue through active engagement (Kaplan and Kaplan, 1989; Kaplan, 1995). Using regression analyses, the Kaplans and their colleagues found that an environment's capacity to foster understanding and exploration among users are the two most important factors in identifying environmental preferences (Kaplan and Kaplan, 1989).

More recent research has ventured further into gathering more quantitative data to better understand human perceptions and preferences through visual analysis. Brent Chamberlain and Michael Meitner's 2012 research explored the subject of visual preference by simulating different forestry harvesting technique visuals, showing that preferences for harvesting patterns changed based on relative complexity and original shape (Chamberlain and Meitner, 2012). Concurrently, Marc Berman and his colleagues have explored how human perceptions of a scene's given "naturalness" can be measured and predicted with relative accuracy by a machine-learning algorithm, based on a scene's low-level visual features (Berman, et. al, 2014).

Research has also shown that green spaces in urban environments have been linked to different aspects of human behavioral change. These studies have shown that responses to more abundant, well-maintained, vegetation in urban spaces include increased perceived levels of safety, reduced levels of fear, as well as having a positive effect on incidences of criminal activity (Kuo, et. al, 1998; Kuo and Sullivan, 2001).

With the issue of a new potential mental health risk resulting from prolonged exposure to heavily urbanized environments addressed, it would seem that policy reform might be the best approach to mitigating this issue (Groenewegen, et. al, 2006). However, with access to the types of environments known to reduce stress shrinking, due in part to urban renewal and redevelopment efforts becoming the new norm in city centers, we may need to begin to look at alternative strategies that can still address these issues. To incite such changes, more than just qualitative data must be collected to measure and back the claims made.

Medical fields have been utilizing different forms of biophysical feedback for many years in efforts to gain more quantifiable insight into human responses to external stimuli (Everly, Jr and Rosenfeld, 1981; Everly, Jr and Lating, 2013). The use of biofeedback is to show patients and researchers how the patients are responding to certain stimuli and allow the patients to make adjustments to their responses that would improve their overall health. This form of data collection is not limited to the research of the medical community; it can be applied in many different fields, particularly those that rely heavily on qualitative data but seek more insight from a

quantitative standpoint. Using biophysical feedback equipment in conjunction with geospatial information can open paths into new realms of research relating to human perceptions of different types of spaces, leading to more well-informed design and policy decision making strategies.

In the past few years, a new design trend has also led to more informed design and policy decision making efforts. Tactical urbanism encourages the public to instigate change in their cities and neighborhoods by showcasing their ideas in the form of temporary interventions. Working with city officials, these low-risk/high-reward projects spring up from grassroots efforts led by citizens that want to see their ideas considered in local planning challenges. The use of temporary interventions provides a sort of living laboratory that offers numerous benefits to communities, ranging from attracting potential investors, providing real time feedback on design strategies, and low commitments to both time and costs (Lydon and Garcia, 2015).

The social interactions that community spaces inherently provide can positively impact a person's well-being. Using tactical urbanism as a way to incite change can lead to a stronger sense of community, increased well-being among community members, and improve the physical state of the community by addressing and showcasing problems to city officials that have the power to make permanent changes. Often times it is the citizens who have the greatest knowledge of their communities, and once city officials can learn to utilize this great resource they may find that improvements to one aspect of a community has the potential to have a far broader influence than they had imagined.

HUMAN RELATIONSHIPS WITH THE NATURAL ENVIRONMENT

This leads to the research question: *How does the built environment affect stress-related responses in users because of its architectural, planning, and landscape characteristics?* With data showing urbanization rapidly increasing worldwide, it is important to reflect on previously conducted research in the realms of evolutionary biology theory, environmental psychology, and policies on design guidelines to better understand the underpinnings of human responses to environments. This ongoing paradigmatic shift that is isolating people from the types of environments early humans evolved in and alongside is nearly unprecedented, and research must be conducted to understand the new relationships humans as a species are forming with their environments.

RESEARCH OBJECTIVES

The objectives of this research proposal are to:

- Gain insight into human-environment relationships
- Understand design as an influence on (in)voluntary behavioral changes
- Test capacity of different design strategies to alter perception/behavior

LITERATURE REVIEW 2

The literature review can be broken into three sections: human relationships with the natural environment; different understandings of the human stress response; and design strategies aimed at improving design and policy decision-making efforts. Many of the cited works span two, and in some cases, all three areas. One of the primary goals of this project is to gain a better understanding of human perceptions, particularly those dealing with natural environments. An integral part in many of these readings is how perception functions as a basis of judgment, and that these judgments inform behavioral responses that can be seen across small and wide population samples, both endemically and at a cosmopolitan scale. After separating the literature into different sections and establishing the ubiquity of perception across the works, the review and analysis process can begin.

Given trends of people moving to more densely populated cities and away from rural and more isolated lifestyles, certain issues with the general publics' health may become exacerbated, and the environments people are moving into may be the cause. The result of urban environments designed with the intent of maximizing developmental density has been an increased stress on available community spaces that can offer a contrasting aesthetic to the built environments. A reduction in these types of environments can often lead to increased levels of stress among community members (Ulrich, et. al, 1991, Ulrich, 1981; Ulrich, 1984; Kaplan and Kaplan, 1989; Kaplan, 1995; Parsons, 1991; Parsons, et. al, 1998). Given citizens' limited input into the design process of their communities, there is little they can do to influence changes they want to see. The question driving this research is: *How does the built environment affect stress-related responses in users because of its architectural, planning, and landscape characteristics?*

HUMAN RELATIONSHIPS WITH THE NATURAL ENVIRONMENT

To begin, we must understand that human perceptions and preferences are inherent and have come as a result of the evolutionary process. E. O. Wilson, a biological theorist, is credited with introducing the theory of "biophilia", which he uses to describe the concept of an innate relationship humans have with nature. This relationship is the result of millions of years of human evolution where we were dependent on nature to provide for us. This led to the propagation of many human responses to nature and natural environments rooted in evolution and carried over to modern man (Wilson, 1984).

Before Wilson, however, Jay Appleton posed the first questions regarding whether specific landscapes, apart from aesthetics, had an impact on human behavior. He believes that any animal's most basic drive, even before procreation, is habitat selection. When visually confronted with a landscape that suits biological needs, Appleton wrote, all animals, including humans, elicit a positive response and experience pleasure, noting that biological needs should be thought of not only as food, but also prospect and refuge (Appleton, 1975).

Catharine Ward Thompson's research also delved into the historical aspects of the human-nature relationship. Thompson notes that throughout history and across cultures, humans have always considered having access to some form of nature as a fundamental need, not merely as an amenity as it is often viewed today. While noting that historic writers have always recognized the landscape as providing for our basic well-being, many of the challenges facing us today are a result of cultivating environments for our daily lives that present more harm and risks to our health than benefits (Thompson, 2011). While it may seem that public policy reform may provide communities with the best results (Groenewegen, et. al, 2006), further clarification of which policies may need to be changed must first be considered.

Dr. Roger Ulrich's research into public health design has been viewed as some of the initial and seminal studies into and standard for how humans respond to exposure to natural environments[1] (Ulrich, 1981; Ulrich, 1984; Ulrich, et. al, 1991). His research has shown that stress-reduction[2] rates tend to be higher when partici-

1 For the purpose of this study, natural environments may be defined as "those environments that are under minimal to no human influence at a given time".

2 For the purpose of this study, stress may be defined as "something that causes strong feelings of worry or anxiety" (Merriam-Webster Dictionary).

pants have access to, either visually or physically, natural environments as opposed to built environments.

Additionally, Ulrich found that the presence of natural elements in built environments played a role in stress-reduction as well (Ulrich, 1991). When exposed to built environments devoid of natural elements, such as trees and other forms of planting, recovery rates from stressful events were markedly slower in participants as opposed to those who were exposed to similar built environments with natural elements present (Ulrich, 1984).

While the complexity of both scenes remained relatively similar, compared to the effect of urban scenes, Ulrich noted the effect of exposure to nature increased "positive affect"[3], including feelings of affection, friendliness, playfulness, and elation, while simultaneously reducing fear arousal. In contrast, urban exposure had the effect of significantly increased sadness, while also holding attention of subjects less effectively than natural exposure (Ulrich, et. al, 1991).[4]

More recent research has aimed to quantify these perceptions and preferences. Brent Chamberlain and Michael Meitner's 2012 research explored the subject of visual preference by simulating different forestry harvesting technique visuals. After identifying three shape characteristics to investigate (geometric primitive [circle, square, etc.], complexity, and aspect ratio), subjects rated a series of images with varying degrees of the aforementioned characteristics. Results showed that preferences for harvesting patterns changed based on relative complexity and original shape of the harvested area. (Chamberlain and Meitner, 2012).

In a similar vein, Marc Berman's research into human perceptions of "naturalness" showed similar findings. In an attempt to quantify what aspects of natural environments produced salubrious psychological effects, Berman and his colleagues sought to delineate what is natural versus what is unnatural. This study quantified naturalness in two ways: "first, implicitly using a multidimensional scaling analysis and second, explicitly with direct naturalness rating" (Berman, et. al, 2014). The identified features that most related to perceptions of naturalness came from "density of contrast change, the density of straight lines, the average color saturation, and average hue diversity in the scene" (Berman, et. al, 2014). Using a machine-learning algorithm, they were then able to predict if a scene was perceived as natural or not based on the given features with over 80 percent accuracy (Berman, et. al, 2014).

DIFFERENT UNDERSTANDINGS OF THE HUMAN STRESS RESPONSE

In addition to qualitative data collection, researchers have been using different modalities to collect data on stress quantitatively. For more than 40 years, different professions have utilized biophysical feedback[5] tools to treat and research numerous maladies. The concept of using biophysical data collection in individuals is to construct a "feedback loop" in which the person can see the data collected being processed, and can then alter their habits to improve the biological activity they are engaged in (Everly, Jr and Lating, 2013; Everly, Jr. and Rosenfeld, 1981). Many different modalities have been used to try to understand, quantitatively, certain behaviors that are perception-based, such as stress responses.

Of the myriad different biophysical recording devices developed and used, two in particular have been used in efforts to quantify stress: heart rate variability (HRV) and electrodermal activity (EDA). The concept of using HRV as a method of measuring stress is rather straightforward; the autonomic nervous system acts, largely, unconsciously and regulates numerous body functions (heart rate, diges-

3 Positive affect refers to "the extent to which an individual subjectively experiences positive moods such as joy, interest, and alertness" (David Miller).

4 Another semi-related, but interesting note to be made about Ulrich's 1984 studies was that he found that hospital patients with views of nature from their hospital rooms showed quicker recovery times and used less pain-reduction medication.

5 For the purpose of this study, biophysical feedback can be defined as "a procedure in which data regarding an individual's biological activity are collected, processed, and conveyed back to the person so that he or she can modify that activity" (Everley Jr. and Lating, 2013)

tion, respiration, etc.) and is divided into two structures: sympathetic and parasympathetic divisions. These two divisions often operate in opposition to one another, with the sympathetic system controlling the "fight-or-flight" responses, and the parasympathetic promoting "rest-and-digest" functions. Citing the heart as a clear terminus for these two systems, one can infer through cardiac function what processes are occurring in the brain (Pocock, 2006).

Two primary indications of sympathetic nervous activity in cardiac function are increased heart rates and increased contractility, or force with which the heart beats. Physiologically, these changes are fairly slow and easily traceable with modern technology. Parasympathetic activity, on the other hand, operates by lowering the heart rate and changes occur much more quickly, making it difficult to trace (Pocock, 2006).

The other method of measuring stress responses, EDA, has been used as another way to measure sympathetic activity. Rather than relying on cardiac function, electrodes are worn on the skin and measure the electrical characteristics of the skin. For example, a sympathetic response of the skin often comes in the form of increased sweat gland activity, leading to reduced electrical resistance of the skin and increased electrodermal activity (Peek, 2003). Another study (Shi, et. al, 2007) objectively showed the value of EDA data as an indicator in cognitive load levels. The appeal of this form is that although responses are rather rapid for sympathetic activity, they are still relatively easy to measure (Everly, Jr and Lating, 2013). However, due to the somewhat erratic nature of the recorded responses, it can be quite difficult to read the data output from these biophysical devices.

Psychologist Russ Parsons' research supports Ulrich's theories of the natural environment playing a role in restoration and stress reduction. In his 1991 work, Parsons' findings showed that urban environments in fact produced stress among users, which he postulated was the result of an evolutionary response. This response was triggered by an absence of protection or support from the environment, which earlier humans had relied on, and as Appleton (1975) had written, is our most basic drive. Additionally, the increased stress hormones produced by exposure to the urban environment have both behavioral and long-term health effects (Parsons, 1991).

Furthering his research alongside Ulrich, Parsons and his team found that stress reduction could be measured using blood pressure, EDA, and facial electromyography (EMG) activity. They also showed that natural scenes not only had the capacity to reduce stress, but to improve behavioral responses to future stressors (Parsons, et. al, 1998).

Gary Evans' work "Environmental Stress" is a collection of research on how stress and the stress response can be modeled (Baum, Singer, and Baum) and how design as a dynamic process can affect the perceptions and how solutions can resolve "misfits" in the stress model (Zimring).

Baum, Singer, and Baum cite previous stress models (Selye, 1976; Lazarus, 1966) as the basis for their own. Seyle's "General Adaptation Syndrome" (GAS) is based on the idea that the body can cope with stress, but coping has costs for subsequent copings, leading to a depletion of one's adaptive reserves when exposed to prolonged or repeated instances of stress (Selye, 1976). Lazarus' believed that the responses to stress are determined by the degree to which an event is perceived as threatening, harmful, or challenging, with appraisal of stressors depending on numerous factors including attitude towards, prior experience with, and knowledge of the consequences of the stressor (Lazarus, 1966).

Baum, Singer, and Baum's model suggests that stressful situations can be understood by analyzing three components: stressors (environmental factors), transmission variables (situational factors), and recipients of stress (users). These environmental factors often induce stress by inhibiting one's ability to attain a goal or fulfill a need in a certain manner. For example, a complex route to a destination may be the stressor, while excess traffic and time constraints would be transmission variables acting on the driver, or recipient of the stress, trying to get to their destination, their goal or need (Baum, Singer, and Baum, 1982).

Using Baum, Singer, and Baum's stress model, Craig Zimring explores how built environments can influence social interaction, either positively or negatively, and how these affect the goals and needs of a space's users, particularly their level of desired social interaction. He notes that his research using Baum, Singer, and Baum's model relies on two suppositions: "stress results from dynamic processes in which people attempt to achieve a fit between their needs and goals, and what the environment provides. The process is dynamic because an individual's needs are highly variable over time and vary widely from person to person; environments vary widely as well" (Zimring, 1982).

Design, he wrote, can either propagate or thwart goals of social interaction, and when thwarting occurs and no efficient coping strategies are present, psychological and social consequences may arise. These "misfits" between goal and what the environment provides can often be a result of design decision-making (Zimring, 1982).

Researchers (Altman, 1975; Reizenstein, 1980) have suggested that interactions and designed environments may be organized by hierarchical spaces, where public spaces support impersonal contact and anonymous interaction, and private spaces support solitude and intimate interaction. Without access to the needs at these different levels, behavioral consequences (misfits) may arise (Zimring, 1982). Additionally, Zimring notes that some studies (Evans, 1980; Weisman, 1979) have also linked poor wayfinding and disorientation (common misfits in densely developed urban environments) as sources of anxiety among users. He concludes by stating that an understanding of design-related coping strategies people use to regulate interactions in various settings is a necessary direction for future research.

The research of David Halpern identifies different classes of stressors: chronic or acute, and in varying severity (major and minor). Most environmental stressors, he wrote, tend to be minor but chronic in nature, though the severity of some may lead to being described as major. Though he acknowledges that many of these stressors may be ephemeral (crowding, noise, etc.), they are often present in daily life. Stressors he names are: seasonal change, weather pattern variations (sunlight, temperature, barometric pressure, wind), air pollutants, and noise (Halpern, 1995).

While Ulrich, Parsons, Halpern, and Evans' arguments conform to the idea that built environment may increase stress with prolonged exposure, or at the very least inhibit stress-reduction rates, Stephen and Rachel Kaplan, professors of psychology at the University of Michigan, postulate another theory into the human-nature relationship.

Much of Kaplan and Kaplan's research has been into the Attention Restoration Theory (ART), which states that attention is separated into two components: involuntary attention, and voluntary (or directed) attention (Kaplan and Kaplan, 1989; Kaplan, 1995; Berman, et. al, 2008). The theory does not address stress reduction, but mentions the different states of attention a person can be in and the resulting mental fatigue[6] that result from extended periods of focus, or "directed attention". They hypothesized that by shifting attention elsewhere, such as away from mentally taxing tasks, the fatigue would not only subside, but opportunities for reflection and introspection may come along with the new focus of attention, which they refer to as "involuntary attention", or "fascination". The culmination of Kaplan and Kaplan's 1989 work focused on these "restorative environments" which have received continued interest (Kaplan and Kaplan, 1989; Kaplan, 1995).

The "restorative environment", as conceptualized by Kaplan and Kaplan, refers to "an environment in which the recovery of mental energies and effectiveness is enhanced" (Kaplan and Kaplan, 1989; Kaplan, 1995). Perhaps the biggest proponent of the importance of restorative properties in landscapes is famed American landscape architect Frederik Law Olmsted. Stephen Kaplan, citing Frederik Law Olmsted's sensitivity to the role of natural scenery in the restoration process in his 1995 work: "it employs the mind without fatigue and yet exercises it;

6 For the purpose of this study, mental fatigue may be defined as "a transient decrease in maximal cognitive performance resulting from prolonged periods of cognitive activity".

tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system" (Olmsted, 1865).

Further into Dr. Kaplan's research he proposed an integrated theory of stress-oriented restoration, initially put forward by Dr. Ulrich and his colleagues (Ulrich, et. al, 1991), but that permits a significant role for attention decline, which Ulrich had originally noted as a consequence of stress (Ulrich, et. al, 1991). Stephen Kaplan's 1995 work proposed an integration that delineates stress responses into two categories:

- stress response as an "adaptive mobilization to deal with a potentially negative situation", which is categorized into:

- *direct harm; and*
- *perceptual pattern or signal recognition (Kaplan, 1995); and*

- stress response as a "resource inadequacy", where one focuses on the resources necessary to deal with the situation one is facing, which is categorized into:

- *appraisal - by which it is determined available resources are insufficient;*
- *intuitional – which processes much faster than appraisal and is likely to be an unconscious decision; and*
- *gradual depletion – which occurs when a circumstance draws down a resource, leading to a stress reaction (Kaplan, 1995)*

Regardless of the type of stress response, Kaplan notes that the resource inadequacy raises questions as to what resources may be involved. Though he acknowledges a litany of potential factors, he proposes that directed attention fits the requirements of a resource that may be inadequate. He states "...directed attention is important because of the central role of selectivity in human information processing, and because of the significance of inhibition in managing behavior. It is also important for the very reason that it is fragile - it is susceptible to fatigue. As the weak link in the chain, it is a highly likely cause of [noted] behaviors" (Kaplan, 1995). He concludes that while the restoration of stress is absolutely desirable, directed attention restoration plays a significant role in human health as well. Further research conducted by Stephen Kaplan, as well as Marc Berman and John Jonides, aimed to validate Kaplan's Attention Restoration Theory (ART). The study compared the restorative effects on cognitive function resulting from interactions with natural and urban environments. ART states that nature garners attention in a bottom-up[7] manner, giving directed-attention mechanisms, described as a top-down[8], the chance to replenish. Urban environments, on the other hand, are filled with stimuli that attract attention instantaneously, requiring additional directed attention, making them less restorative. Their experiment showed that by walking in natural environments, or simply viewing images of natural scenes, directed attention abilities were improved, validating the attention restoration theory (Berman, et. al, 2008).

The benefits of green space in urban environments are also noted to stretch beyond the benefits of mental well-being. William Sullivan, professor and department head of landscape architecture at the University of Illinois-Champaign, has conducted numerous studies into the significance of green space in urban areas on human behaviors. Initial studies by Sullivan and his colleagues (Kuo, et. al, 1998; Kuo and Sullivan, 2001) were conducted in inner-city neighborhoods of Chicago and questioned the role vegetation can play in perceptions of safety, as well as potential impacts on incidences of criminal activity.

While law enforcement officials have argued against the case for "greening" inner-city neighborhoods, research showed decreases in criminal activity in more densely vegetated settings within inner-city neighborhoods. The researchers showed 100 residents of an inner-city Chicago apartment building manipulated

7 In bottom-up processing, a bodily response occurs first. This leads to an emotional response followed by the brain's cognition and subsequent directive for actions.

8 In top-down processing, the brain is active first. The brain's cognition leads to an emotional response followed by the brain's directive for action driving the bodily response.

photographs of an adjacent green space with different levels of tree cover, grass maintenance, and tree placement. Data showed strong preferences and an increased sense of safety in those images depicting greater tree density and moderate grass maintenance (Kuo, et. al, 1998).

Additionally, the researchers' findings uncovered that residents living in "greener" neighborhood areas have reported lower levels of fear, fewer incivilities, and less aggressive behaviors. Their study used incidents of crime to examine spatial relationships between vegetation and crime within inner-city neighborhoods. Across almost 100 apartment buildings with varying levels of nearby vegetation, data showed that buildings with denser vegetated surroundings showed lower instances of violent and property crimes (Kuo and Sullivan, 2001).

More recent research by Sullivan and his colleagues has been into stress-recovery in urban environments linked to densities of tree canopies. A study of 160 participants were put through the Trier Social Stress Test to induce stress, then were randomly assigned to watch one of ten three-dimensional videos of street scenes that showed varied tree cover, ranging from 2% coverage up to 62%. Participants then completed a Visual Analog Scale questionnaire at three points throughout the experiment. The researcher's analysis showed a positive, linear association between density of urban street trees and self-reported stress recovery, with relationships holding after accounting for gender, age, and baseline stress levels. The written narratives of the participants showed a similar but even stronger association (Jiang, et. al, 2014).

Additional research outside of the immediate realm of natural environments' influence stress responses has been conducted by Marc G. Berman. In 2012, Berman and his collaborators aimed to explore whether walking in natural environments could be beneficial to individuals suffering form major depressive disorder (MDD). Their study first tested the mood and short-term memory of the participants, who were suffering from MDD, to establish a baseline. Next, they were asked to recall an unresolved negative event in their life to start rumination before going on a nearly hour-long walk in either a natural or urban setting. Once the walk was completed, participants' moods and short-term memory were reassessed. After one week, participants returned to repeat the entire procedure, but walked in the other location (if urban setting for first test, then natural setting during the second test). Their findings showed significant increases in memory span after the walk in the natural environment relative to the urban environment. Participants also showed increases in mood, but these were not correlated with memory effects (Berman, et. al, 2012).

A recently published study by Berman and his colleagues aimed to quantifiably measure the effects of greenspace presence within the neighborhoods of large urban centers. Using Toronto, Ontario as the testing ground, the researchers examined satellite imagery and tree data from the city combined with self-reports of general health perception and mental illness from the Ontario Health Study. The results suggested that people living in neighborhoods with a higher density of trees along streets reported significantly better health perceptions. They found that having 10 more trees in a city block, on average, improves health perception in ways comparable to an increase in annual personal income of $10,000, or being seven years younger (Kardan, et. al, 2015).

STRATEGIES TO IMPROVE DESIGN & POLICY DECISION-MAKING EFFORTS

This body of research seems to insist that exposure to natural environments, or images of natural scenery, can have a dramatic impact on human behavior. However, this research is all for naught if it cannot be applied in a competent manner. Often times, it is the users of these environments who know what is best for them, or at the very least offer their suggestions for improvement. When faced with resistance from local governing bodies, this attitude has given way to new practices of inciting change in neighborhoods, led by the citizens themselves.

Recently, a new design trend has emerged in many neighborhoods and communities across the United States and other parts of the world called "tactical urbanism"[9] or "guerilla urbanism". This new trend challenges citizens to improve the livability of their neighborhoods by implementing changes at the street-, block-, and building-scales, instead of waiting for large-scale undertakings with non-guaranteed social and economic benefits. By beginning at these smaller scales, local actors can oversee this approach as a type of testing-ground, which can then be further evaluated before making significant political and financial commitments (Lydon and Garcia, 2015).

"Tactical urbanism is a deliberate approach to city-making that features the following five characteristics:

- *"a deliberate, phased approach to instigate change;*
- *an offering of local ideas for local planning challenges;*
- *short-term commitment and realistic expectations;*
- *low-risks, with a possibly high reward; and*
- *the development of social capital between citizens, and the building of organizational capacity between public/private institutions, non-profit/NGOs, and their constituents" (Lydon and Garcia, 2015).*

The benefits of tactical urbanism as a temporary laboratory of experimentation are numerous. It can give investors opportunities to test the feasibility of their ideas and allow for observation and feedback in real time. Additionally, when experiments are performed inexpensively, budgets are not exhausted and changes are not permanent, allowing for revaluation before any permanent decisions are made. Furthermore, this movement hinges on the direct involvement of the public and end-users, and making their voices heard by community leaders and officials. With different tactics ranging from unsanctioned, "guerilla" acts such as guerilla gardening, bike parking, and intersection repair, to sanctioned activities like street fairs, open streets, and pavement to plazas and many hybrid acts in between, the end goal remains the same: short-term action creating long-term change (Lydon and Garcia, 2015).

While no mention has been made of tactical urbanism interventions' capacity to influence public health, some overlap in ideas can be considered. The social activity and engagement that drives successful tactical urbanism ventures is cited as one of the many ways that landscapes can impact a person's well-being (Abraham, et. al, 2009; Altman, 1975; Reizenstein, 1980; Zimring, 1982). Additionally, multiple studies (Berman, et. al, 2008; Berman, et. al, 2012; Groenewegen, et. al, 2006; Jiang, et. al, 2014; Kardan, et. al, 2015; Kuo, et. al, 1998; Maas, et. al, 2006; Parsons, 1991; Parson, et. al, 1998; Ulrich, 1981; Ulrich, 1984; and Ulrich, et. al, 1991) have shown the benefits, both empirically and perceptually, that exposure to natural environments, or at the very least natural elements in urban environments, have on human health. Following Appleton and Wilson's theories of evolution-rooted preferences dictating responses to environments (Appleton, 1975; Wilson, 1984), tactical urbanism offers opportunities for people to improve their habitat in manners they find most fitting to increase their prospects and enhance their refuges.

9 For the purpose of this study, tactical urbanism may be defined as "an approach to neighborhood building and activation using short-term, low-cost, and scalable interventions and policies (Lydon and Garcia, 2015)

METHODOLOGY 3

PRE-TEST OPERATIONS

The extensive review of relevant literature was the first step in the investigation. The information collected from the literature served to inform the following steps of the methodology, but it was particularly useful in separating what was known from what was unknown information.

Few studies have been done using quantitative measures to understand human perceptions or emotional responses to one's environment, and even fewer have been conducted during the recent paradigmatic shift of renewed city centers and urban cores. Past studies (Berman, et. al, 2008; Berman, et. al, 2012; Groenewegen, et. al, 2006; Jiang, et. al, 2014; Kardan, et. al, 2015; Kuo, et. al, 1998; Maas, et. al, 2006; Parsons, 1991; Parson, et. al, 1998; Ulrich, 1981; Ulrich, 1984; and Ulrich, et. al, 1991) have shown how exposure to nature changes human behaviors as opposed to exposure to urban environments. However, given the current trend of maximizing developmental density in urban cores, coupled with the ongoing demographic shift away from rural areas and into more urbanized environments, new public health issues may arise from the absence of data and research on how these environments affect everyday users. This project aimed to provide insight into how design decision-making, as well as public policy, can be better informed and augmented to mitigate potential public health concerns among the growing urban population.

This research strove to understand what aspects of an urban environment affect stress-related responses in users. The methods that were used to investigate the claim involved field testing participants using biophysical feedback equipment that can output empirical data measuring physiological responses throughout these environments. Additionally, participants were asked to narrate their perceptions of the selected environments qualitatively. These two forms of data were used to analyze the testing environments and look for correlations between the environment and heightened responses of stress, both quantitatively and qualitatively.

To obtain data, participants were asked to walk along a delineated route that exposes them to different types of urban and neighborhood environments. The idea behind using different environments is to try to expose subjects to the extremes of built environment states (e.g., new, pedestrian-friendly urban streetscapes; neglected, infrastructure-heavy alleyways), as well as the inclusion of typical conditions, as determined by neighborhood character. These extremes are anticipated to elicit certain stress-related responses from users.

Careful consideration was given to identifying a suitable project site. To begin, a goal was to select a location that a large share of the participant population was not likely to have strong familiarity with. This step alone eliminated a strong candidate for a potential site. Next, the site had to include the aforementioned types of environments (recently developed, neglected, and "typical" conditions). Finally, the researchers required steady access to the site, both for site analysis documentation purposes as well as ease of access for the actual testing, both for the researchers and the participants. This step relegated the testing site to local area. Figure 3.01 shows the selected site with adjacent context. The site was selected because it matched all the criteria above and allowed for the delineation of a relatively simple route that would lead participants through all the desired environments.

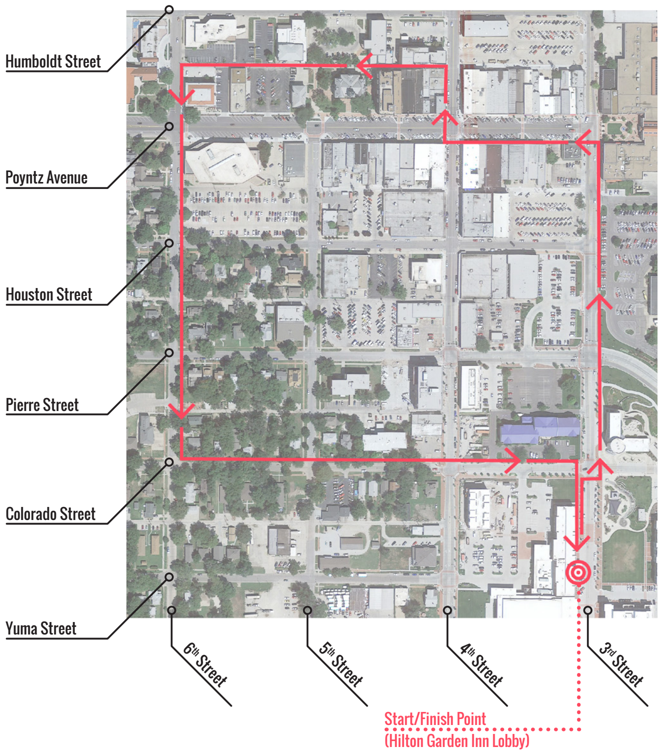

Figure 3.01: Walking Route. (Image by Author.)

After identifying a suitable location for testing, the next step was to conduct the appropriate site analysis. For the purpose of this study, the analysis primarily involved conducting an inventory of existing site conditions that may influence the behavior of the participants. Identifying the different characteristics across the site could be critical to determining factors that may influence the data collected from the participants.

Items inventoried are: adjacent building height; presence of vegetation; presence of light; delineated crosswalks; sidewalk walkability; and undesirable forms of infrastructure present, which were determined to be overhead electrical power lines, large waste collection receptacles, and potholes. Completion of the analyses took place before the study began. Other conditions that were controlled for were: temperature, relative cloud cover, wind speed and direction, and phase of the moon. Each condition was recorded on the testing dates. More information on site analysis can be seen in the following section: Site Inventory and Analysis.

Before conducting the field study, becoming familiar with the equipment was necessary. After consulting the literature and learning the availability of different sensors from campus resources, two types of biophysical feedback sensors were selected for implementation into the testing: electrodermal activity (EDA) and heart rate variability (HRV). These two methods were selected based on the relevance of the physiological feedback they record, as well as being minimally invasive to the participants.

In addition to the biofeedback equipment, a GoPro video recording device was also used by participants. This was used to record the field testing procedures and served as a secondary geo-spatial reference for the data collected by the biofeedback equipment. The GoPro device was mounted to the participants' heads using a minimally-invasive mount designed for extreme sports activities. The video recording from the GoPro provided a control for noise throughout each participant's walk, as well as acted as a reference to sort out any suspected anomalies in the biofeedback data.

Participant recruitment involved contacting professors and department heads of relevant programs, including: psychology, geography, kinesiology, computer sciences, architecture, landscape architecture, interior architecture/product design, and regional/community planning. Interested participants in the courses offered by these departments were asked to sign up either during in-class visits by investigators, or through email correspondence with the investigators. Once a large recruiting pool had been established a website link to a survey with time slots was sent to all who had expressed interest, where potential participants could sign up for time slots.

Those who volunteered were in contact with the investigators in the days leading up to their study time. Upon learning each individuals' availability using the survey, the participants were sent a set of provisional guidelines to be followed leading up to testing. These guidelines include information on food, drink, and drug consumption that are to be followed prior to their test (see Appendix A).

DEVICE SET-UP AND BRIEFING

As collateral for the equipment, the survey moderator required that participants leave behind either a cellular phone or debit/credit card and also Photo ID (K-State ID applicable). Their belongings were held in a locked safe and they were given 1 of 2 keys to open the box. The other key was held in the LARCP Departmental Office, which the investigators had access to after hours. Participants were then fitted with the biophysical equipment and seven minutes of baseline data were collected, five of which took place while the participant was sitting, while participants stood up and walked a short distance for the other two minutes[1]. Lastly, participants were fitted with video-recording equipment. They were also given a smartphone for their safety, should the participant had needed to contact emergency services or the survey moderator during their walk.

The skin conductance device was an Empatica E4 wristband that was attached by the survey moderator to each participants' left wrist (see Figure 3.02).

1 These baseline collection timeframes were recommended by collaborator Dr. Greg Norman and his graduate students at the University of Chicago for an ambulatory test such as this.

This device recorded EDA, HRV, blood volume pulse (BVP), acceleration (in g's), and skin temperature. For the purpose of this study, only the EDA and HRV datasets were analyzed. Another ability of this device was to mark "instances" using a button on the wristband. Participants were instructed to mark an instance if they were startled by something unexpected (e.g., a dog barking, tripping over an obstruction on the sidewalk, emergency sirens, etc.). Additionally, the survey moderator marked an instance after the baseline time period was over and the participant began their walk, and when they had returned at the conclusion of their walk.

Next was the heart rate monitoring device, which was a two-piece Polar V800 unit. The first piece was an electrode strap that participants wore directly below their breast plate. This piece requires direct contact with the skin, so participants self-administered this device with instructions for fitting given by the survey moderator. Individuals with a greater-than-normal amount of body hair required electrode gel for the sensor to function properly. This gel could be administered directly to the electrode strap, rather than to the skin, prior to fitting the device. The second component of the heart monitoring device is a watch. This watch was worn on the right wrist of all participants and paired with the electrode strap on the chest via Bluetooth. The watch device records and displays heart rate data from the electrodes, and also records GPS, which was used to monitor the participants' location temporally (see Figure 3.02).

The last piece of equipment to be fitted to the participants was the GoPro camera. The camera was head mounted (see Figure 3.02) to allow for hands-free operation by the participants and to increase the accuracy of the data (e.g. direction of attention, reaction to noise). Depending on weather conditions, gloves or mittens may have been worn to increase the subjects' comfort.

Finally, participants were given a map with directions (see Appendix B) and briefed on their requirements and safety procedures (no use of artificial light sources unless absolutely necessary, participants not allowed to carry a concealed weapon during testing, smartphone may be used to make emergency calls if necessary, etc.). Once ready, they began their route.

FIELD TESTING

Participants started the route at the entrance/exit of the Hilton hotel lobby. Once outside, they headed north on west side of 3rd Street. Once they had reached the intersection of Colorado and 3rd Street, subjects turned east and crossed 3rd Street on the south side of Colorado, before crossing Colorado on the east side of 3rd Street. Subjects walked north along the east side of 3rd Street to Poyntz Avenue. They then crossed 3rd Street, moving west, on the south side of Poyntz Avenue and continued west until reaching 4th Street, crossing over to the west side of the street. Subjects then turned north and crossed Poyntz Avenue and continued north until reaching the mid-block alley between Poyntz Avenue and Humboldt Street, where they turned west, continuing west for two blocks until reaching 6th Street. Staying on the east side of 6th Street, subjects turned south, crossing Poyntz Avenue again, and continuing south for three blocks until reaching Colorado Street. At the intersection of 6th Street and Colorado, subjects then turned east and continued for three blocks on the north side of Colorado. After reaching the intersection of 3rd Street and Colorado, subjects crossed Colorado, moving south and staying on the west side of 3rd Street, continuing to the starting point of the Hilton hotel lobby, completing a near one-mile loop. Please see Appendix B: 'Walking Route' for a visual reference.

Upon completion of the route, the equipment was disconnected from the subject and they could collect their personal belongings from the locked safe. Immediately following the field test, participants were brought to a different area of the Hilton hotel lobby for a post-walk questionnaire.

The first portion of the questionnaire asked participant-specific questions. These include: participants' gender; body type; socioeconomic and cultural background and upbringing; habitual drug use; physical activity levels; current medications; and adherence to aforementioned provisional guidelines on food, drink, and drug consumption leading up to testing. Additionally, they completed Cohen's

EQUIPMENT DIAGRAM

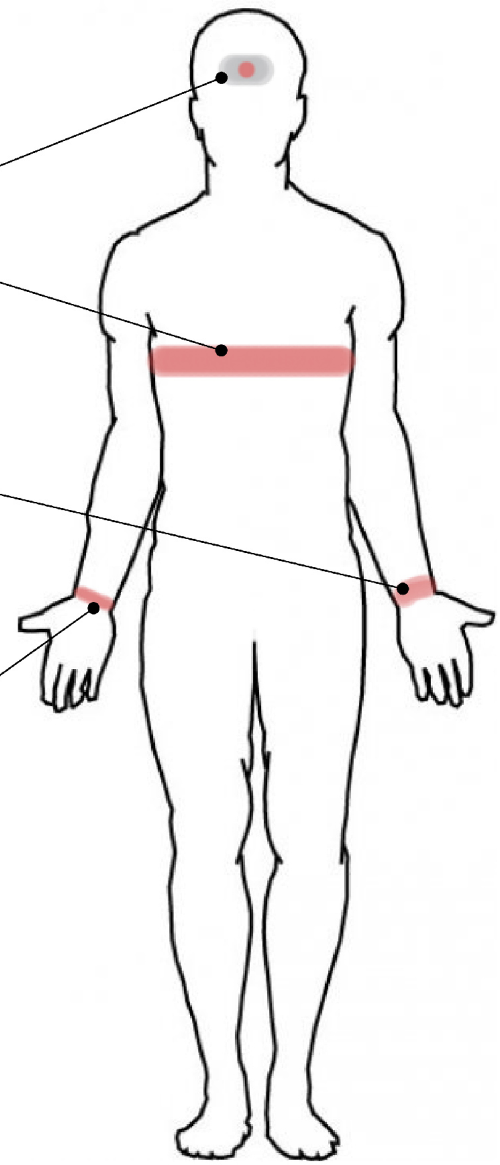

Figure 3.02: Equipment Placement. (Image by Author.)

GoPro Camera

- ? Record audio and video of first-person experience
- ? Difficult data to analyze and code; huge data pool
- + Secondary data source; identify anamolies in data
- − Potential stressor on participants; massive file sizes

Polar V800

- ? Collect heart rate (HR) and GPS data from particpants
- ? Some gaps in HR data; GPS data affected by buildings
- + Wireless HR and GPS data collection; minimally invasive
- − Strap tightness, body hair affect quality of HR data

Empatica E4

- ? Collect EDA (electrodermal activity) and other data
- ? Device fit and participants' movements may alter data
- + Records EDA, HR, and other measures wirelessly
- − Very sensitive to fit and movement by participants

? Rationale
? Challenges
+ Benefits
− Limitations

“Perceived Stress Scale” for researchers to understand each participant’s propensity to suffer from stressful behaviors. These variables would help identify potential variances between subjects in the data and will be kept confidential.

The second portion involved a mixture of each participants’ quantitative analysis and the narratives of their perceptions of the environments encountered along the route. Using photographs taken along the route, subjects were asked to quantitatively reflect on their experiences. Selection of the photographs was based on capturing the changes in environmental character as the participants would experience the route. Figures 3.03, 3.04, and 3.05 are examples of the pictures used during this section of the questionnaire, referenced spatially to a context map (Figure 3.06). Using a Likert scale, subjects denoted their perceived level safety or comfort along different segments of the route.

Next, using a randomized sample of images taken from the route, participants gave their qualitative responses in the form of written narratives. They were asked to elaborate on what aspects of the environment gave them feelings of comfort or discomfort while on their walk. The content of the narrative responses of the images was mined for their critical assessment of architectural, planning, and landscape characteristics that either increased or decreased the participants’ perceived levels of comfort. Particular themes to be sought out in the content analysis included: aesthetics, materials/textures, enclosure, color, lighting, safety, and navigation. Information drawn from this analysis, though tertiary to the sensor data and quantitative image data, may be compared with the two sets of quantitative data. This comparison may help the investigators determine design characteristics along the route that increase or decrease positive affect.

Within the last two portions of the questionnaire, participants were asked for their quantitative and qualitative evaluation of “altered environments” along the route. Using photo-editing software, photographs taken of the route were manipulated to portray different possible interventions that could be installed to change the character of the spaces. The photographs selected for alteration were chosen based on their content and the feasibility of the subject matter to be altered in the manner chosen (e.g., a photograph of a building with brick walls and moderate lighting conditions was selected to be altered by adding graffiti to the wall) Examples of interventions included: additional lighting, different screening techniques to impact and direct views, public art installations, and alternative forms of graffiti. These interventions were selected based on their presence being more common in urbanized environments.

The inclusion of the “altered environments” in this post-walk questionnaire is to understand how different design strategies may influence perceptions psychologically. It would be ideal to also test these altered environments for changes in physiological responses, but multiple constraints prevent us from doing so at this time. Participants evaluated these altered environments in the same manner as the evaluated existing conditions. At the conclusion of their evaluations, a debriefing statement will be attached for participants to read. To see the full questionnaire, see Appendix C: Post-Walk Questionnaire.

DATA ANALYSIS

At the conclusion of the field testing procedures, data analysis began. The Polar V800 unit provided us with raw data on heart rate and geolocation. The heart rate data came in the form of beats per minute with a one-hertz frequency (one measure per second) while the geolocation data came in the form of latitude and longitude coordinates, also measured at a one-hertz frequency.

Raw data recorded by the Empatica E4 wristband included heart rate, blood volume pulse (BVP), electrodermal activity (EDA), and skin temperature. Additionally, participants used “tags” on the E4 device to mark the exact times they started and stopped their walk, as well as marking any instances that may have caused a physiological response (e.g., an unseen dog barking, passing vehicle with sirens, etc.) The frequencies of each of these measures were one hertz for heart rate, sixty-four hertz for BVP, and four hertz for EDA and skin temperature.

Figure 3.03*: Alley. (Image by Author.)
* Images depict conditions experienced by participants.

Figure 3.04*: 6th Street. (Image by Author.)
* Images depict conditions experienced by participants.

Figure 3.05*: Poyntz Avenue. (Image by Author.)
* Images depict conditions experienced by participants.

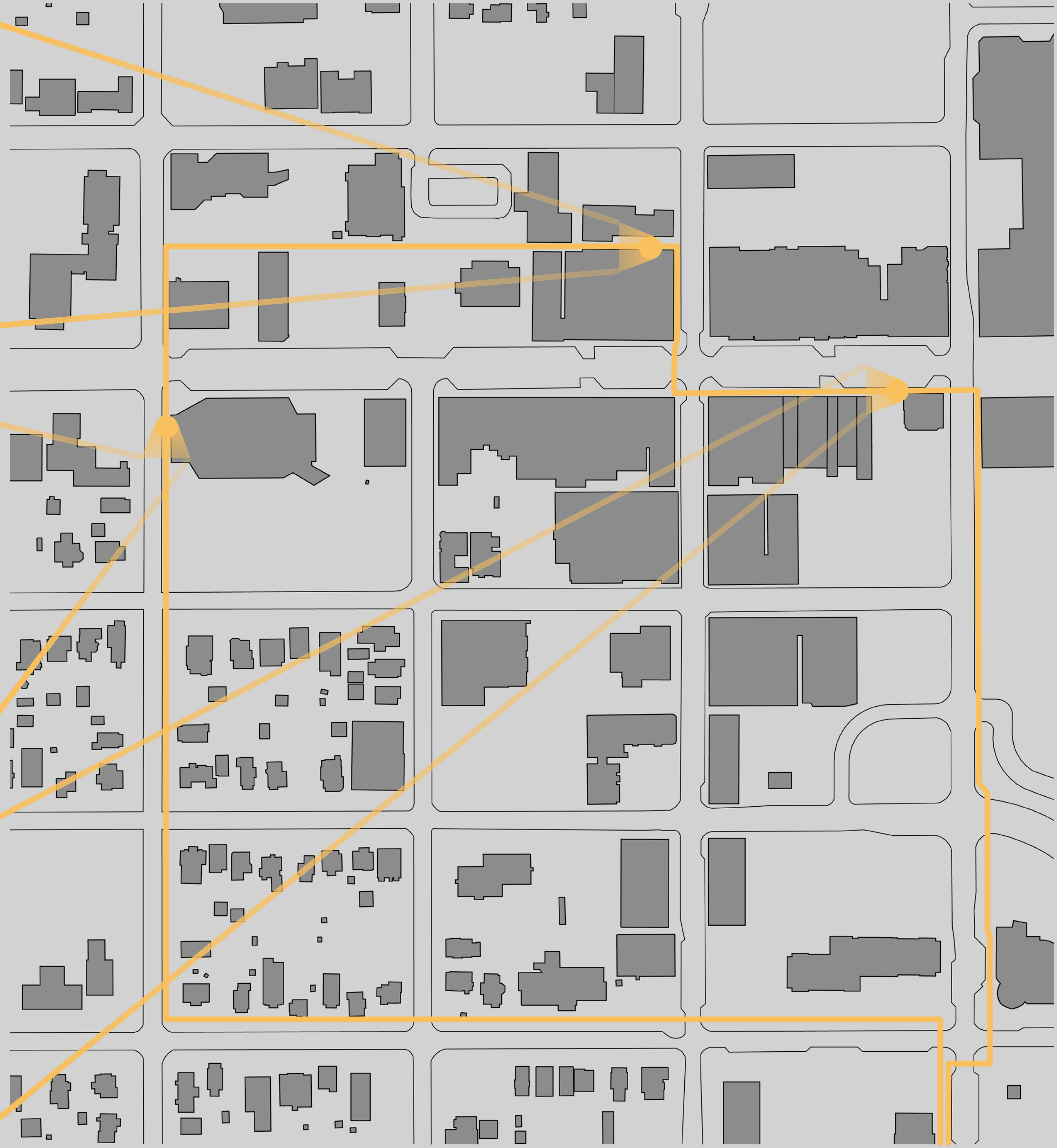

Figure 3.06: Site Photographs and Context Map. (Image by Author.)

After downloading the datasets from both Polar and Empatica's companion websites, master files were created to manage the data from each device and participant. Data were then organized within the master sheets to better accommodate for ArcGIS analysis. Appendices D and E provide further clarification and show the step-by-step process of organizing and formatting data.

Once all raw data from the Empatica and Polar devices had been formatted following the processes in Appendices D and E, a master file was created combining the data from both devices. Appendix F shows the step-by-step process of creating the combined master files. This step was taken to create a file that was compatible with ArcGIS and could easily translate the data into a geo-spatial format.

In ArcGIS, the master files containing the Empatica and Polar data for each participant were imported into a geodatabase for organizational purposes. Once the data were brought into GIS, a model was made to streamline the data analysis process. Appendix G shows the steps taken in GIS to translate the raw data into mapped geo-spatial points with the attached physiological data at each geo-spatial point. Mapping the data using geo-spatial points provided quantitative information on physiological responses elicited by subjects throughout their walks.

Initial analysis was done comparing the quantitative responses to the images of the route with the biophysical data collected during the walk. The hope for this form of analysis was to reinforce or contradict the biophysical data collected along the walk with the quantified preferences of the individuals. This could lead to further confirmation or questioning regarding the differences between psychological and physiological perceptual responses to environmental character.

SITE INVENTORY AND ANALYSIS 4

Conducting site analysis and inventory allowed us to make note of the existing conditions in the designated project site that may be relevant to or directly influence the outcomes of the study. For this study, identifying and inventorying characteristics that have been noted as potentially influential on outcomes can benefit the investigation by examining any correlations between these characteristics and the data collected in the field. However, no connections should be inferred directly from correlations between design characteristics and any changes in stress response drawn from the physiological data collected. In order to more accurately draw connections between behavioral changes and design character, an analysis was conducted of the quantitative data alongside the written qualitative analysis of the participants. Should the information in the written responses be thorough enough, and the physiological data in good condition, this may give us enough information to identify legitimate correlations between stress response and design characteristics.

Citing literature (Evans, 1982; Halpern, 1995; Parsons, 1991; Parsons, et. al, 1998; Ulrich, 1981; Ulrich, 1984; Ulrich, et. al, 1991) that has identified certain characteristics as having the capacity to either reduce, induce, or inhibit stress response regulation, a number of factors have been identified that will be inventoried and analyzed in this site analysis. These factors include: height of buildings in the study area; presence of vegetation; lighting; walkability; and undesirable forms of infrastructure present, which have been determined to be overhead electrical power lines, large waste collection receptacles, and surface drains.

These site characteristics were inventoried and/or analyzed prior to the field study taking place. It is of note that the time of testing may influence some of these factors, particularly the presence of vegetation, as most all non-evergreen or semi-evergreen plants have gone into their dormant states. It would be ideal to perform the field testing operations at a time when all plants (annuals, biennials, perennials, deciduous, semi-evergreen, and evergreen) are out of dormancy. However, given temporal constraints, this was not possible.

The idea of performing the field testing operations during different seasons will be made into a future consideration for further testing. With data collected from some or all of the seasons, a possible comparative analysis between the datasets taken from each testing session could take place, making note of variances in the data that may come from any seasonal changes.

The results of the inventory collection and analyses operations for each variable can be seen on the following pages.

OTHER VARIABLES AND CONTROLS

Noise levels can be seen as a comforting or discomforting factor in urban settings. However, similar to the issue addressed with enclosure, a more densely developed and populated urban setting is likely to produce more noise. As a result, individual responses to the level of noise during testing may also be a product of the environment in which the participant had their upbringing. Additionally, the absence of any noise has been known to create some discomfort in humans. To control for noise, which is a noted characteristic that may contribute to comfort or discomfort, audio taken from the GoPro video recording device must be analyzed alongside the biophysical data.

On the selected dates of testing, certain weather conditions were monitored as well. These factors include: temperature at time(s) of testing, precipitation, wind speed and direction, and relative cloud cover. Our colleagues at the University of Chicago have stated that these are the typical weather variables they record during their outdoor testing, but have noted little to no significant changes in the data collected with variable conditions.

LIGHTING

Lighting can have a powerful effect on human behavioral changes. The presence of lighting can be a calming factor to many, while prolonged absences of light can increase discomfort. Moving north along 3rd Street, the sidewalks are fairly well illuminated, and the number of light posts increases as you move towards Poyntz Avenue. Along Poyntz Avenue, light posts are regularly spaced on both sides of the street and an additional source of light comes from buildings adjacent to the street. Turning north onto 4th Street, light posts are still regularly spaced and providing good light, but after turning down the mid-block alley lighting is minimal until getting past the the large buildings. However, behind the courthouse building there are clusters of light posts illuminating the route, though the presence of light sources diminishes as one approaches 6th Street. Lighting conditions along 6th Street becomes quite ephemeral after crossing Poyntz Avenue, with pedestrians relying heavily on ambient light coming from housing, with the only permanent fixtures being in the form of large street lights at intersections. Conditions on Colorado Street are similar, with more lighting present as one approaches 3rd Street.

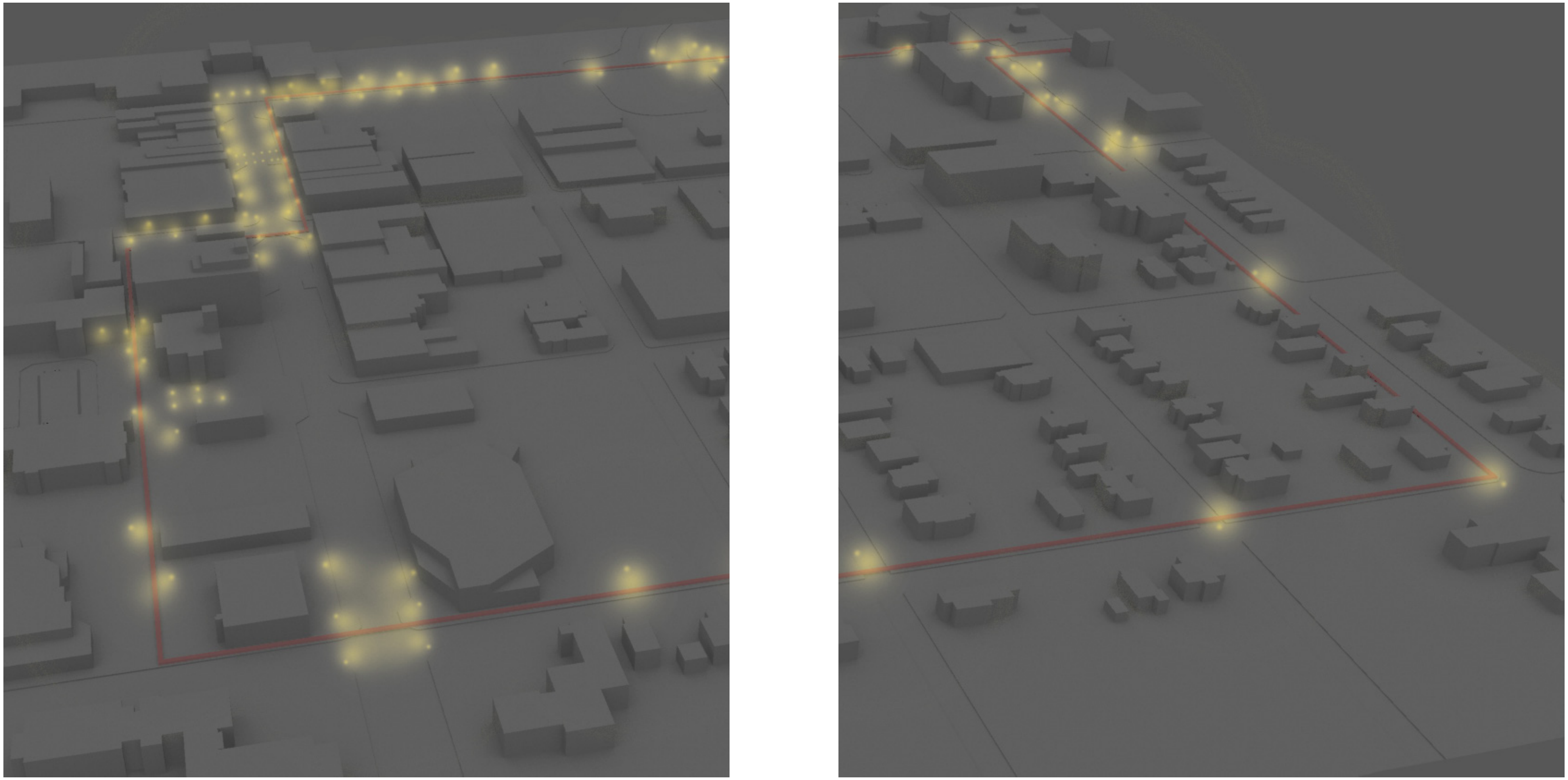

Figure 4.01: Lighting. (Image by Author.)

BUILDING HEIGHTS

Enclosure may also play a role in pedestrian comfort, though preferences may differ from person to person. This may be a result of the type of environment (rural, suburban, urban) the person was raised in and finds themselves most comfortable in, a product of nature versus nurture. Though variances in building heights and subsequent enclosure at the street level is much lower in this site than other highly urbanized cities, data may still show relationships between enclosure and relative comfort. The structures along 3rd Street range from one to three stories and vary in building mass. Additionally, there are surface parking lots that break up the buildings, reducing enclosure. Along Poyntz Avenue, structures are abutted along walkways and range in height from two to three stories. The mid-block alley participants will be walking down is enclosed by the tallest buildings along the route, creating a greater sense of enclosure than anywhere else along the route. Immediately after passing the tallest structure, however, the space opens up with further set back buildings that are lower in height. Moving along 6th and Colorado Streets, most homes are one or two stories in height, though buildings near the intersection of 3rd and Colorado Streets are greater in stature.

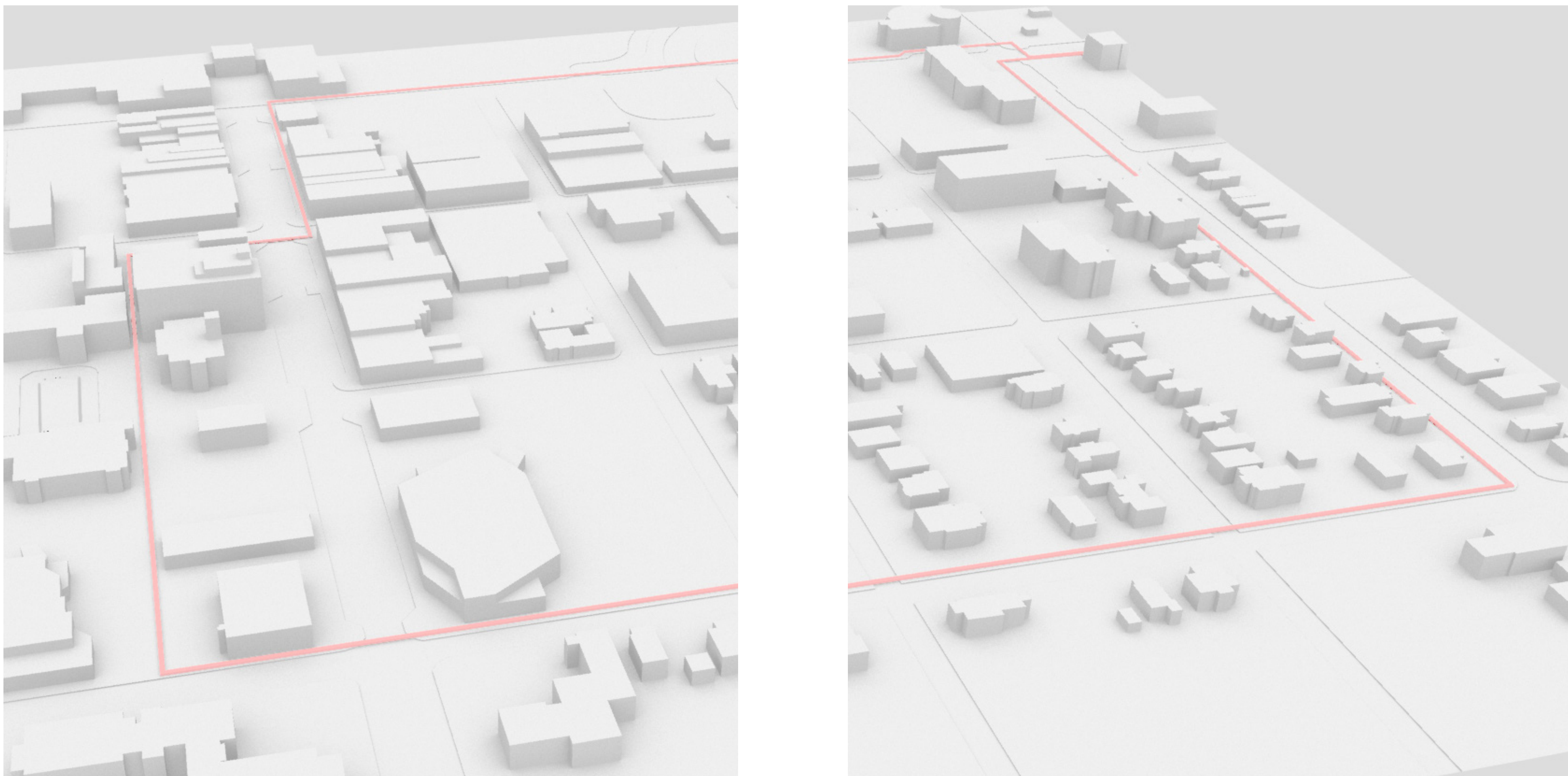

Figure 4.02: Building Height. (Image by Author.)

VEGETATION

As mentioned previously, the state of the vegetation along the study route may influence the findings of this investigation. A comparative study should be conducted to investigate the influence of "green" vegetation on the participants' results. Regardless of the condition of the vegetation, it is still important to conduct an inventory of the vegetation present along the route. Street trees and other forms of vegetation are present rather frequently throughout the route in various statures. The segments of the route that have undergone more recent development have younger, smaller trees while the neighborhood areas have larger, older specimen.

The presence of groundcover, particularly lawn grasses, is relatively high in neighborhood areas and in some areas of newer development. However, the more recently developed areas show a preference for smaller "pockets" of shrubbery that are contained in a variety of planters rather than groundcover. Areas with absences of vegetation are rather small and infrequent across the route.

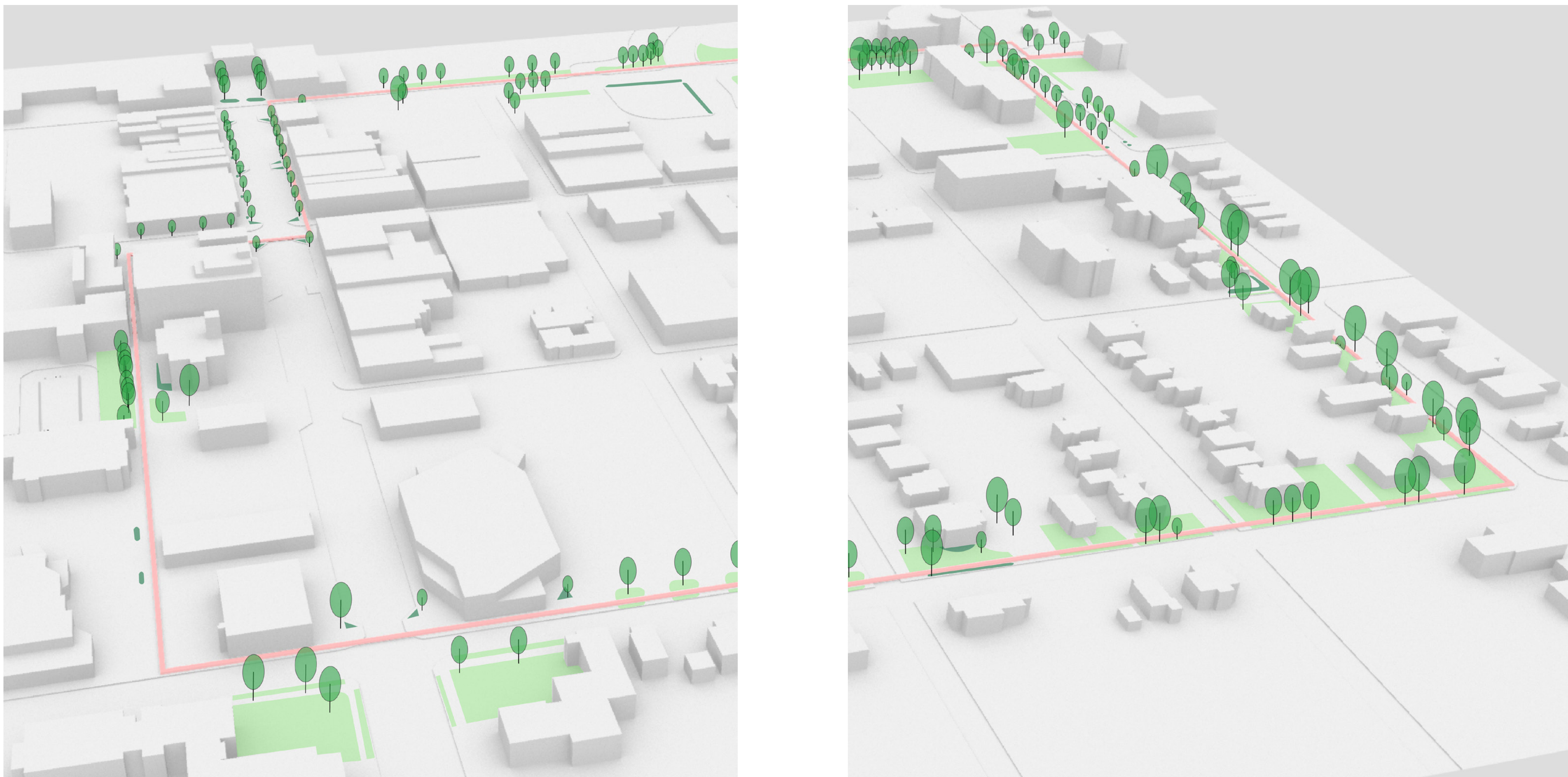

Figure 4.03: Vegetation. (Image by Author.)

WALKABILITY

Walkable environments have numerous salubrious benefits, spanning different realms. Using Sickmann's Sidewalk Walkability Evaluation methodology (see Appendix H), all sidewalks were evaluated for their walkability at the scale of one city block. Each block segment of the route was evaluated across five factors: vegetation present; site furnishing present; surface material and albedo; stormwater management infrastructure; and sidewalk quality. The "scores" of each factor were then compiled into a composite total, determining the walkability of each block.

The analysis revealed that the most recently updated sections of the route were the most walkable, due primarily to quality of sidewalks and presence of vegetation and site furnishings. The northwest corner of the route was deemed least walkable, based on a lack of vegetation as well as furnishings, though sidewalk qualities were fair. The blocks in residential neighborhoods fell in the middle. While vegetation was present, poor sidewalk quality lowered most of the scores. One consideration for these areas, is the absence of furnishings. While lighting was poor in most of these areas, the absence of other furnishing is not necessarily a detriment, given these are unnecessary characteristics in single-family neighborhoods.

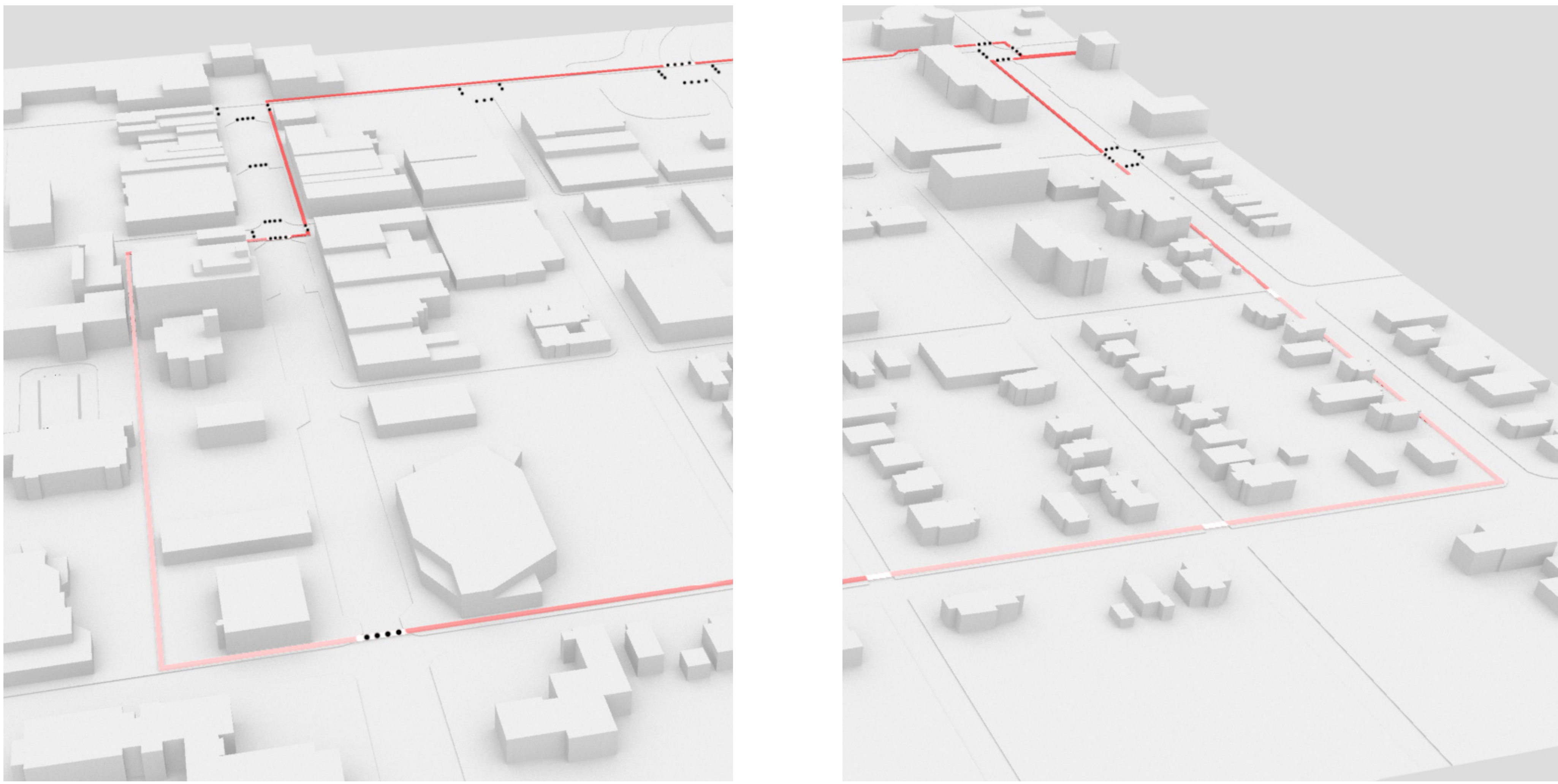

Figure 4.04: Walkability. (Image by Author.)

INFRASTRUCTURE

The presence of infrastructure in urban settings can create unpleasant impacts on sensory responses in pedestrians. Unsightly visuals, malodorous scents, and the presence and collection of unwanted precipitation are just a few byproducts of infrastructure in urban settings. The presence of these perceived nuisances can create feelings of discomfort and influence how pedestrians may utilize spaces that suffer from these effects. Along the study route, the greatest presence of infrastructure is in the mid-block alley north of Poyntz Avenue between 4th and 6th Streets. Upon entering the alley, participants will be faced with a great amount of overhead electrical infrastructure providing power to nearby buildings. Additionally, beneath the overhead power lines at the pedestrian level are broken walking surfaces, and large waste collection receptacles. Moving further down the alley, the presence of overhead electrical infrastructure is reduced but becomes present again nearing 6th Street. Along this segment, more waste collection receptacles are present. There is also some light overhead electrical infrastructure along 6th Street, but this ceases after crossing Houston Street.

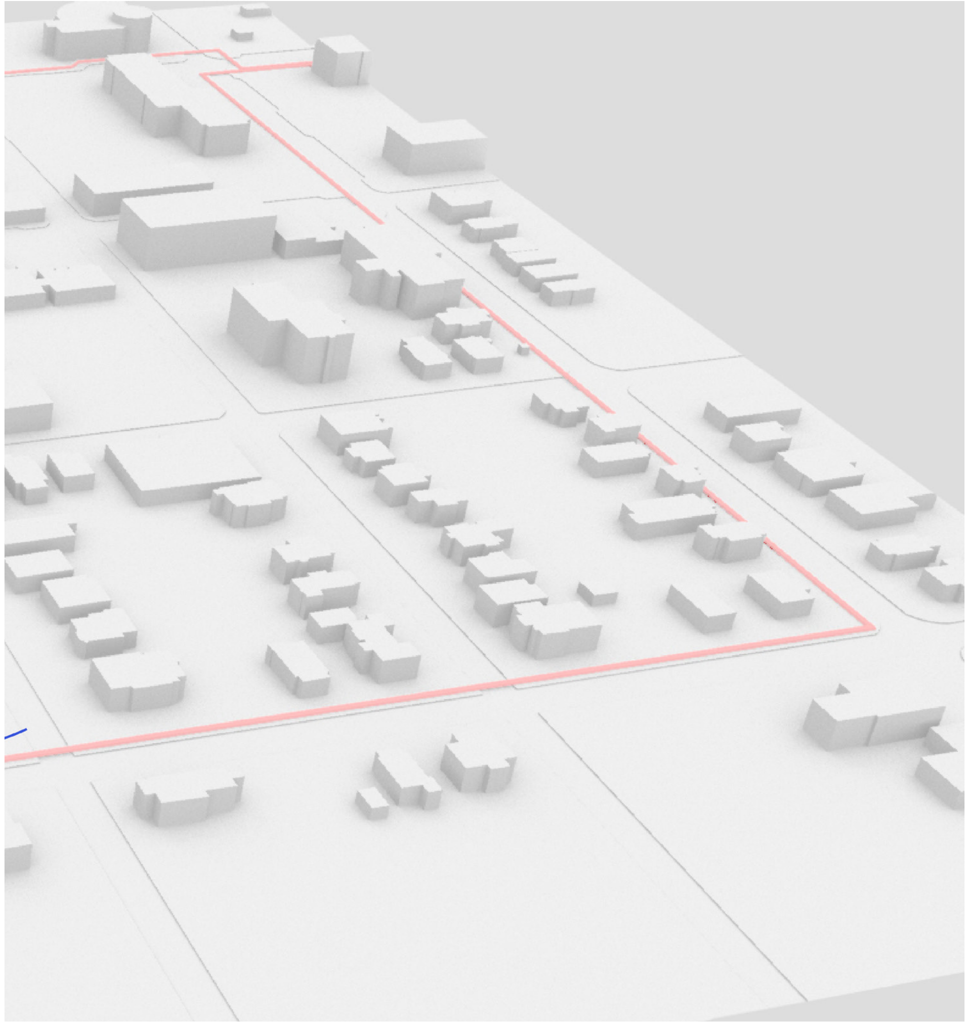

Figure 4.05: Infrastructure. (Image by Author.)

RESULTS 5

In an attempt to quantify "stress" in space, each participant was fitted with the aforementioned devices (see Chapter 3 - Methodology). The significance of the devices, as well as the post-walk questionnaire, was to provide the different sources of feedback deemed necessary in the attempt to quantify stress. Each device recorded a unique dataset, which was then categorized under either physiological or perception-driven data.

PARTICIPANT INFORMATION

The participants for this study were all students at Kansas State University. The study population was a mixture of females (81%) and males (19%) between the ages of 20 and 40 years old. The participant pool showed a range of cultural and socio-economic backgrounds, physical activity levels, and habitual drug use (caffeine and tobacco) across the population, providing a strong variation from participant to participant. Though the desired *n* value was 30 participants, due to time constraints and conflicting schedules, only 17 participants completed the testing, and three of the 17 were excluded due to incorrect test conduct, leaving the final participant count at 14, slightly less than half of the desired sample size.

PHYSIOLOGICAL DATA SIGNIFICANCE

The Polar and Empatica devices were used to collect the physiological data from each participant. The measures collected by these devices were heart rate, electrodermal activity (EDA), blood volume pulse (BVP), skin temperature, and geo-location (GPS). Data collected by the Empatica device that was used included EDA, BVP, temperature, and heart rate measures. Though the Polar device collected heart rate data, upon review the data was identified as incorrect and in poor condition. However, the GPS data collected by the Polar device was excellent, and was incorporated into this study. For this particular study, BVP and temperature were not factored into the results or analysis, though the values were kept in place for any future analysis. The three remaining measures (heart rate, EDA, and GPS) were

	VARIABLES	FREQUENCY	VARIATIONS @ 1/SEC
PHYSIOLOGICAL	Heart Rate	1/sec.	HR
	Electrodermal Activity (EDA)	4/sec.	MAX/MIN/AVG
	Blood Volume Pulse (BVP)	64/sec.	MAX/MIN/AVG
	Temperature	4/sec.	MAX/MIN/AVG
	Latitude	1/sec.	Lat
	Longitude	1/sec.	Lng
	Audio	– –	MAX/MIN
	Video	30/sec	– –
ENVIRONMENTAL	Outdoor Temperature	per participant	– –
	Wind Vector	start of test	– –
	Phase of Moon	nightly	– –
SITE	Inventory and Analysis	– –	– –

* used in analysis

Table 5.01: Variables collected. (Table by Author.)

identified as variables absolutely necessary to determine where physiological stress occurred in space. Table 5.01 shows all variables collected and those that were used in this study.

Heart rate was a selected measure based on the heart being a clear terminus for both sympathetic (fight-or-flight) and parasympathetic (rest-and-digest) nervous activity, allowing one to observe cardiac function and infer what processes are occurring simultaneously in the brain (Pocock, 2006). Another factor in selecting heart rate as a variable to record stress was the clarity of the data, as well as the ability to measure it effectively in an unobtrusive manner.

EDA was utilized as a secondary way to measure sympathetic nervous activity. Rather than measuring cardiac function, EDA measures electrical characteristics of the skin. A common response of sympathetic activity is an increase in sweat gland activity, thereby reducing electrical resistance and increasing electrical activity (Peek, 2003; Everly, Jr and Lating, 2013). One caveat of relying on EDA, however, is the mercurial nature of the data and the devices recording the data. Proper fitting is an absolute necessity to minimize the mobility of the device's contact point(s), which was compounded even further by the ambulatory nature of this test.

The final measure, GPS, provided latitude and longitude coordinate points at one-second intervals throughout the walk. These coordinates could then be plotted geospatially as points, with the physiological responses recorded at each point listed as attributes of the geospatial point. Collectively, the physiological measures were compiled into a “stress” measure that could be then be evaluated in space using the GPS data.

PERCEPTION-DRIVEN DATA

By recording video using a head-mounted camera, researchers would be able to identify anomalies in data, control for noise present along the route, and gain a sense of the first-person experience for each user. The first-person experience provided opportunities to see what drew participants’ interests while on the walk. Unfortunately, due to constraints of time and limited resources, this data was not analyzed for this study.

Information from the survey, namely background data and the qualitative image evaluation, were the other form of perception-driven data to be used in this study. Analysis of participant’s backgrounds and their evaluation of spaces was to be conducted to look for any correlations between personal information and how these influenced perceptions of space. However, with limited time to complete the project and the primary focus on the relationships between physiological responses and space, this step was not taken.

GIS ANALYSIS

The raw data outputs from GIS (see Appendices D through G for steps of formatting, processing, and handling of data) revealed no significant qualitative correlations between heart rate variability and location along the route, as well as no correlations between inventoried items (see Chapter 4 – Site Inventory and Analysis) and heart rate variability (see Figure 5.01).

However, there were some noted qualitative correlations between EDA and inventoried items. Moving east along Colorado Street, EDA levels across participants gradually increased up to the intersection of 3rd and Colorado Street. Along Colorado Street the presence of lighting is lower than on any other segment of the route before an increase between 4th and 3rd Street (see Figure 5.02). Figures 5.03 through 5.06 depict the relative environmental conditions from different spaces along the walk. The section references can be seen in Figures 5.01 and 5.02.

IMAGE ANALYSIS

The results from the image evaluation can be seen in Table 5.02. Many of the ratings followed closely with what was anticipated. For example, Figure 5.08 shows a spaces with low levels of light were consistently evaluated as “unsafe”, while Figures 5.09 and 5.10 depict relatively well-lit, urban scenes that were evaluated as “moderately-safe” and “safe”.

The results of images that were altered (see Table 5.03) to include interventions followed closely to what was anticipated as well. Figure 5.11 was altered to include a form of graffiti that is somewhat typical in urban environments. Results indicate participants deemed this space as less “safe” than the original images that

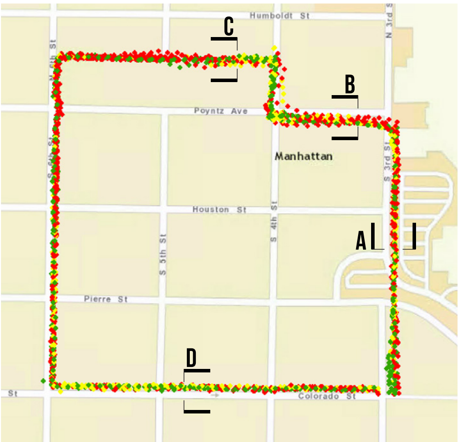

Figure 5.01: Heart Rate Data. (Image by Author.)

Figure 5.02: EDA Data. (Image by Author.)

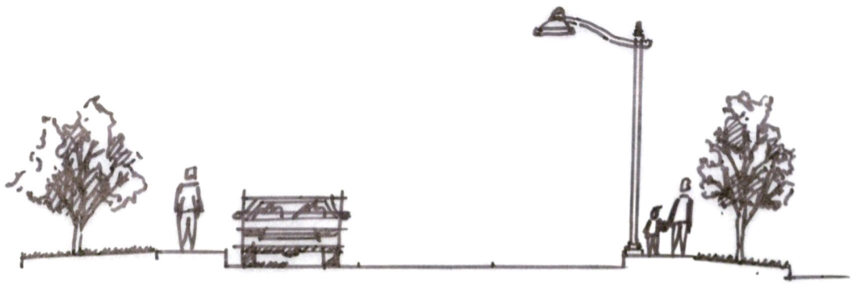

Figure 5.03: Section A. (Image by Author.)

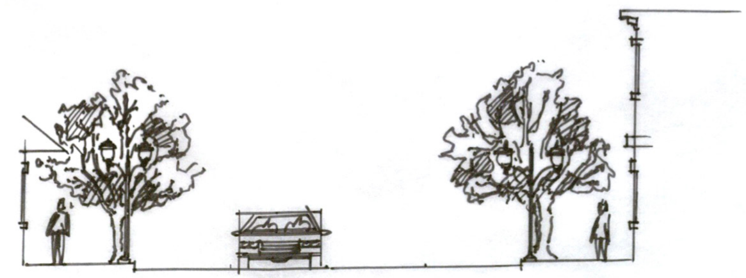

Figure 5.04: Section B. (Image by Author.)

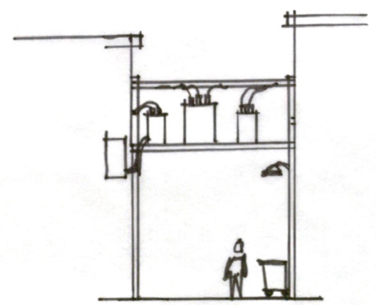

Figure 5.05: Section C. (Image by Author.)

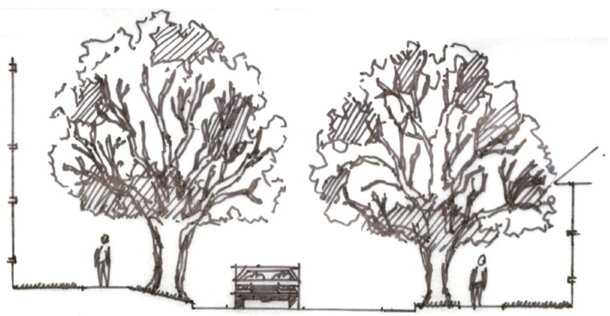

Figure 5.06: Section D. (Image by Author.)

did not include interventions. Figure 5.12, which depicts the alley space with an overhead screening element and additional light was viewed as more "safe" than the original image by the majority of participants. Figure 5.13 shows an installation of public art, and though the average rating was slightly lower than the original image, there is no statistical significance in the change.

After completing GIS analysis, data from the post-walk questionnaire was evaluated in Excel (see Appendix I) alongside the GIS data. Results from the questionnaire showed a shared preference among participants for certain images over others. The mean rating values of all participants for each image were then compared alongside GIS data from each image's "zone". These "zones" were delineated in GIS based on where each image in the survey was taken along the route (see Figure 5.07 for zones). The data from all participants within these zones was then isolated (see Appendix I) for a comparative analysis with the image ratings.

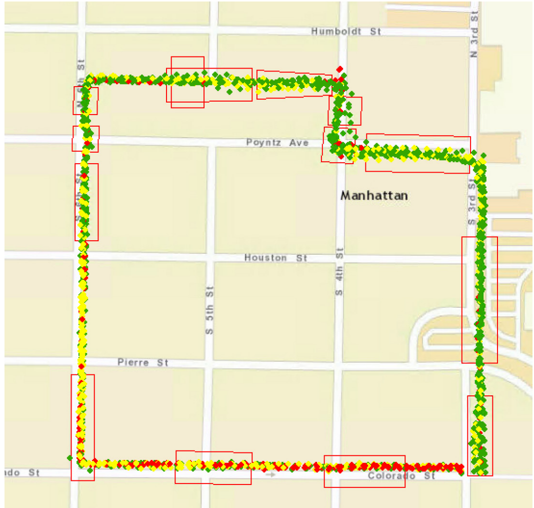

Figure 5.07: GIS Zones. (Image by Author.)

The analysis revealed some, albeit limited, statistical correlations between image preference ratings from the survey and elicited physiological responses. Table 5.04 shows the correlation statistics between rated images and EDA levels measured in the corresponding zones. Figures 5.04 and 5.10-5.14 represent the highest correlation values. A value of 1 or -1 indicates a perfect correlation, while ranges between (-).3 and (-).7 indicate a moderate correlation, and values below (-).3 indicate weak to no correlations. The EDA data collected shows a range of correlation from moderate (-.569) to almost none (.005), while heart rate data also shows a range from moderate (.588) to almost none (-.02).

RESULTS

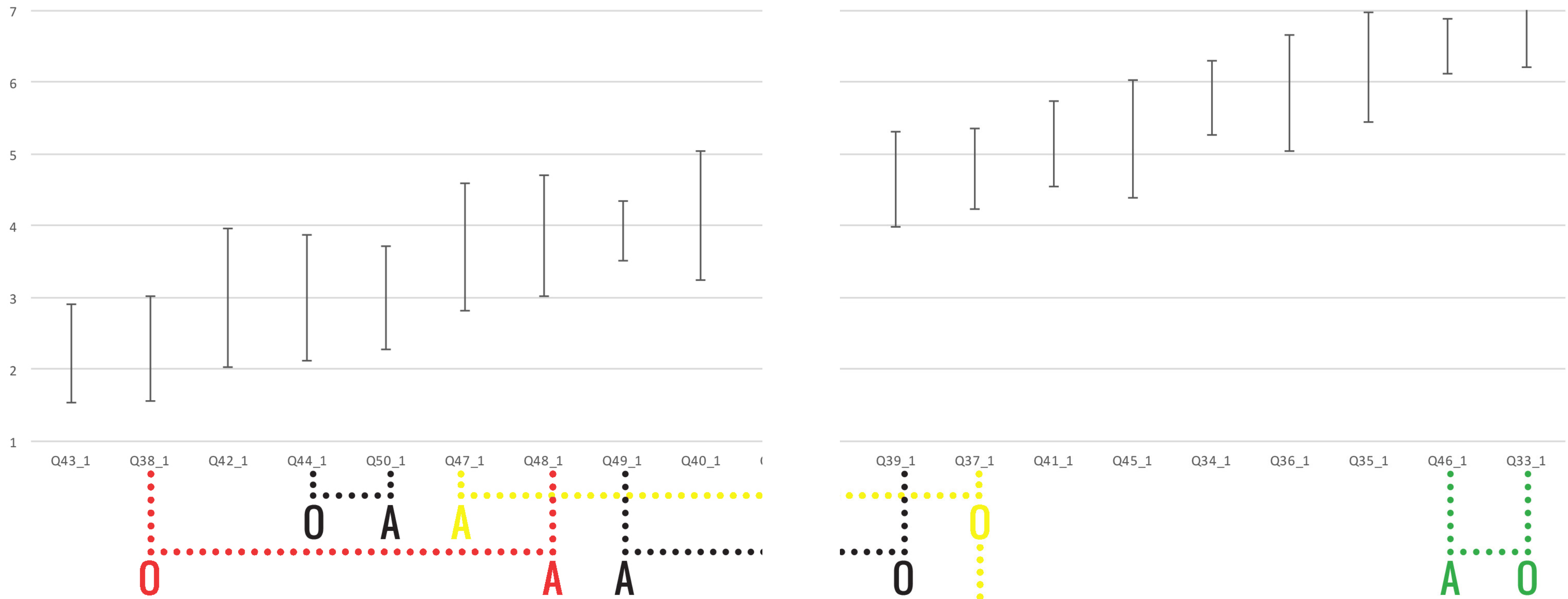

Table 5.02: Image Ratings - Original. (Table by Author.)

Figure 5.08: Image "Q38_1". (Image by Author.)

Figure 5.09: Image "Q37_1". (Image by Author.)

Figure 5.10: Image "Q33_1". (Image by Author.)

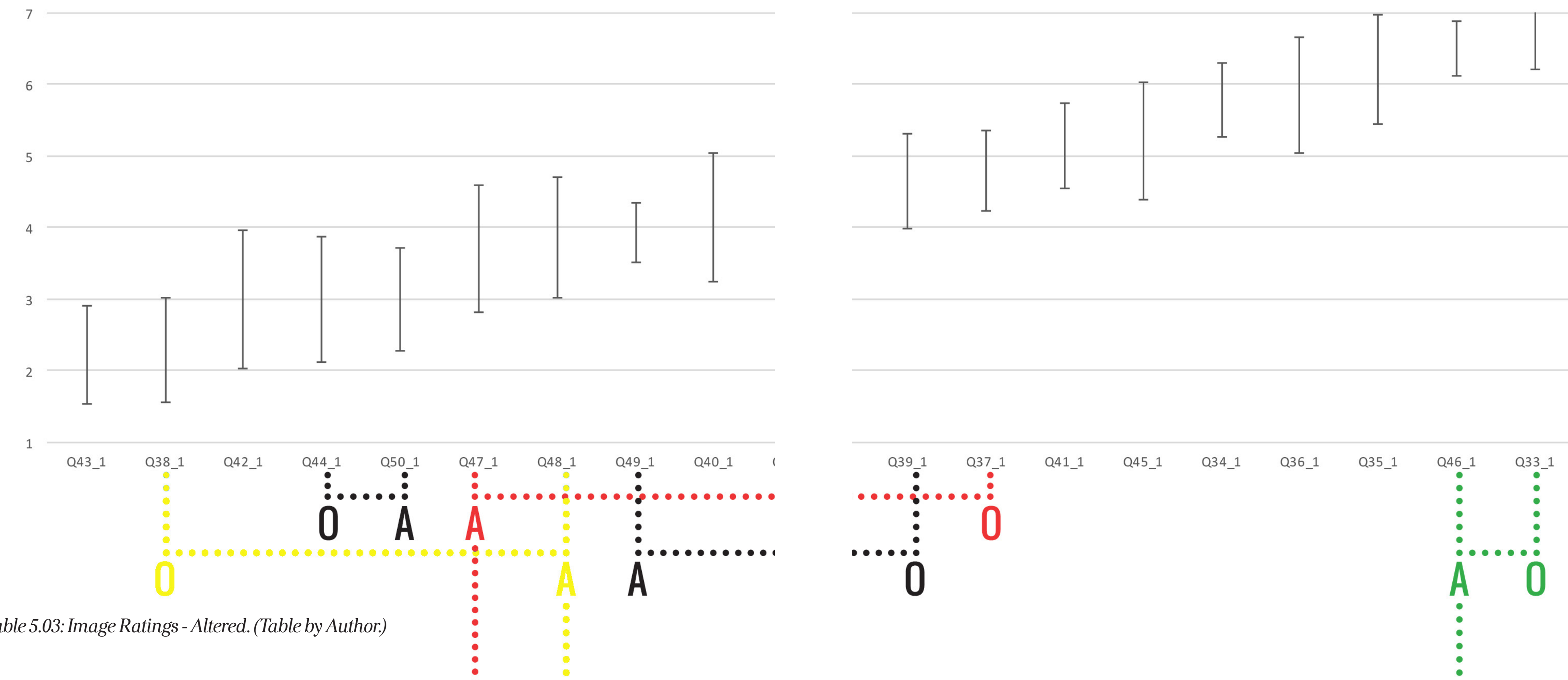

Table 5.03: Image Ratings - Altered. (Table by Author.)

Figure 5.11: Image "Q47_1". (Image by Author.)

Figure 5.12: Image "Q48_1". (Image by Author.)

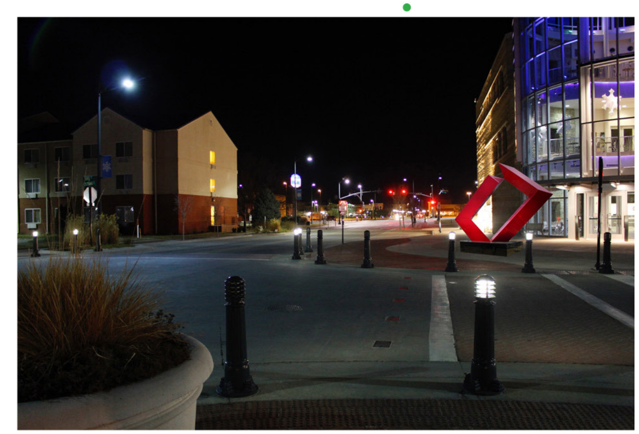

Figure 5.13: Image "Q46_1". (Image by Author.)

RESULTS

The actual results showed some consistencies with what was anticipated, namely the physiological response to presence of lighting and the feeling of safety. One inconsistency between anticipated and actual, however, was the physiological responses to the segment of the walk that lead participants down an alley. This was where the negative physiological responses were anticipated, but the data revealed a wide range of responses, with most being moderate to high. Data from the questionnaire showed a common discomfort shared by participants when evaluating the images of the route that included segments of the alley, but the correlations between physiological data and evaluations were rather weak.

It is also important to note that the statistical significance of these results is minimal, given the number of participants (fourteen) tested. Once the desired *n* value of 30 is reached, further analysis of the additional participants would need to be conducted. Results after reaching the desired *n* value would have much more significance statistically than what current results show.

	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40
Image Rating/ EDA Correlation	0.20620376	-0.1059112	0.31406748	0.29945042	0.37315145	-0.2170348	0.05522909	-0.4278152
P-Value	0.47939964	0.71858358	0.27415626	0.29829667	0.18880888	0.45608331	0.8512504	0.12701749

Table 5.04: Correlation Statistics. (Table by Author.)

Figure 5.09: Image "Q37_1". (Image by Author.)

Figure 5.14: Image "Q40_1". (Image by Author.)

Figure 5.15: Image "Q43_1". (Image by Author.)

RESULTS

	Q41	Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50
52	-0.012061	-0.2069882	-0.487055	-0.1360879	0.12769321	0.1206939	0.2353148	0.00539095	-0.4370479	-0.0526121
49	0.96735849	0.47769224	0.07733472	0.64272752	0.6635427	0.6810729	0.41802851	0.98540725	0.11813979	0.85823236

Figure 5.16: Image "Q44_1". (Image by Author.)

Figure 5.17: Image "Q49_1". (Image by Author.)

Figure 5.18: Image "Q50_1". (Image by Author.)

DISCUSSION 6

RESULT SIGNIFICANCE

As noted in the previous chapter (Chapter 5 – Results), the actual results did not entirely align with the hypothesis that different environments played a role in affecting human behavioral changes, though there were some exceptions. Beginning with the anticipated results, the particular route was chosen based on early anticipated results. Expectations were that the segments of the route that had recently undergone redevelopment would make participants the most comfortable. The inclusion of the segment that leads participants through the alley was intended to incite discomfort and, to an extent, question the safety of the route. However, these two examples were not necessarily the case.

Though some of the trends in the data showed a correct anticipation, namely in the impact of lighting on participants' feelings of safety and comfort, the extent to which it affected them was not anticipated. While the heart rate data did not show any trends towards environmental factors noted in the inventory and analysis section, there seemed to be a moderate (qualitative) correlation between the presence of lighting and electrodermal activity (EDA). After reviewing the written narratives of participants that asked them to elaborate on what aspects of the experienced spaces influenced feelings of comfort, many did in fact confirm that the presence of lighting and other pedestrians had the greatest impact on feelings of safety and comfort. Of note, however, is that while EDA levels appeared to increase in areas of lower light, some of the highest levels of EDA were near the end of the route where lighting conditions improved greatly compared to the rest of Colorado Street. One hypothesis about this phenomenon is that participants began to anticipate the end of the walk was near, which led to increased excitement, keeping EDA levels high, though this is purely speculative.

In future testing, it would be beneficial to test this hypothesis by having a handful of participants walk the route in the opposite direction and see if the results followed the same trend of increased EDA levels when nearing the end of the route. If the results from those who walked the route in the opposite direction indicated that EDA levels did not increase when nearing the end, this would quickly prove this hypothesis to be false.

The response to lighting was rather intriguing, and though the study was designed to elicit responses due in part to the absence of sunlight, the results were somewhat unexpected. The design character of the alley was rather unsettling and discomforting (as shown in the image ratings), but it would seem that the presence of light has a greater effect on physiological responses than the overall design character of a space. For future considerations, it would appear that lighting may need to become more of a primary focus and used as a supplement to the rest of the design.

While there seemed to be correlations, though purely qualitative, between the presence of light and physiological responses, the impacts of other inventoried items and factors noted in previous studies (Berman, et. al, 2008; Berman, et. al, 2012; Halpern, 1995; Jiang, et. al, 2014; Kaplan and Kaplan, 1989; Kaplan, 1995; Kardan, et. al, 2015; Ulrich, 1981; Ulrich, 1984; Ulrich, et. al, 1991;) were not as significant as what was anticipated. This may be the case because of the condition of some of the factors within the study environment. The absence of light and much of the vegetation, due to dormancy, are two factors that were viewed as extremely influential on potential outcomes based on their ability to impact spatial experience.

Though the study was always planned to take place at night in order to elicit higher responses, of noted importance to this project was the impact of vegetation and other "green" elements because of the "restorative" properties they offered, according to Dr. Stephen Kaplan and others (Berman, et. al, 2008; Kaplan and Kaplan, 1989; Kaplan, 1995; Kardan, et. al, 2015). The timeline of this study aligned with the dormancy period of many deciduous and non-evergreen plants. This essentially removed a factor from the study environment with known "restorative" qualities. Considering this, it would be of great interest and benefit to this study if a similar testing procedure was carried out during periods where local vegetation is not dormant, and participants could experience the walk with vegetation present.

Another note to consider is that while this study aimed to understand how “urban environments” influenced behavioral changes in participants, the testing environment is not particularly urban at all when compared to other larger metropolitan areas. As a result, data collected from a truly urbanized environment may produce radically different results. However, many other external factors would likely need to be accounted for that were not present in this study environment in order to truly understand what the sources of discomfort are in tested participants.

As previously mentioned, the actual results showed little qualitative correlation between physiological responses and inventoried factors, as well as some, albeit limited, correlation between feelings of safety based on image ratings and physiological responses, these results could potentially be skewed. While the dormancy of vegetation along the route may have some influence on results, there are other factors dealing with the study design itself that may influence data. For example, the results to date include data from fourteen participants. This number is not nearly enough to make any legitimate assumptions from what was collected and analyzed. By increasing the sample size, even if the results did not change, clearer assumptions and arguments could be made from what was collected.

Another study design factor may be in the biophysical instruments used to record the physiological data. Though the accuracy of the devices was rather strong, different modalities of biofeedback may be better suited for this study. However, finding accessible equipment with ambulatory capabilities can be rather difficult and often in cases where it is possible, the devices are extremely cost-prohibitive if they are to be bought. Something else to consider is the sheer volume of data that is produced by these devices that will need to be sorted, formatted, and analyzed in order to be legible and of any use to the researcher(s). In addition to EDA and heart rate, facial electromyography (EMG) and electroencephalogram (EEG) are two other biofeedback devices commonly used in behavioral testing, though finding ambulatory devices for these may prove difficult.

The other variables noted in Table 5.01 (page 67) that were not factored into this analysis may not play as significant of a role in determining the influence of the environment on participants as was initially expected. Of those not used, the factors with the most potential to influence outcomes may be the audio and video recordings. These two variables would provide data on a participant-by-participant basis, and would play a role in controlling for environmental factors that vary from participant to participant.

In this study, participant influence may have played a greater role than anticipated as well. Though the post-walk questionnaire asked participants questions about their familiarity with the study environment, individual physical fitness, and their propensity to become “stressed” these items were not factored into the final results, due to constraints dealing with time and complexity of the statistical analysis. However, these factors, once reviewed and normalized, could alter output data. It is not inconceivable to believe that one participant who grew up in a rural lifestyle may experience greater than normal levels of discomfort when walking around an urban environment than they would in a less-densely developed one. Factors such as these, or in this circumstance not accounting for these factors, could potentially skew data.

STUDY DESIGN

In short, the two primary data sources for this research came in the form of collected biofeedback data, and the responses to the survey. These two data sources were viewed as a necessary dichotomy to the outcome of the study design; biofeedback to record the participants’ involuntary psychophysiological responses, and the ratings of images as voluntary responses. Going through the study design process, it seemed imperative that every potential variable be included and accounted for before testing took place. Working within the set parameters, namely the time frame, would simply be something that had to be addressed in the depth and breadth of the study itself. Given the small window where the study could actually take place, there came a point where considerations had to be made as to what was an absolute necessity to the study and what could be parsed down or left for further review and analysis.

It was at this point, along with gathering and analyzing the first set of results, where the shortcomings in the study design became evident. Many of the shortcomings simply came down to the short time frame available to conduct the study, while others could have been avoided had considerations been made earlier in the process. For as many shortcomings as there were, there were also numerous invaluable lessons that were learned that may not have been learned had the study not taken place in the exact manner it did.

SHORTCOMINGS

Of the shortcomings, the first to be addressed was the study environment. As previously mentioned, the intent of the study was to understand how a densely-developed, urbanized environment could potentially influence behavioral changes in everyday users. Early considerations were laid out that would have moved the study location to a larger, more urbanized area (Kansas City, MO), but those were quickly dismissed based on limitations of time and travel expenses. Ideally, the route would have had participants in an urbanized setting, lead them through parts of a large, urban landscape (e.g, walking the streets of Brooklyn before entering Prospect Park) for a segment of route, then brought participants back into the urban setting before finishing their walk. Given that no such comparable environments were present in Manhattan, the route was tailored to expose participants to the most densely-developed areas of the city and to some "green" elements, and for that it performed quite well.

Additionally, the limited time did not allow for proper analysis of the perception-driven data. In regard to the video recordings. Further research could be done that incorporates low-level visual analysis of scenes throughout the walk. The intent would be to identify common design characteristics along the walk that elicited negative physiological responses, clearly delineating something that has an adverse effect on users. Analysis of the background information and qualitative responses to images would ideally give similar results to what was revealed in the video analysis, and give researchers a better understanding of how one's background and upbringing influences their personal preferences and perceptions when it comes to experiencing a space.

Also coming at the expense of the given time frame was the season in which the study was conducted. Although it worked out that the winter weather was relatively mild on days of testing, as mentioned before, the majority of the vegetation along the walk was dormant. This, in a sense, removed one potentially influential factor on participants from the study environment. Completing a similar study to this under different climatic and/or seasonal circumstances may play a role in the outcomes of the study.

Though the timing of the participant testing was always set up to be at nighttime, the results truly only revealed that the presence of lighting was seemingly the only factor that influenced the physiological data. This result was anticipated, but given the results collected from testing, it appears to be that is the only factor that influences a change in behavior. It would be interesting to conduct a similar study during daylight hours to note and better understand physiological responses that were not influenced directly by the presence (or absence) of light. This study would provide even further information into how design decisions may or may not alter changes in human behavior.

The final shortcoming to be addressed deals with fitting the biofeedback devices. Initially the testing would have had researchers fit participants with all of the necessary equipment prior to the walk. However, the IRB voiced concerns that it may be an inappropriate task for researchers of the opposite sex to fit participants with the equipment, namely the Polar device's electrode strap that is worn around the chest. Rather than address these concerns by employing another researcher to fit participants with chest strap properly, participants were asked to do the fitting themselves. However, after reviewing the collected data, gaps in the heart rate recordings from the Polar device became quite common. Fortunately, the Empatica device also collected heart rate and that data was used. A future consideration to be made for this type of study would be to get an additional trained researcher to fit participants with the Polar's electrode strap. Additionally, it appears that the Empatica device performed well given the limited time familiarize with it prior to testing, but further understanding is still needed as far as proper fitting and controlling of ambulatory testing motions.

LESSONS LEARNED

Of the numerous invaluable lessons learned during the study design process, many came at critical junctures where no previous consideration had been given to what was to be learned. For this particular study, numerous factors were unaccounted for in the first few iterations of the study design. It was not until these factors were met upon review that it became apparent they needed to be addressed. Other lessons were learned simply from short-sightedness and a lack of familiarity with this type of study.

Designing and operating a study in a semi-controlled environment with a wide range of participants shed light on how many different uncontrollable variables must be accounted for in order to attain accurate results. Addressing and factoring these variables into the study design and the results, may seem to create more questions than they end up answering. While as many of these variables were accounted for as possible, the time frame of the study only allowed for initial result findings and analysis, but setting up the study design and acknowledging the myriad potential outlying factors must be done in order to create a more holistic, accurate study. Simply not accounting for uncontrolled variables will not lend much credibility to the final results, and could detract from any substantial findings.

Much of what was learned about biofeedback for this study was done by experimenting with the equipment prior to testing. Having no initial familiarity with any form of biofeedback may have ended up being a blessing in disguise, as it led to questioning everything and seeking out a greater understanding of the equipment which led to greater depth and breadth in the design. In addition to having no familiarity, it afforded the opportunity to learn from professionals and others with significant experience and expertise in different fields, which was extremely beneficial and allowed for the opportunity to reflect and see the study design through different lenses. A common theme among professionals was that the ambulatory nature of the study presented numerous difficulties in itself. This required even further understanding of the exact measures taken by the different devices, as well as different techniques to ensure proper data collection. When conducting participant testing, careful instructions had to be relayed to the participants to ensure they used proper etiquette while wearing the devices, otherwise risk collecting flawed data.

Having never worked with participants in this manner before, getting the chance to consult with professional researchers and others who have conducted similar studies was an invaluable lesson. The common message from them was to show confidence in your study. The importance of expressing a strong understanding of the project, showing confidence in the study design, and the professionalism with which the testing is conducted when working with participants cannot be understated. This message carries over even earlier into the recruiting process. When pursuing recruiting endeavors to gather participants for the study, the manner in which the project is presented and how impactful it is the first time they hear about it could end up meaning the difference between a handful of recruits and more than what the entire study needs from one visit.

FUTURE CONSIDERATIONS

While this study has been quite unique and experienced its own successes, there are considerations that can be made to future iterations of it. In reviewing previous works (Berman, et. al, 2012; Kaplan and Kaplan, 1989; Kaplan, 1995; Ulrich, 1981; Ulrich, 1985; Ulrich, et. al, 1991) with similar study designs, these researchers would take individuals that were already experiencing stress then study how different environments affected the stress recovery period of the participants. This idea of inducing stress first was floated around during early iterations of the study design, but a major concern was that this may have raised concern with the IRB. It is an interesting consideration to be made, because of the impact these studies have had on future studies and the understanding of "restorative" environments.

As previously mentioned in the shortcomings, there are other considerations that could be taken in developing future studies. These include: moving the study environment to a more heavily urbanized environment with nearby access to a large urban landscape; performing the testing during different times of the year and in different climates; carrying out the testing during daylight hours as opposed to at night; and introducing another researcher whose sole focus was ensuring proper fitting of the biofeedback devices.

IMPACT ON LANDSCAPE ARCHITECTURE

One of the possible outcomes of this study is to use it as a tool to influence the future of public policy decision-making. Results from comparable study can provide concrete evidence that public decision-making priorities may need to be re-evaluated. If substantial evidence is uncovered that can show that different design characteristics do in fact play a role in perceived comfort, even if it is not backed by physiological data, this will at the very least create a dialogue within public and governing agencies. If there is support for change, then the results could be presented to a governing body as a way of advocating for more of the same design characteristics shown to increase comfort to be present throughout a greater area. Whether this comes in the form of additional vegetation, additional lighting, more space allocated for pedestrians, or whatever is shown to positively effect the spatial experiences of users, the argument will be grounded in fact. Whether changes are made or not, the importance is that these issues at least come to light in the eyes of public decision makers. Creating spaces that people enjoy, or at the very least do not dread being in, only serves to improve the quality of life for the end user.

As much influence as studies similar to this may have on public policy, there are just as many positive effects it may have on the field of design. While design is strongly rooted in individual preference, there seems to be certain preferences that are shared among the greater human population. While tapping in to these preferences may be difficult, some evidence can be seen from previous studies (Appleton, 1975; Kaplan and Kaplan, 1989; Kaplan, 1995; Kardan, et. al, 2015; Kuo, et. al, 1998; Kuo and Sullivan, 2001; Ulrich, 1981; Ulrich, 1985; Ulrich, et. al, 1991) that indicates a common preference shared among large populations. Though creating a catch-all design framework that encapsulates these preferences is, for all intents and purposes, a fruitless endeavor given the nature of individual preference, simply addressing what can be learned from these studies, as well as theory on evolutionary psychology, designers can create spaces that have a proven positive effect on their users. While simply incorporating these "comfort" elements into designs may create very blasé, "cut-and-paste" environments, folding these factors along with more site-specific cultural characteristics into a design could produce some of the most resounding, relatable environments people have ever encountered. Though it seems to be that a shared preference among the greater population is present, there is something to be said about grounding projects into local cultural landscapes.

CLOSING THOUGHTS

This project began with the desire to understand how human behavior could be influenced by alterations to an environment, in the form of a built installation. Much of this was simply a result of wanting to build something, having never gotten the opportunity to do so earlier in university. However, it became apparent rather quickly just how difficult it would be to understand how human behavioral changes, particularly those involving "stress", would be quantified. At that point, this study became much more of a "why" do people respond to certain interventions and environments, instead of "what" types of interventions and environments do they respond to.

As was noted in the literature review (Chapter 3 - Literature Review), many human preferences and perceptions are rooted in our evolutionary processes. These have been refined and passed through generations to improve our species' chances at survival, resulting in many shared perceptions across the entirety of the human population, but with each individual still maintaining their own. These individual perceptions appear to be driven by personal experiences resulting from exposure to different cultural environments and influences, which then impact and dictate one's personal preferences.

For a designer, it is incredibly important to understand the impact of relating a project's design to a (preferably locally-influenced) cultural environment and incorporating the appropriate cultural influences into the project. In doing this, the design becomes a manifestation of the local perceptions based on the existing cultural environment and influences. This creates spaces and places that end users can relate personally to, leading to deeper connections between the space and the communities they serve. Simply collecting quantitative data can provide insight into how design and policy decisions should be made, but a strong understanding of the deep-rooted preferences and perceptions of the communities who are affected by these decisions should be something that all designers strive for.

In closing, this project aimed to: gain insight into human-environment relationships; understand design as an influence on (in)voluntary behavioral changes; and test capacity of different design strategies to alter perception/behavior. Throughout this research, it became quite evident that understanding how to relate a design to a greater contextual cultural environment, and incorporating cultural influences into a design may have the greatest influence on how users respond to a given space. There are, of course, different conditions that go beyond cultural influences that are necessary for humans to feel fit in their environments, namely suitable prospect-and-refuge conditions. However, by folding these factors into a culturally-significant design to create spaces that are both suitable habitats and foster connections with their users, design transcends space, becoming place.

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FIGURE REFERENCES

Figure 3.01: Ruskamp, P. (2016). *Walking Route* [Map]. ESRI ArcGIS and Adobe Illustrator.

Figure 3.02: Ruskamp, P. (2016). *Equipment Placement* [Diagram]. Adobe Photoshop and Adobe Illustrator.

Figure 3.03: Ruskamp, P. (2016). *Alley* [Photograph]. Photo by Author.

Figure 3.04: Ruskamp, P. (2016). *6th Street* [Photograph]. Photo by Author.

Figure 3.05: Ruskamp, P. (2016). *Poyntz Avenue* [Photograph]. Photo by Author.

Figure 3.06: Ruskamp, P. (2016). *Site Photographs and Context Map* [Map]. ESRI ArcGIS and Adobe Illustrator.

Figure 4.01: Ruskamp, P. (2016). *Lighting* [Diagram]. ESRI ArcGIS, Rhinoceros, and Adobe Photoshop.

Figure 4.02: Ruskamp, P. (2016). *Building Heights* [Diagram]. ESRI ArcGIS and Rhinoceros.

Figure 4.03: Ruskamp. P. (2016). *Vegetation* [Diagram]. ESRI ArcGIS and Adobe Illustrator.

Figure 4.04: Ruskamp, P. (2016). *Walkability* [Diagram]. ESRI ArcGIS and Adobe Illustrator.

Figure 4.05: Ruskamp, P. (2016). *Infrastructure* [Diagram]. ESRI ArcGIS and Adobe Illustrator.

Figure 5.01: Ruskamp, P. (2016). *Heart Rate Data* [Map]. Microsoft Excel and ESRI ArcGIS.

Figure 5.02: Ruskamp, P. (2016). *EDA Data* [Map]. Microsoft Excel and ESRI ArcGIS.

Figure 5.03: Ruskamp, P. (2016). *Section A*. [Section]. Image by Author.

Figure 5.04: Ruskamp, P. (2016). *Section B*. [Section]. Image by Author.

Figure 5.05: Ruskamp, P. (2016). *Section C*. [Section]. Image by Author.

Figure 5.06: Ruskamp, P. (2016). *Section D*. [Section]. Image by Author.

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Figure 5.09: Ruskamp, P. (2016). *Image "Q37_1"* [Photograph]. Photo by Author.

Figure 5.10: Ruskamp, P. (2016). *Image "Q33_1"* [Photograph]. Photo by Author.

Figure 5.11: Ruskamp, P. (2016). *Image "Q47_1"* [Photograph]. Photo by Author, altered using Adobe Photoshop.

Figure 5.12: Ruskamp, P. (2016). *Image "Q48_1"* [Photograph]. Photo by Author, altered using Adobe Photoshop.

Figure 5.13: Ruskamp, P. (2016). *Image "Q46_1"* [Photograph]. Photo by Author, altered using Adobe Photoshop.

Figure 5.14: Ruskamp, P. (2016). *Image "Q40_1"* [Photograph]. Photo by Author.

Figure 5.15: Ruskamp, P. (2016). *Image "Q43_1"* [Photograph]. Photo by Author.

Figure 5.16: Ruskamp, P. (2016). *Image "Q44_1"* [Photograph]. Photo by Author.

Figure 5.17: Ruskamp, P. (2016). *Image "Q49_1"* [Photograph]. Photo by Author, altered using Adobe Photoshop.

Figure 5.18: Ruskamp, P. (2016). *Image "Q50_1"* [Photograph]. Photo by Author, altered using Adobe Photoshop.

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Table 5.02: Ruskamp, P. (2016). *Image Ratings - Original* [Table]. Microsoft Excel.

Table 5.03: Ruskamp, P. (2016). *Image Ratings - Altered* [Table]. Microsoft Excel.

Table 5.04: Ruskamp, P. (2016). *Correlation Statistics* [Table]. Microsoft Excel.

APPENDICES

APPENDIX A - PRE-TEST PROVISIONAL GUIDELINES

Research Participant,

You are scheduled to participate in the survey on:

(XX:XX PM) on (DATE).

Please respond either to this email, via phone, or via text to the number listed below confirming your attendance and participation at your selected time.

Upon your arrival, you will be debriefed on the study, its intent, and our goals as researchers. Additionally, you will be hooked up to our minimally-invasive equipment that will provide us with our data. At the conclusion of field testing, you will fill out a short questionnaire on the field testing session.

Provisions for food, drink, tobacco, exercise:

- Drink ample fluids over the 24-hours preceding the testing period.
- Refrain from consuming alcohol during the 24-hours preceding testing.
- Refrain from consuming food, beverage (with the exception of water), caffeine, and tobacco for 2 hours before testing.
- Refrain from strenuous exercise 2 hours before testing.

Clothing:

- Wear warm clothing to permit freedom of movement
- Wear comfortable footwear

If you have any further questions, comments, or concerns, please do not hesitate to contact me at this email address or the phone number listed below.

Thank you again for interest, I am very much looking forward to working with you.

APPENDIX B - WALKING ROUTE

APPENDIX C - POST-WALK QUESTIONNAIRE

Introduction/Brief of Questionnaire

This questionnaire is in three sections and should take roughly 15-20 minutes to complete. The first section requests personal information to support the research. The second and third sections will request you evaluate the different environments you have just experienced to further support the research.

REMINDER: ALL INFORMATION YOU SUBMIT FOR THIS STUDY IS ANONYMOUS.

Background Information

Please identify your gender.

Male
Female

Please identify your age

[ ]

What is your discipline of study? (ie. Ecology, Fine Art, etc.)

[ ]

Which best describes your body type?

Ectomorph (Thin build, lanky)
Mesomorph (Medium build, moderate)
Endomorph (Heavy build, stout)

Which type of environment best describes your background and upbringing?

Rural
Suburban
Urban

What type of environment do you now most identify with?

Rural
Suburban
Urban

Which of the following best describes your economic background and upbringing?

Lower-income
Middle-income
Higher-income

Prior to this evening, how familiar were you with the study area? (ie, the route and downtown Manhattan?)

Not at all (hardly ever visited any part)
Barely (visited before, but in vehicle)
Somewhat (visit one or two places by vehicle)
Familiar (occasionally walk in parts of the study area)
Very Familiar (regularly frequent parts of the study area)

How often do you engage in cardio-vascular physical activities?

Never
Rarely
Sometimes
Regularly
Frequently

Do you consume tobacco or caffeine with relative frequency?

Neither
Tobacco yes, caffiene no
Caffeine yes, tobacco no
Both

In the last 24 hours, have you consumed alcohol?

Yes
No

In the last three hours, have you consumed any food or beverages other than water?

Neither
Food yes, beverage no
Beverage yes, food no
Both

In the last three hours, have you consumed any tobacco or caffeine?

Neither
Tobacco yes, caffeine no
Caffeine yes, tobacco no
Both

In the last three hours, have you done any moderate to strenuous exercise?

Strenuous
Moderate
None

During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?

Number of days (0-7)

How much time did you usually spend doing vigorous physical activities on one of those days?

Hours per day
Minutes per day
Don't know/Not sure

During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

Number of days (0-7)

How much time did you usually spend doing moderate physical activities on one of those days?

Hours per day
Minutes per day
Don't know/Not sure

During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

Number of days (0-7)

In the past week, how much time did you spend walking? (Do not include instances under 10 minutes)

Hours per day
Minutes per day
Don't know/Not sure

During the last 7 days, how much time did you spend sitting on a week day?

Hours per day
Minutes per day
Don't know/Not sure

Please list any medications you are currently taking and the condition for which they were prescribed.

Perceived Stress Scale

In the last month, how often have you been upset because of something that happened unexpectedly?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you felt that you were unable to control the important things in your life?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you felt nervous and "stressed"?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you felt confident about your ability to handle your personal problems?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you felt that things were going your way?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you found that you could not cope with all the things that you had to do?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you been able to control irritations in your life?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you felt that you were on top of things?

Never Almost Never Sometimes Fairly Often Very Often

In the last month, how often have you been angered because of things that were outside of your control?

Never Almost Never Sometimes Fairly Often Very Often

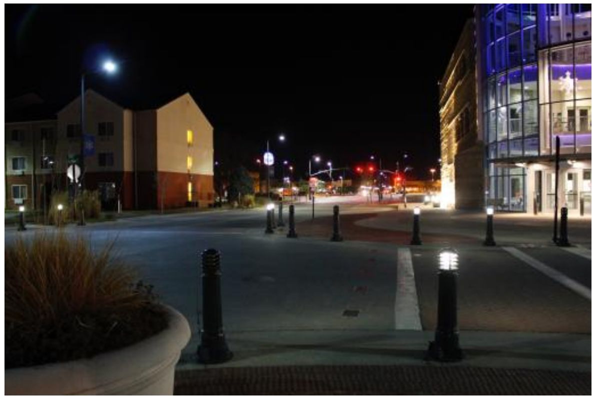
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

Never Almost Never Sometimes Fairly Often Very Often

Image Ratings Introduction

This section of the questionnaire will ask you to rate 18 different images based on how safe you feel. The images come from the environment you just experienced. Some of these images have been digitally altered.

Image Ratings



Very Unsafe — Very Safe

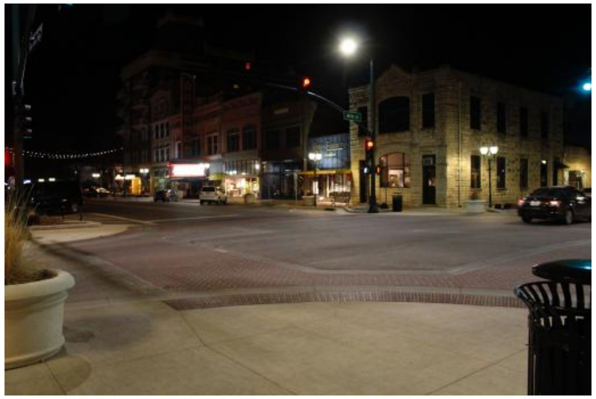
Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

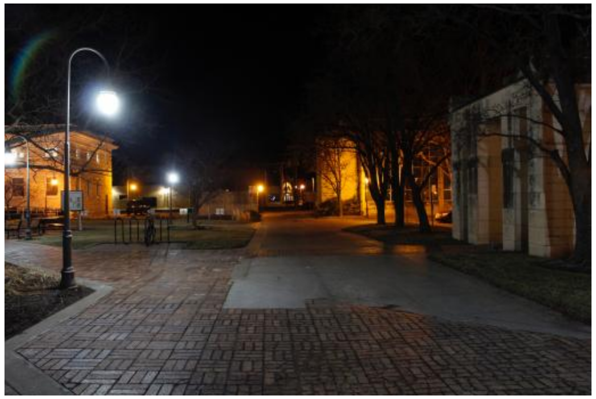


Very Unsafe — Very Safe

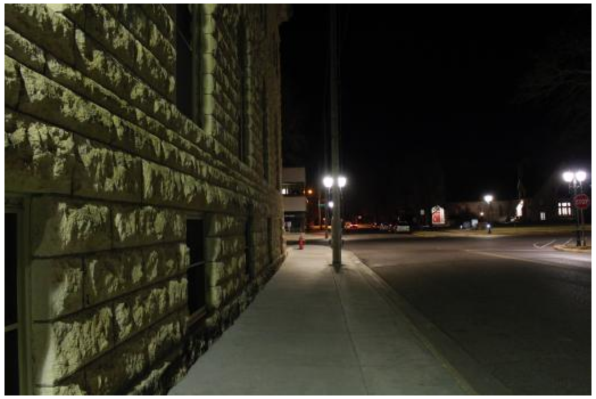
Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○

	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○



	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○



	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

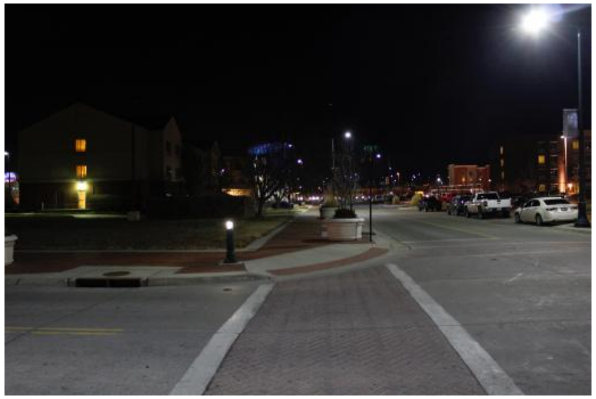
Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

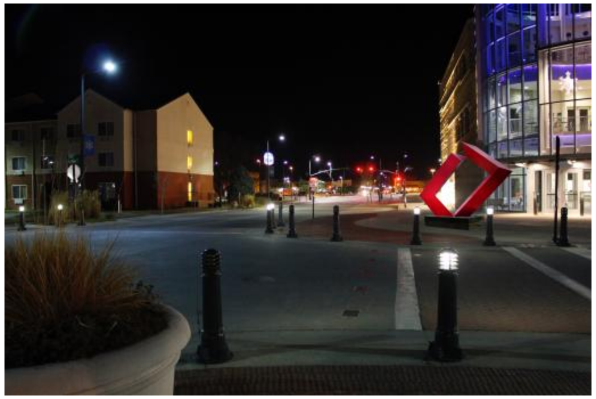
Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○



Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○



Very Unsafe — Very Safe

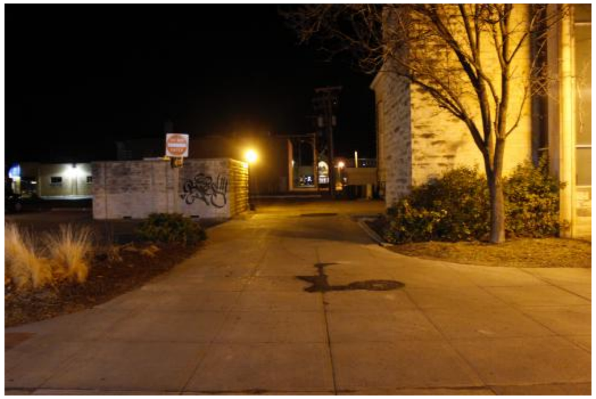
Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○

Very Unsafe — Very Safe

Rate your feelings of safety in this space. ○ ○ ○ ○ ○ ○ ○



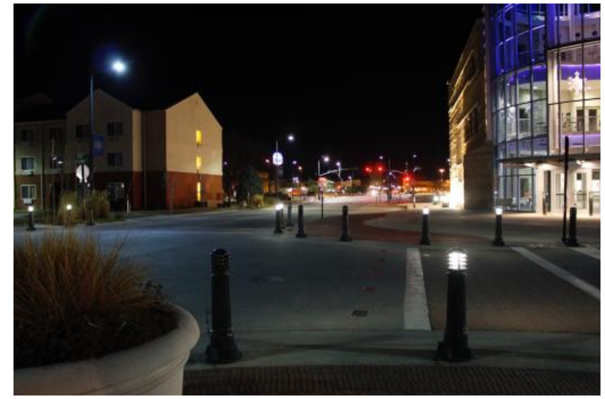
	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○

	Very Unsafe						Very Safe
Rate your feelings of safety in this space.	○	○	○	○	○	○	○

Image Comments Introduction

You're almost done! Next, we ask that you comment on the following 8 images. Please provide a written statement explaining what characteristics of the scene increase or decrease your feelings of safety.

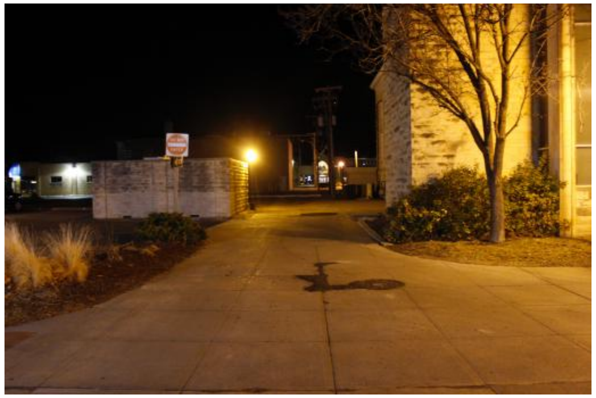
Image Comments



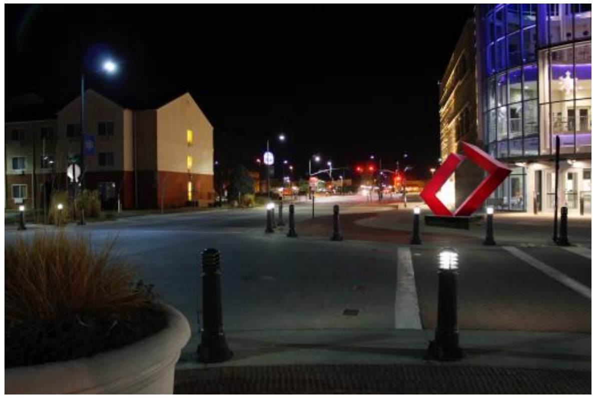
In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.

In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.

In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.



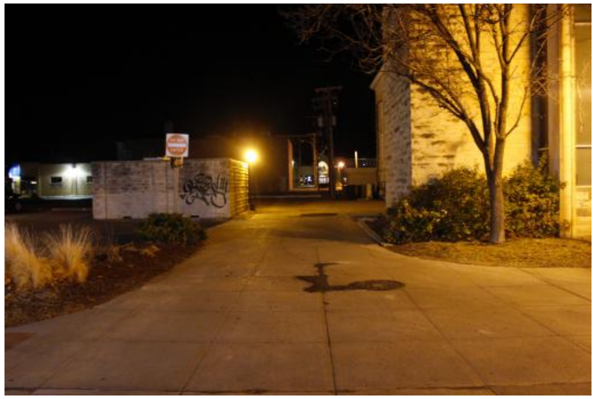
In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.



In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.

In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.

In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.



In the box below, please express what characteristics of this space increase or decrease your feelings of safety. Please be as articulate, critical, and thorough as possible. By doing so, you will give us the best possible data.

Debriefing Statement

The investigators would like to express our sincerest gratitude for your help with our research. We appreciate your willingness to take time out of your schedule to assist us with our study!

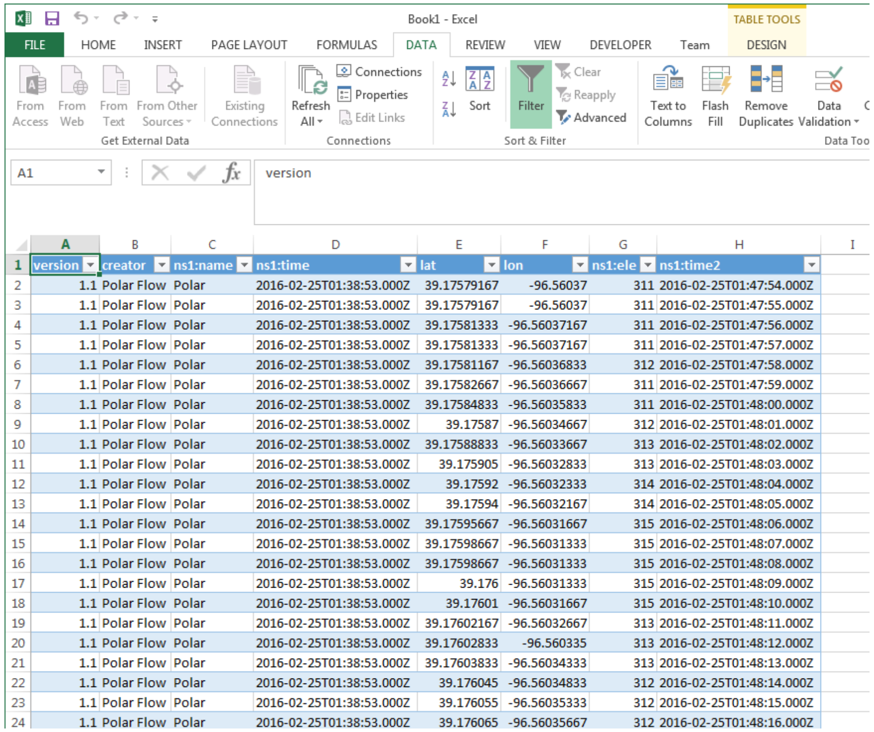
Our hope is that the findings will better inform public policy decision-making efforts regarding design and public health guidelines. This is just one of the first steps in understanding the effects environments play on human behaviors.

If you would like to receive notice of any publications of findings that come from this research, please pass along your email or contact information (note that this will not be linked with the data we collected from you today - the data is confidential). Your contact information will only be used for communication of results.

Again, I would like to thank you for all of your help and cooperation. We are incredibly grateful and fortunate to have had your assistance. We could not have done it without you!

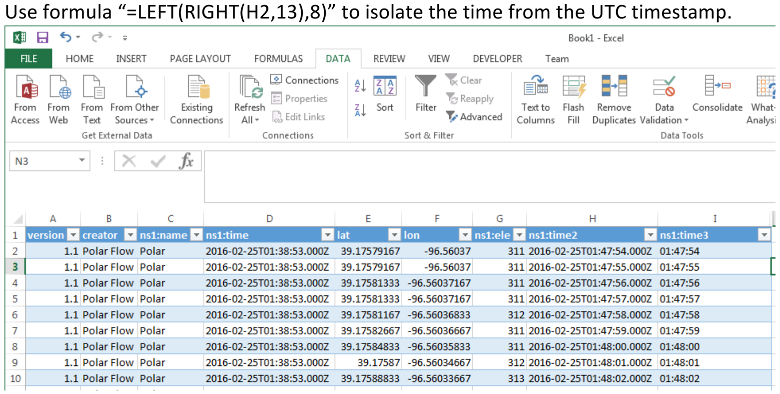
APPENDIX D - FORMATTING POLAR DATA

1. Rename .gpx files to .xml **before opening the file**.
2. Open Excel
3. Data > From Other Sources (import)
4. Accept defaults and data should look like a table:



5. Extract time:

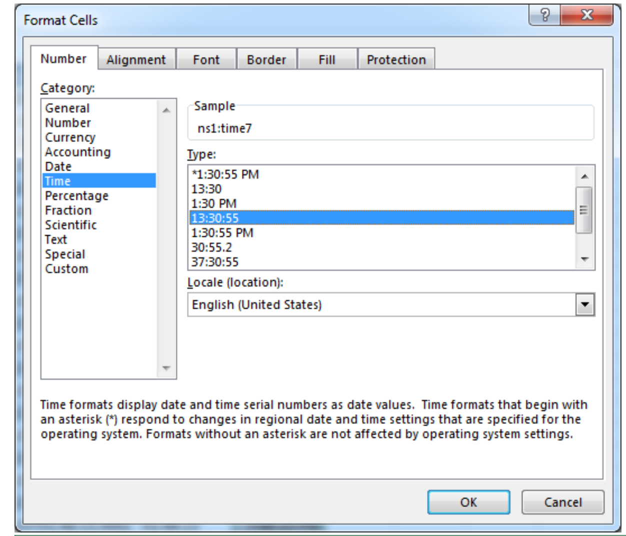
   a. Use formula "=LEFT(RIGHT(H2,13),8)" to isolate the time from the UTC timestamp.

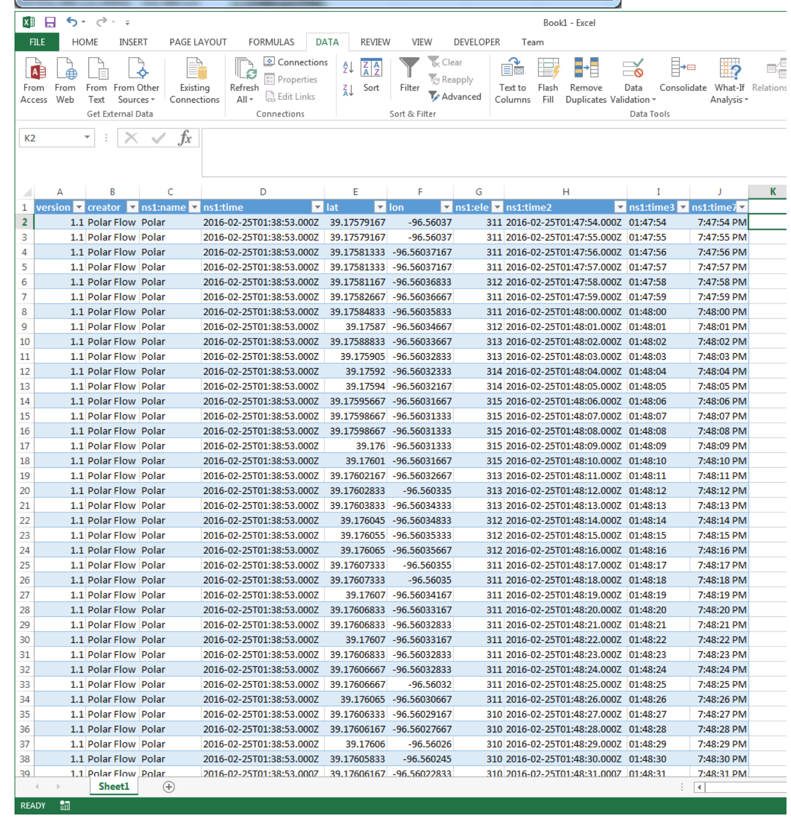


   b. Then *correct for UTC time*[1] using the following formula:" =I2+TIME(-6+24,0,0)" where cell I2 is UTC time.

[1] The formula to the right uses 6 hour time difference for Central Standard Time, **ensure that correction considers daylight savings**.

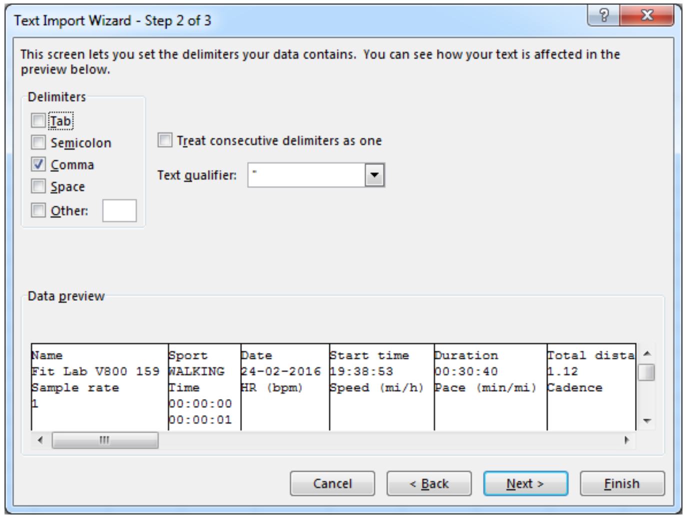
   c. Format the column to time (using Military time)





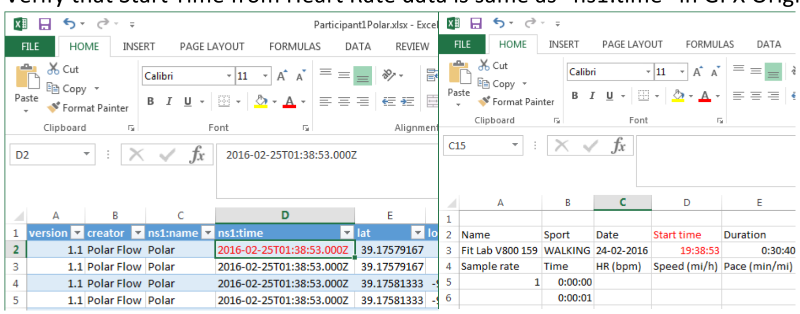
6. Save this file as Participant"X"Polar.xlsx
7. Rename Sheet1 (worksheet) to "GPX Original"
8. Create a new worksheet called "Heart Rate"
9. Import the participant csv heart rate data: Data>FromText

a. Select the csv file and ensure that you are selecting comma as the delimiter:

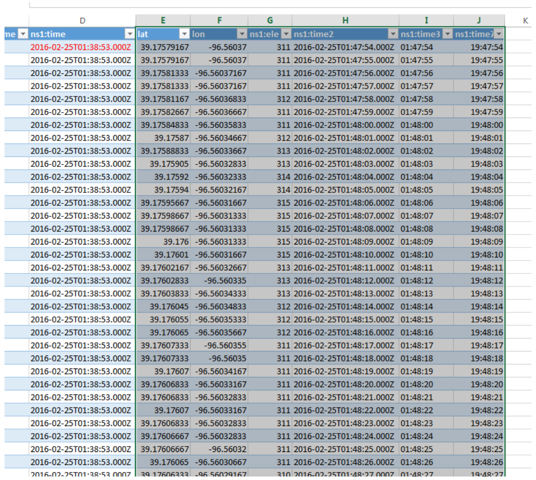


b. Accept default formats

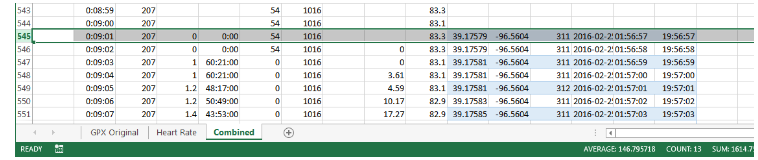
10. Verify that Start Time from Heart Rate data is same as "ns1:time" in GPX Original:



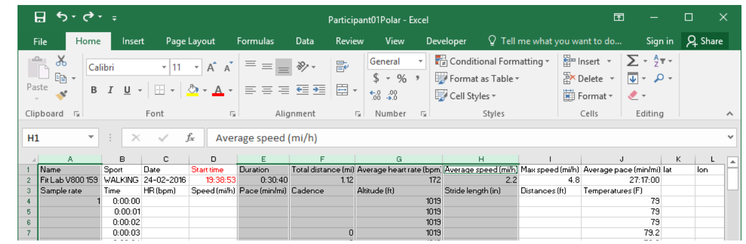
11. Create new worksheet called "Combined"
12. Copy all contents from "Heart Rate" into Combined
13. Remove superfluous data (e.g. height, weight, etc…everything right "max pace))
14. From "GPX Original", copy all columns from "lat" to the right (lat, long, ns1:ele, etc.)



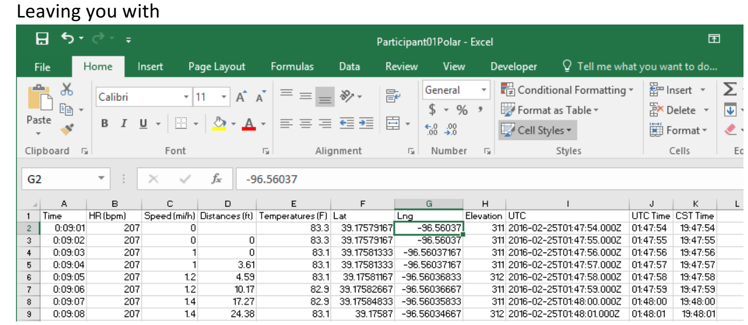
15. In "Combined", paste copied data into row corresponding with beginning of walk
    a. To do this, find the difference between the time the equipment was started, and the time the walk began



16. Create new sheet, called "Combined-Clean"
    a. Copy/paste all data from "Combined" sheet into "Combined-Clean"
        i. Delete columns A, E, F, G, and H.

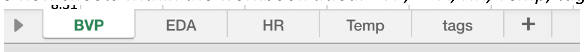


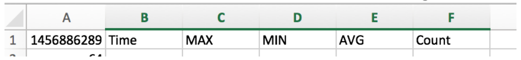
        ii. Next, delete all rows between the title row at the top of the page and the first row of data that came from the sheet "GPX Original"
        iii. Delete all rows in columns A, B, C, D, and E that do not have corresponding latitude and longitude data. The amount of data you delete will vary.
        iv. Leaving you with

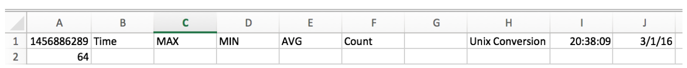


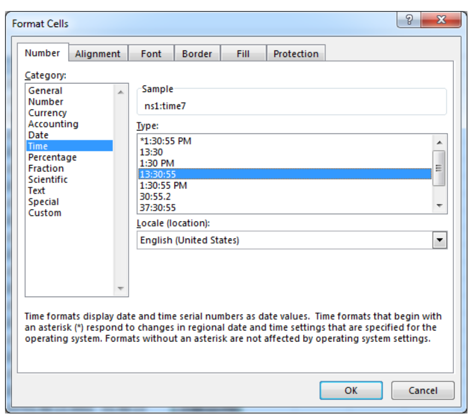
            1. Note that columns will need to be renamed as shown above

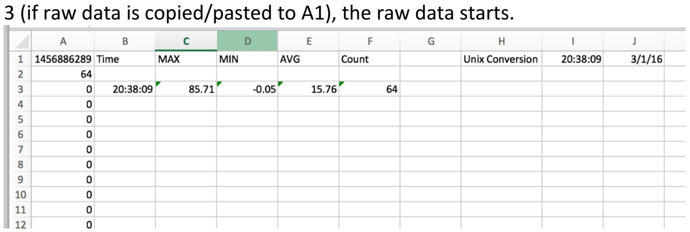
APPENDIX E - FORMATTING EMPATICA DATA

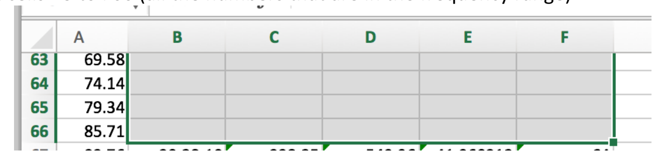
1. Create new workbook for each participant (*ParticipantXXEmpatica.xlsx*)
2. Create 5 new sheets within the workbook titled: *BVP, EDA, HR, Temp, tags.*
    a. 

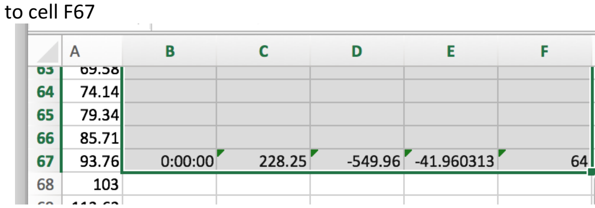
3. BVP
    a. Copy all BVP raw data from the downloaded Empatica zip file (file should be named BVP.csv) and paste into participant workbook sheet "BVP" in cell A1.
    b. In columns B-F add**, IN ORDER**,: *Time, Max, Min, Average, Count*
        i. 

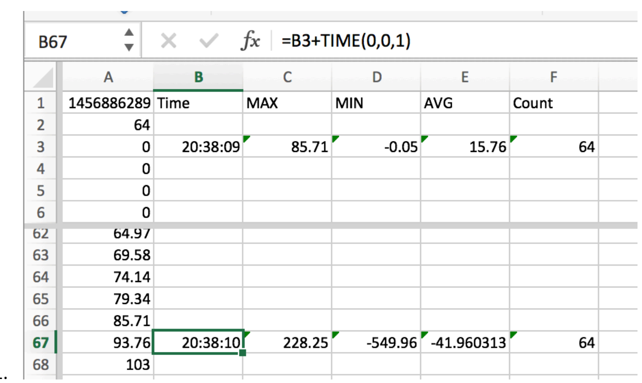
    c. The first figure (cell A1 if copied/pasted correctly) is a Unix Time/Date Stamp. To convert this, use the formula: "=(((A1/60)/60)/24)+DATE(1970,1,1)+(-6/24)"
        i. "(A1/60)/60)/24)" establishes 60 sec/min, 60 min/hour, 24 hours/day
        ii. "DATE(1970,1,1)" establishes the first day of the Unix calendar
        iii. "(-6/24)" establishes time zone relative to UTC (CST is -6 hours from UTC)
            1. **make sure to account for Daylight Savings as well!!!!**
        iv. In two separate columns, input the above formula. The output numbers will be the same. Format one column for time (use Military) and the other for date. The time and date result from Unix conversion represent the start time and date of data recording.
            1. 

            2. 

    d. The number below the Unix Time/Date Stamp indicates the frequency of the collection measure. BVP is recorded at 64 intervals/second.
        i. In Row 3 (if raw data is copied/pasted to A1), the raw data starts.
            1. 

        ii. In cell B3, enter the formula "=I1"
        iii. In cell C3, enter the formula "=MAX(A3:A66)"
            1. Cells A3 to A66 totals 64 cells, the number of the frequency range
        iv. In cell D3, enter the formula "=MIN(A3:A66)"
        v. In cell E3, enter the formula "=AVERAGE(A3:A66)"
        vi. In cell F3, enter the formula "=COUNT(A3:A66)"
            1. This step isn't necessary, but is a good fail safe to make sure you have the correct number of cells selected for your frequency
        vii. Select cells B3 to F66 (all the numbers that are in the frequency range)
            1. 

        viii. Click and drag the square in the bottom-right corner of the selection area down to cell F67
            1. 

        ix. In cell B67, input the formula "=B3+TIME(0,0,1)". This formula references the original Unix conversion reformatted into a timestamp "B3" then adds one second "+TIME(0,0,1)" to the timestamp of each frequency range.
            1. 

x. Select cells B67 to F130 (all cells in the next frequency range).

xi. Double-click on the square in the bottom-right of the selection area to auto-fill the rest of the table. Each subsequent row of data should have the military timestamp, max, min, average, and count values for each of the 64-interval frequency ranges. To double-check, make sure the timestamps between each frequency range show a one-second difference and the count remains 64.

1.

	A	B	C	D	E	F
65	79.34					
66	85.71					
67	93.76	20:38:10	228.25	-549.96	-41.960313	64
68	103					
69	112.62					
70	121.73					
128	163.18					
129	156.15					
130	148.81					
131	141.3	20:38:11	141.3	0.13	26.2871875	64
132	133.69					

4. EDA

a. Copy all EDA raw data from the downloaded Empatica zip file (file should be named EDA.csv) and paste into participant workbook sheet "EDA" in cell A1

b. In columns B-F add**, IN ORDER**,: *Time, Max, Min, Average, Count*

i.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count

c. The first figure (cell A1 if copied/pasted correctly) is a Unix Time/Date Stamp. To convert this, use the formula: "=(((A1/60)/60)/24)+DATE(1970,1,1)+(-6/24)"

i. "(A1/60)/60)/24)" establishes 60 sec/min, 60 min/hour, 24 hours/day

ii. "DATE(1970,1,1)" establishes the first day of the Unix calendar

iii. "(-6/24)" establishes time zone relative to UTC (CST is -6 hours from UTC)

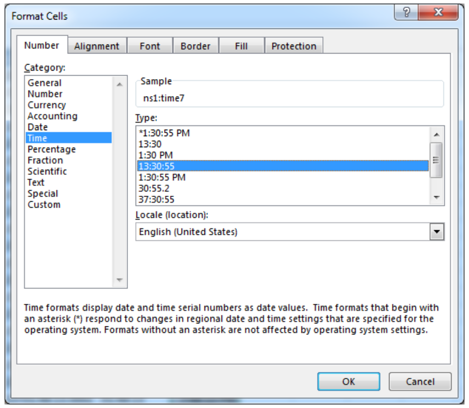
1. make sure to account for Daylight Savings as well!!!!

iv. In two separate columns, input the above formula. The output numbers will be the same. Format one column for time (use Military) and the other for date. The time and date result from Unix conversion represent the start time and date of data recording.

1.

	A	B	C	D	E	F	G	H	I	J
1	1456886289	Time	MAX	MIN	AVG	Count		Unix Conversion	20:38:09	3/1/16
2	64									

2.



d. The number below the Unix Time/Date Stamp indicates the frequency of the collection measure. EDA is recorded at 4 intervals/second.

i. In Row 3 (if raw data is copied/pasted to A1), the raw data starts.

1.

	A	B	C	D	E	F	G	H	I	J
1	1456886289	Time	MAX	MIN	AVG	Count		Unix Conversion	20:38:09	3/1/16
2	4									
3	0	20:38:09	0.165262	0	0.0996055	4				

ii. In cell B3, enter the formula "=I1"

iii. In cell C3, enter the formula "=MAX(A3:A6)"

1. Cells A3 to A6 totals 4 cells, the number of the frequency range

iv. In cell D3, enter the formula "=MIN(A3:A6)"

v. In cell E3, enter the formula "=AVERAGE(A3:A6)"

vi. In cell F3, enter the formula "=COUNT(A3:A6)"

1. This step isn't necessary, but is a good fail safe to make sure you have the correct number of cells selected for your frequency

vii. Select cells B3 to F6 (all the numbers that are in the frequency range)

1.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	0	20:38:09	0.165262	0	0.0996055	4
4	0.078147					
5	0.155013					
6	0.165262					

viii. Click and drag the square in the bottom-right corner of the selection area down to F7

1.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	0	20:38:09	0.165262	0	0.0996055	4
4	0.078147					
5	0.155013					
6	0.165262					
7	0.170386	0:00:00	0.175511	0.170386	0.172628	4

ix. In cell B7, input the formula "=B3+TIME(0,0,1)". This formula references the original Unix conversion reformatted into a timestamp "B3" then adds one second "+TIME(0,0,1)" to the timestamp of each frequency range.

1.

B7 =B3+TIME(0,0,1)

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	0	20:38:09	0.165262	0	0.0996055	
4	0.078147					
5	0.155013					
6	0.165262					
7	0.170386	20:38:10	0.175511	0.170386	0.172628	
8	0.171667					

x. Select cells B7 to F10 (all cells in the next frequency range).

xi. Double-click on the square in the bottom-right of the selection area to auto-fill the rest of the table. Each subsequent row of data should have the military timestamp, max, min, average, and count values for each of the 4-interval frequency ranges. To double-check, make sure the timestamps between each frequency range show a one-second difference and the count remains 4.

1. B7 — Name Box — f_x =B3+TIME(0,0,1)

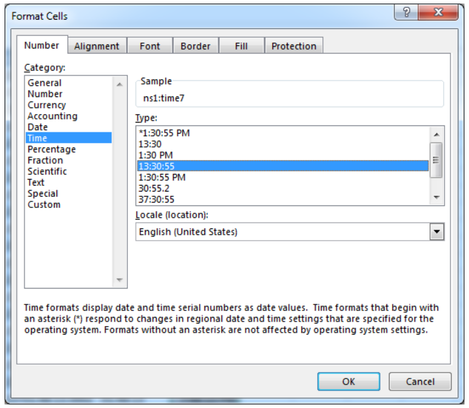
	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	0	20:38:09	0.165262	0	0.0996055	4
4	0.078147					
5	0.155013					
6	0.165262					
7	0.170386	20:38:10	0.175511	0.170386	0.172628	4
8	0.171667					
9	0.172948					
10	0.175511					
11	0.175511	20:38:11	0.178073	0.175511	0.17647175	4
12	0.175511					
13	0.176792					
14	0.178073					
15	0.178073	20:38:12	0.178073	0.176792	0.17711225	4
16	0.176792					
17	0.176792					
18	0.176792					
19	0.176792	20:38:13	0.176792	0.175511	0.1761515	4
20	0.176792					

5. Heart Rate
   a. Copy all HR raw data from the downloaded Empatica zip file (file should be named HR.csv) and paste into participant workbook sheet “HR” in cell A1
   b. In column B, add *Time.*
      i.

	A	B
1	1456886299	Time
2	1	--

   c. The first figure (cell A1 if copied/pasted correctly) is a Unix Time/Date Stamp. To convert this, use the formula: “=(((A1/60)/60)/24)+DATE(1970,1,1)+(-6/24)”
      i. “(A1/60)/60)/24)” establishes 60 sec/min, 60 min/hour, 24 hours/day
      ii. “DATE(1970,1,1)” establishes the first day of the Unix calendar
      iii. “(-6/24)” establishes time zone relative to UTC (CST is -6 hours from UTC)
         1. **make sure to account for Daylight Savings as well!!!!**
      iv. In two separate columns, input the above formula. The output numbers will be the same. Format one column for time (use Military) and the other for date. The time and date result from Unix conversion represent the start time and date of data recording.
         1.

	A	B	C	D	E	F
1	1456886299	Time		Unix Conversion	20:38:19	3/1/16
2	1	--				
3	61	20:38:19				

         2. 

   d. The number below the Unix Time/Date Stamp indicates the frequency of the collection measure. HR is recorded once per second.
      i. In Row 3 (if raw data is copied/pasted to A1), the raw data starts.
         1.

	A	B
1	1456886299	Time
2	1	--
3	61	20:38:19

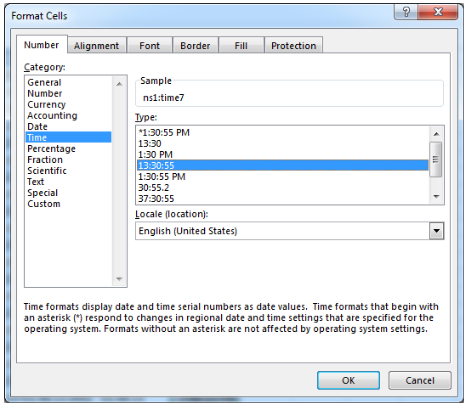
      ii. In cell B3, enter the formula “=E1”.
      iii. In cell B4, input the formula “=B3+TIME(0,0,1)”. This formula references the original Unix conversion reformatted into a timestamp “B3” then adds one second “+TIME(0,0,1)” to the timestamp of each frequency range.
      iv. With cell B4 selected, double-click on the square in the bottom-right of the selection area to auto-fill the rest of the table. Each subsequent row of data should have the military timestamp next to the data figure.

6. Temperature
   a. Copy all Temp raw data from the downloaded Empatica zip file (file should be named TEMP.csv) and paste into participant workbook sheet “Temp” in cell A1.
   b. In columns B-F add**, IN ORDER**,: *Time, Max, Min, Average, Count*
      i.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count

   c. The first figure (cell A1 if copied/pasted correctly) is a Unix Time/Date Stamp. To convert this, use the formula: “=(((A1/60)/60)/24)+DATE(1970,1,1)+(-6/24)”
      i. “(A1/60)/60)/24)” establishes 60 sec/min, 60 min/hour, 24 hours/day
      ii. “DATE(1970,1,1)” establishes the first day of the Unix calendar
      iii. “(-6/24)” establishes time zone relative to UTC (CST is -6 hours from UTC)
         1. **make sure to account for Daylight Savings as well!!!!**
      iv. In two separate columns, input the above formula. The output numbers will be the same. Format one column for time (use Military) and the other for date. The time and date result from Unix conversion represent the start time and date of data recording.
      v.
         1.

	A	B	C	D	E	F	G	H	I	J
1	1456886289	Time	MAX	MIN	AVG	Count		Unix Conversion	20:38:09	3/1/16
2	64									



2.

d. The number below the Unix Time/Date Stamp indicates the frequency of the collection measure. Temperature is recorded at 4 intervals/second.

i. In Row 3 (if raw data is copied/pasted to A1), the raw data starts.

1.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	382.18	20:38:09	719.924	719.924	719.924	4

ii. In cell B3, enter the formula "=I1"

iii. In cell C3, enter the formula "=((MAX(A3:A6))*1.8+32)"

1. Cells A3 to A6 totals 4 cells, the number of the frequency range
2. "*1.8+32" represents the conversion from Celsius to Fahrenheit

iv. In cell D3, enter the formula "=((MIN(A3:A6))*1.8+32)"

v. In cell E3, enter the formula "=((AVERAGE(A3:A6))*1.8+32)"

vi. In cell F3, enter the formula "=((COUNT(A3:A6))*1.8+32)"

1. This step isn't necessary, but is a good fail safe to make sure you have the correct number of cells selected for your frequency

vii. Select cells B3 to F6 (all the numbers that are in the frequency range)

1.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	382.18	20:38:09	719.924	719.924	719.924	4
4	382.18					
5	382.18					
6	382.18					

viii. Click and drag the square in the bottom-right corner of the selection area down to F7

1.

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	Name Box					
3	382.18	20:38:09	719.924	719.924	719.924	4
4	382.18					
5	382.18					
6	382.18					
7	31.35	0:00:00	88.43	88.43	88.43	4

ix. In cell B7, input the formula "=B3+TIME(0,0,1)". This formula references the original Unix conversion reformatted into a timestamp "B3" then adds one second "+TIME(0,0,1)" to the timestamp of each frequency range.

1.

B7 | *fx* =B3+TIME(0,0,1)

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	382.18	20:38:09	719.924	719.924	719.924	4
4	382.18					
5	382.18					
6	382.18					
7	31.35	20:38:10	88.43	88.43	88.43	4
8	31.35					

x. Select cells B7 to F10 (all cells in the next frequency range).

xi. Double-click on the square in the bottom-right of the selection area to auto-fill the rest of the table. Each subsequent row of data should have the military timestamp, max, min, average, and count values for each of the 4-interval frequency ranges. To double-check, make sure the timestamps between each frequency range show a one-second difference and the count remains 4.

1.

B7 | *fx* =B3+TIME(0,0,1)

	A	B	C	D	E	F
1	1456886289	Time	MAX	MIN	AVG	Count
2	4					
3	382.18	20:38:09	719.924	719.924	719.924	4
4	382.18					
5	382.18					
6	382.18					
7	31.35	20:38:10	88.43	88.43	88.43	4
8	31.35					
9	31.35					
10	31.35					
11	31.35	20:38:11	88.43	88.43	88.43	4
12	31.35					
13	31.35					
14	31.35					
15	31.33	20:38:12	88.394	88.394	88.394	4
16	31.33					
17	31.33					
18	31.33					
19	31.35	20:38:13	88.43	88.43	88.43	4
20	31.35					

7. Tags

a. Copy all tags raw data from the downloaded Empatica zip file (file should be named tags.csv) and paste into participant workbook sheet "tags" in cell A1

i.

	A	B
1	1456886662	
2	1456888011	
3		

b. These figures are Unix Time/Date Stamps. To convert these, use the formula: "=(((A1/60)/60)/24)+DATE(1970,1,1)+(-6/24)". If there is more than one tag, make sure to alter the formula for each subsequent row (A2, A3, etc.)

i. "(A1/60)/60)/24)" establishes 60 sec/min, 60 min/hour, 24 hours/day

ii. "DATE(1970,1,1)" establishes the first day of the Unix calendar

iii. "(-6/24)" establishes time zone relative to UTC (CST is -6 hours from UTC)

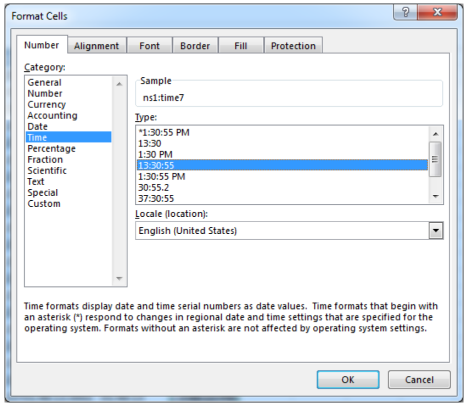
1. **make sure to account for Daylight Savings as well!!!!**

iv. In two separate columns, input the above formula. The output numbers will be the same. Format one column for time (use Military) and the other for date. The time and date result from Unix conversion represent the start time and date of data recording.

1.

	A	B	C	D	E
1	1456886662		Unix Conversion	20:44:22	3/1/16
2	1456888011		Unix Conversion	21:06:51	3/1/16

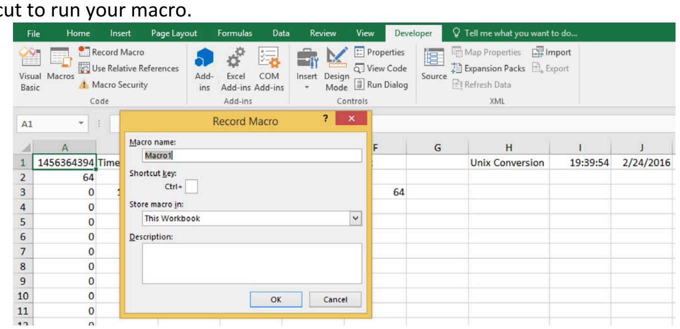
2.

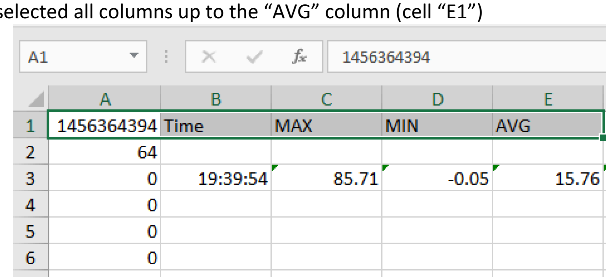


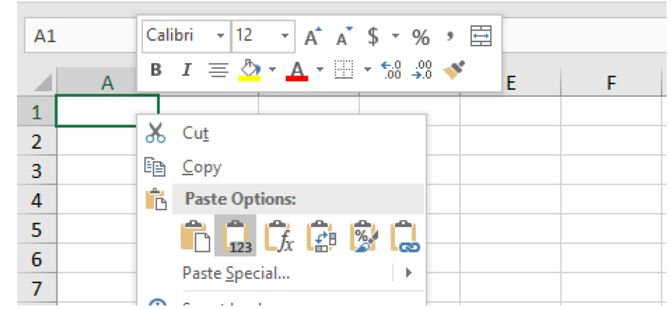
c. These tags indicate "instances". These are useful for denoting the exact times the participant began and ended their walk. Additionally, participants may be instructed to mark an instance when they are startled so researchers can seek out marked stress responses and any physiological changes.

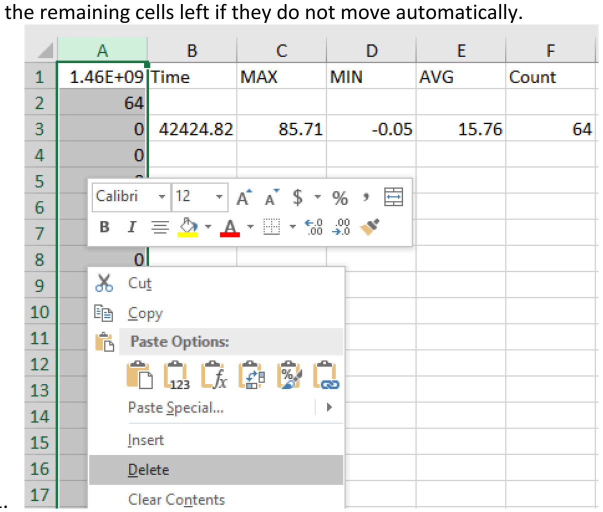
APPENDIX F - CREATING MASTER FILE FOR ARCGIS

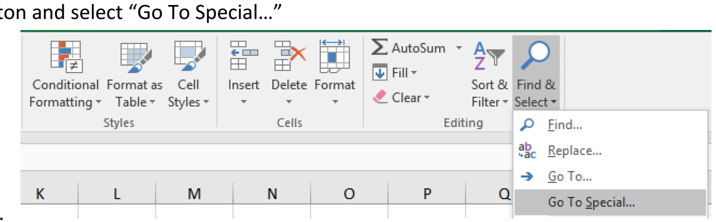
1. Open the Empatica data sheet from Appendix “Preparing Empatica E4 Raw Data” for the selected participant. The worksheets in this file should be “BVP, EDA, HR, Temp, tags”.
2. Save a copy of this file as an ***Excel macro-enabled workbook.***

3. Creating a “cleaning” macro - Empatica
   a. Open the “BVP” sheet first after saving the copy.
   b. Next, develop a macro that will create a new sheet with the “cleaned” data in it. **Make sure you have cell “A1” selected before creating/starting your macro!**
      i. To create the macro, first open excel and go to the “Developer” tab in the ribbon along the top.
      ii. Next, you will click the “Record Macro” button. From here a second window will open, allowing you to name and create the keyboard shortcut to run your macro.
         1. 

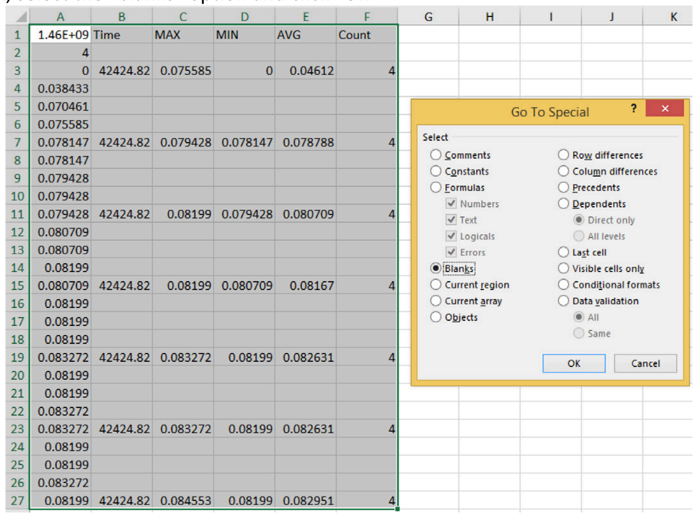
      iii. After choosing your name and shortcut, click the “OK” button in the window. **Make sure you have cell “A1” selected before clicking “OK”.**
         1. Once you have hit “OK”, the macro system will begin recording everything you do until you stop the recording process (this should replace the “Record Macro” button up on hitting “OK”.
      iv. From cell “A1”, hold the shift key and use the right arrow key until you have selected all columns up to the “AVG” column (cell “E1”)
         1. 

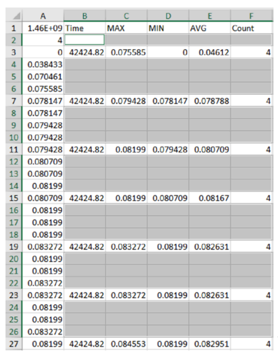
      v. Next, hold the control and shift keys and push the down arrow key to select all data in the columns.
      vi. Copy the data. (Control + C) and create a new sheet.
      vii. In the new sheet, right-click in cell “A1” and under Paste options select “paste values”, shown below.
         1. 

      viii. After pasting values, select “Column A” and delete the entire column. Shift the remaining cells left if they do not move automatically.
         1. 

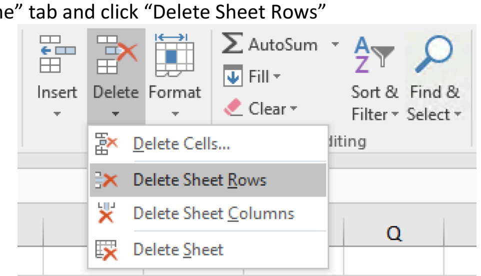
      ix. Select all cells in the newly created sheet (Control + A)
      x. Next, under the “Home” tab on the ribbon, click on the “Find & Select” button and select “Go To Special...”
         1. 

xi. After clicking on “Go To Special…”, a second window will open. In the left column, select the “blanks” option and click “OK”

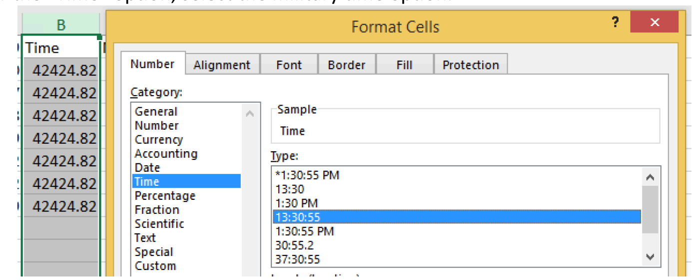
1. 

2.  This should be the result.

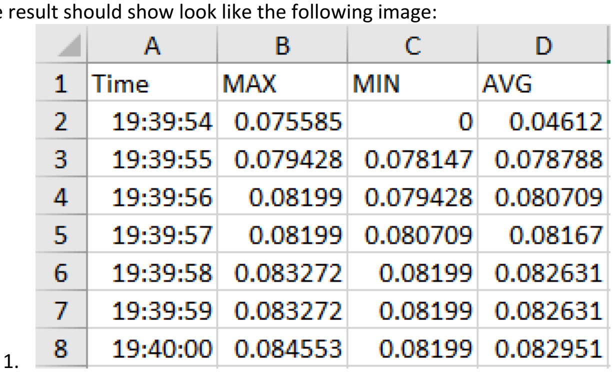
xii. If the image above looks correct, go to the “Delete” button under the “Home” tab and click “Delete Sheet Rows”

1. 

xiii. Under the column “Time”, select the entire column and format the cell. Under the “Time” option, select the military time option.

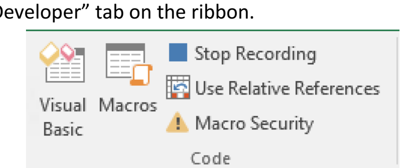
1. 

xiv. The result should show look like the following image:

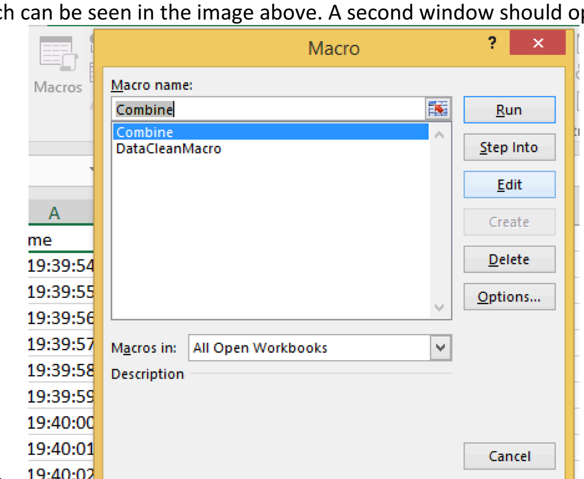
1. 

	A	B	C	D
1	Time	MAX	MIN	AVG
2	19:39:54	0.075585	0	0.04612
3	19:39:55	0.079428	0.078147	0.078788
4	19:39:56	0.08199	0.079428	0.080709
5	19:39:57	0.08199	0.080709	0.08167
6	19:39:58	0.083272	0.08199	0.082631
7	19:39:59	0.083272	0.08199	0.082631
8	19:40:00	0.084553	0.08199	0.082951

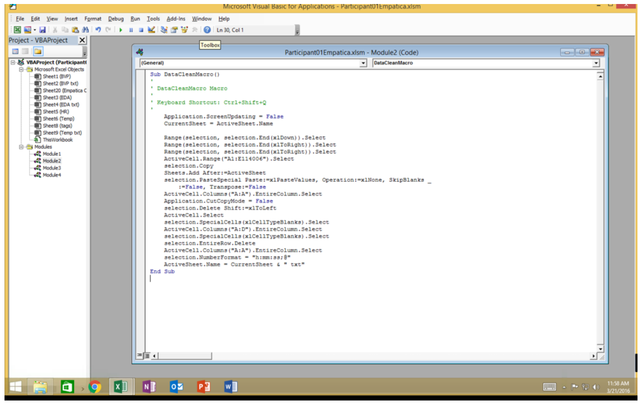
xv. End the macro operation by clicking the “Stop Recording” button under the “Developer” tab on the ribbon.

1. 

xvi. Once you have ended the macro recording, click on the “Macros” button, which can be seen in the image above. A second window should open.

1. 

xvii. Select the macro you have created and click the "Edit" button. This will take you to a new window.

1. 

xviii. Within this new window, create a new line (using the Enter/Return key) immediately before the "End Sub" script. In this new line enter the text "ActiveSheet.Name = CurrentSheet & " txt".

1. This function renames the new sheet you copied the data into using the previous sheets name and adding "txt" at the end.

a.

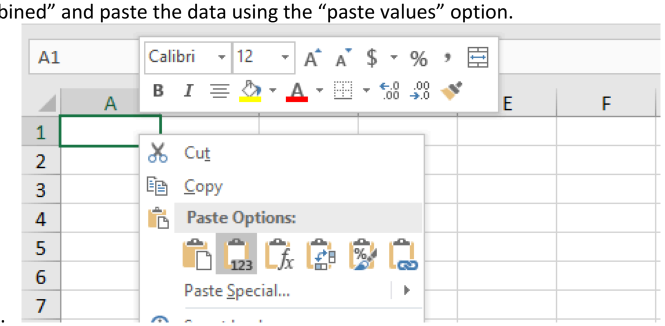
```
    ActiveCell.Select
    selection.SpecialCells(xlCellTypeBlanks).Select
    ActiveCell.Columns("A:D").EntireColumn.Select
    selection.SpecialCells(xlCellTypeBlanks).Select
    selection.EntireRow.Delete
    ActiveCell.Columns("A:A").EntireColumn.Select
    selection.NumberFormat = "h:mm:ss;@"
    ActiveSheet.Name = CurrentSheet & " txt"
End Sub
```

xix. Close out of this window. You have now successfully created a macro that can be used to "clean" the rest of the sheets in the participant's excel document. To run the macro, open the next sheet (ex: EDA) to be cleaned. Simply go to cell "A1" in the new sheet, and enter the keyboard shortcut you chose for your macro. A new sheet should automatically be created and the data should look similar to the image in **Section 3.b.xiv**

1. **NOTE: YOU WILL NOT NEED TO DO THIS FOR THE "HR" DATA BECAUSE THE FREQUENCY IS ONLY ONE RECORDING PER SECOND, LEAVING NO BLANK CELLS THAT NEED TO BE DELETED.**

c. When "cleaning" the Empatica data for other participants, you will need to keep the file you originally created the macro in open to use the macro in the other documents.

4. Combining the "cleaned" data into one set.
   a. In the cleaned sheet "BVP txt", select all cells in the sheet (Control + A)
      i. Create a new sheet at the end of the document called "Empatica Combined" and paste the data using the "paste values" option.

1. 

   b. In the following sheets (EDA txt, HR, Temp txt), copy all data and paste (using "paste values" into the "Empatica Combined" sheet.
      i. When pasting the data from other sheets into the "Empatica Combined" sheet, **make sure the time stamps from the EDA txt, HR, and Temp txt match up with those copied in with the BVP txt.**
         1. You will probably have to delete some rows, as the heart rate data doesn't usually start recording on the Empatica device as quickly as the other measures.
         2. Additionally, you will need to rename the columns to the appropriate title (ex. BVP MAX, BVP MIN, BVP AVG, EDA MAX, etc)
   c. This should leave you with a combined sheet that includes all BVP, EDA, HR, and Temp data with the correlating time stamps.

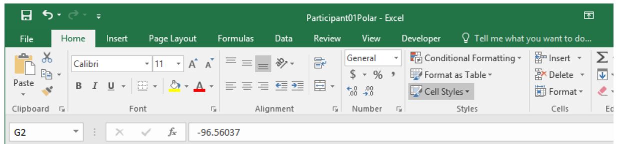
5. Combining Empatica and Polar data into one sheet
   a. Open a new excel document for each participant you are combining data for. Save file as "ParticipantXXMaster" where "XX" is the participant number.
   b. In this new document, create three sheets titled "Empatica Combined, Polar Combined, and Master Combined"
      i. In the participant's Empatica excel workbook, copy all data (Control + A, Control + C) from the "Empatica Combined" sheet into the new excel workbook's sheet titled "Empatica Combined".
      ii. In the new workbook's "Empatica Combined" sheet, create a new column called "Tags". From here, you can manually enter the tags from the participant's Empatica workbook sheet "tags" at the correct time stamps.
         1. In the cells, the first tag should indicate the start time of the walk, while the last should indicate the end of the walk. Tags in between can be considered "events" that participants marked themselves, indicating a potential event that may have elicited a physiological response.

a.

I	J	K	L
TEMP MAX	TEMP MIN	TEMP AVG	Tags
91.67	91.598	91.616	
91.634	91.598	91.625	
91.634	91.634	91.634	
91.634	91.634	91.634	Start

b. **NOTE: THIS STEP CAN ALSO BE DONE EARLIER, AFTER RUNNING THE MACRO.**

iii. Next, repeat the copy/paste process for the participant's Polar data. Copy the data from the Polar workbook's "Combined-Clean" sheet, and paste into the new workbook using the "paste values" option.

a. 

	A	B	C	D	E	F	G	H	I	J	K	L
1	Time	HR (bpm)	Speed (mi/h)	Distances (ft)	Temperatures (F)	Lat	Lng	Elevation	UTC	UTC Time	CST Time	
2	0:09:01	207	0		83.3	39.17579167	-96.56037	311	2016-02-25T01:47:54.000Z	01:47:54	19:47:54	
3	0:09:02	207	0	0	83.3	39.17579167	-96.56037	311	2016-02-25T01:47:55.000Z	01:47:55	19:47:55	
4	0:09:03	207	1	0	83.1	39.17581333	-96.5603717	311	2016-02-25T01:47:56.000Z	01:47:56	19:47:56	
5	0:09:04	207	1	3.61	83.1	39.17581333	-96.5603717	311	2016-02-25T01:47:57.000Z	01:47:57	19:47:57	
6	0:09:05	207	1.2	4.59	83.1	39.17581167	-96.56036833	312	2016-02-25T01:47:58.000Z	01:47:58	19:47:58	
7	0:09:06	207	1.2	10.17	82.9	39.17582667	-96.56036667	311	2016-02-25T01:47:59.000Z	01:47:59	19:47:59	
8	0:09:07	207	1.4	17.27	82.9	39.17584833	-96.56035833	311	2016-02-25T01:48:00.000Z	01:48:00	19:48:00	
9	0:09:08	207	1.4	24.38	83.1	39.17587	-96.56034667	312	2016-02-25T01:48:01.000Z	01:48:01	19:48:01	

2. Create a new column in column L called "Participant".
   a. Add the number of the participant (in study order) to the column for all cells
      i. eg: For Participant 01, enter "1" into the cell in row 2 under the "Participant" column (cell L2), then select the cell and double-click the square in the bottom-right corner of the selected cell to auto-fill to the bottom

iv. In the new workbook's sheet "Master Combined", copy and paste (using the "paste value" option) all data from the "Empatica Combined" sheet.

v. Next, copy and paste (using the "paste value" option) columns B – L from the "Polar Combined" sheet into the "Master Combined" sheet.

1. **When pasting the "Polar Combined" data into the "Master Cominbed" sheet, make sure that the appropriate cell is selected to paste into BASED ON THE CST TIME STAMPS FROM BOTH DEVICES!**
   a. There may be a large difference between where data collection occurs between the "Empatica Combined" and "Polar Combined" leaving you with this:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Time	HR	BVP MAX	BVP MIN	BVP AVG	EDA MAX	EDA MIN	EDA AVG	TEMP MAX	TEMP MIN	TEMP AVG	Tags	HR (bpm)	Speed (mi/h)	Distances (ft)	Temperatures (F)	Lat	Lng
2	19:40:04	58	28.81	-46.42	-2.35796875	0.084553	0.08199	0.083592	92.462	92.462	92.462							
3	19:40:05	55	30.79	-47.59	3.32328125	0.084553	0.083272	0.08359225	92.426	92.426	92.426							
4	19:40:06	56.67	30.35	-48.62	3.8234375	0.084553	0.083272	0.08423275	92.39	92.39	92.39							
5	19:40:07	59	27.6	-47.83	2.25296875	0.085834	0.084553	0.08487325	92.426	92.426	92.426							
6	19:40:08	57.8	22.33	-51.88	-2.25546875	0.085834	0.084553	0.0851935	92.426	92.426	92.426							
7	19:40:09	56.17	191.38	-52.78	5.77125	0.087115	0.083272	0.08551375	92.426	92.426	92.426							
8	19:40:10	58	197.92	-115.13	9.92609375	0.087115	0.084553	0.08615425	92.39	92.39	92.39							
9	19:40:11	59.38	363.22	-261.23	-35.66125	0.087115	0.079428	0.08391225	92.426	92.426	92.426							
10	19:40:12	60.33	91.77	-148.03	-19.30859375	0.084553	0.079428	0.08231075	92.426	92.426	92.426							
11	19:40:13	61	123.38	-138.74	3.30890625	0.092239	0.089677	0.09063775	92.426	92.39	92.399							
12	19:40:14	61.55	515.28	-397.39	26.1096875	0.090958	0.08199	0.086154	92.426	92.39	92.417							
13	19:40:15	61.92	310.7	-378.91	14.41515625	0.087115	0.084553	0.08551375	92.426	92.39	92.399							
14	19:40:16	62.23	236.19	-163.01	-19.0740625	0.089677	0.084553	0.08743525	92.39	92.354	92.363							
15	19:40:17	62.64	234.23	-280.5	-6.856875	0.087115	0.078147	0.082631	92.354	92.3	92.3135							
16	19:40:18	63	159.58	-298.81	-30.9346875	0.096083	0.085834	0.09031775	92.3	92.282	92.2865							
17	19:40:19	63.25	455.87	-55.88	93.26078125	0.084553	0.084553	0.084553	92.3	92.282	92.2955							
18	19:40:20	63.47	254.01	-295.66	-44.2053125	0.085834	0.083272	0.084553	92.3	92.282	92.2865							
19	19:40:21	63.83	218.92	-295.37	16.24671875	0.088396	0.084553	0.08679475	92.282	92.246	92.255							
20	19:40:22	64.05	242.5	-231	-40.00828125	0.094801	0.088396	0.092239	92.282	92.246	92.273							
21	19:40:23	64.2	264.34	-192.79	34.085625	0.097364	0.096083	0.0967235	92.282	92.282	92.282							
22	19:40:24	64.33	60.36	-31.15	9.64578125	0.097364	0.094801	0.09608275	92.282	92.282	92.282							
23	19:40:25	64.45	140.4	-247.42	-15.75640625	0.096083	0.094801	0.095442	92.3	92.282	92.2955							
24	19:40:26	64.61	260.65	-140.06	-28.756875	0.097364	0.094801	0.09608275	92.3	92.282	92.2865							
25	19:40:27	64.79	261.47	-351.01	38.7921875	0.094801	0.092239	0.09384025	92.282	92.246	92.255							
26	19:40:28	65	273.2	-168.42	-16.48984375	0.09352	0.089677	0.092239	92.246	92.174	92.192							
27	19:40:29	65.08	260.09	-316.4	-18.25765625	0.096083	0.089677	0.09320025	92.174	92.138	92.147							
28	19:40:30	65.3	342.93	-170.5	3.5540625	0.096083	0.089677	0.0925595	92.174	92.138	92.165							
29	19:40:31	65.46	176.07	-183.08	23.8565625	0.092239	0.088396	0.09063775	92.174	92.174	92.174							

2. After verifying that the time stamps align after pasting, delete the columns pasted from the "Polar Combined" sheet titled: *Elevation, UTC, UTC Time,* and *CST Time.*
3. Save a copy of this workbook as a .csv file.

6. Combining all participant data into one sheet and normalizing data
   a. Open a new excel workbook and save it as "CombinedParticipantMaster"
   b. Copy and paste (using "paste values" option) all data from each participant's "Master Combined" in sequential order (i.e, Participant 2's data comes immediately after Participant 1 and can be differentiated using the column "Participant")

c. In every cell under the column "Lat" that is blank, enter a value of "-1"
d. Add two new columns titled "EDA AVG NORM" and "HR NORM".

i.

Q	R	S	T	U
Lat	Lng	Participant	EDA AVG NORM	HR NORM
-1		1		
-1		1		
-1		1		
-1		1		
-1		1		

e. In a separate column, add a number for every participant that has been included.
f. Additionally, in row 1 add EDA AVG MAX, EDA AVG MIN, HR MAX, and HR MIN

i.

S	T	U	V	W	X	Y	Z	AA
Participant	EDA AVG NORM	HR NORM			EDA AVG MAX	EDA AVG MIN	HR MAX	HR MIN
1				1				
1				2				
1				3				
1				4				
1				5				
1				6				
1				7				
1				8				
1				9				
1				10				
1				11				
1				12				
1				13				
1				14				
1				15				
1				16				
1				17				

g. In cell "X1" (as shown above), enter the formula: =MAX(IF($Q$2:$Q$29738>=0,IF($H$2:$H$29738>0,IF($S$2:$S$29738=W2,IF($Q$2:$Q$29738>39.1762,$H$2:$H$29738)))))
   i. After entering the formula above into the correct cell, **do not just hit the enter key alone, you must do SHIFT+CONTROL+ENTER otherwise the formula will not function properly.**
   ii. This formula seeks to identify the maximum value in the EDA AVG data for Participant 01.

h. In cell "Y1" (as shown above), enter the formula: =MIN(IF($Q$2:$Q$29738>=0,IF($H$2:$H$29738>0,IF($S$2:$S$29738=W2,IF($Q$2:$Q$29738>39.1762,$H$2:$H$29738)))))
   i. After entering the formula above into the correct cell, **do not just hit the enter key alone, you must do SHIFT+CONTROL+ENTER otherwise the formula will not function properly.**
   ii. This formula seeks to identify the minimum value in the EDA AVG data for Participant 01.

i. In cell "Z1" (as shown above), enter the formula: =MAX(IF($Q$2:$Q$29738>=0,IF($B$2:$B$29738>0,IF($S$2:$S$29738=$W2,IF($Q$2:$Q$29738>39.1762,$B$2:$B$29738)))))
   i. After entering the formula above into the correct cell, **do not just hit the enter key alone, you must do SHIFT+CONTROL+ENTER otherwise the formula will not function properly.**
   ii. This formula seeks to identify the maximum value in the HR data for Participant 01.

j. In cell "AA1" (as shown above), enter the formula:
=MIN(IF($Q$2:$Q$29738>=0,IF($B$2:$B$29738>0,IF($S$2:$S$29738=$W2,IF($Q$2:$Q$29738>39.1762,$B$2:$B$29738)))))
    i. After entering the formula above into the correct cell, **do not just hit the enter key alone, you must do SHIFT+CONTROL+ENTER otherwise the formula will not function properly.**
    ii. This formula seeks to identify the minimum value in the HR data for Participant 01.

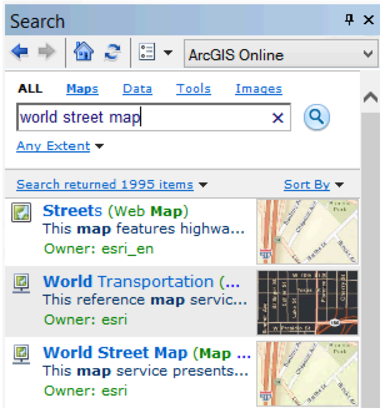
k. After entering all formulas, use the auto-fill function by double-clicking on the selected cell to add the formulas for all participants.

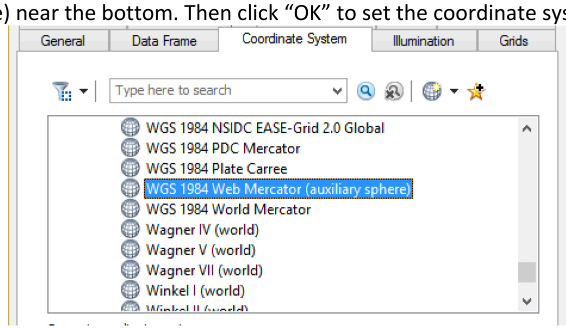
l. In cell "T1" (as shown above), enter the formula:
=IF($Q$2>39.1762,(H2-VLOOKUP(S2, $W$2:$Y$18,3))/(VLOOKUP(S2, $W$2:$Y$18,2)-VLOOKUP(S2, $W$2:$Y$18,3)),"")
    i. This formula uses excel's "VLOOKUP" function to reference the table and normalize the EDA AVG data for each participant based on their maximum and minimum responses.

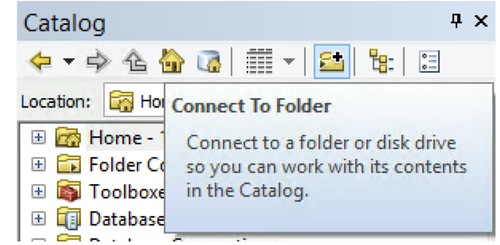
m. In Cell "U1" (as shown above), enter the formula:
=IF($Q2>39.1762,(B2-VLOOKUP($S2, $W$2:$AA$18,5,FALSE))/(VLOOKUP($S2, $W$2:$AA$18,4,FALSE)-VLOOKUP($S2, $W$2:$AA$18,5,FALSE)),"")
    i. This formula uses excel's "VLOOKUP" function to reference the table and normalize the HR data for each participant based on their maximum and minimum responses.

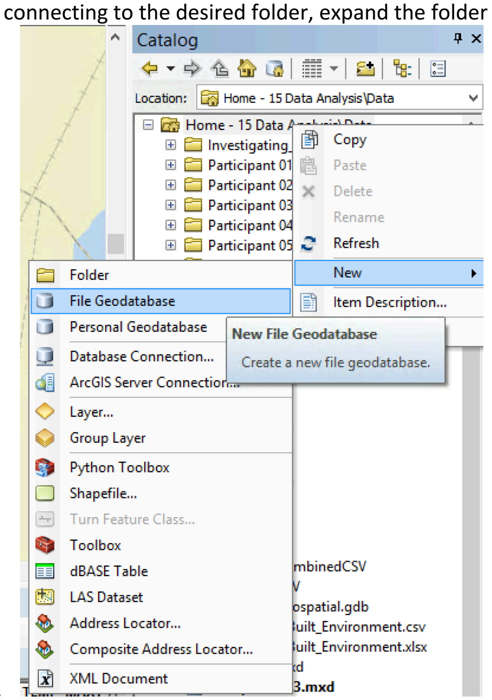
n. Save a copy of this workbook as a .csv file and it will ready to import into GIS.

APPENDIX G - SPATIALLY PROJECTING PARTICIPANT DATA USING ARCGIS

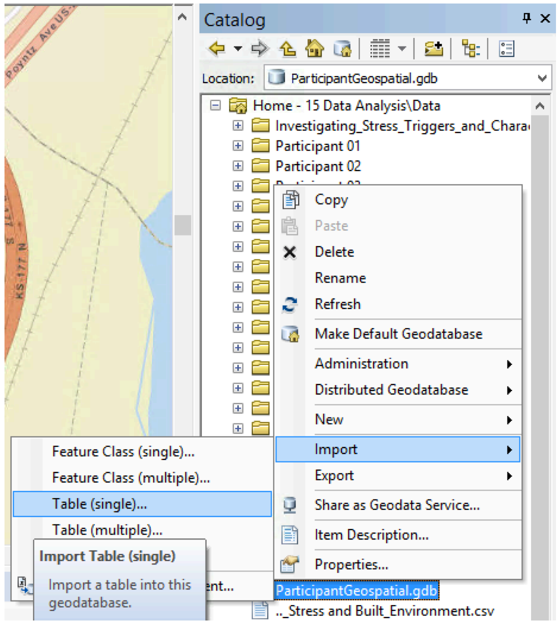
1. Open ArcGIS and create a new map document.
2. First, add a base map. Under the "Search" tab, click the drop-down box and select "ArcGIS Online". In the text field, enter "world street map". Select "World Street Map" and drag it into the model space.
    a. 

3. Once the base map, right click in model space and go to "Data Frame Properties". In the new window, select the tab "Coordinate System". Since this data is going to be projected, a projected coordinate system must be selected.
    a. Expand the "Projected Coordinate Systems" folder, then expand the "World" folder. Within the "World" folder, select "WGS 1984 Web Mercator (auxillary sphere) near the bottom. Then click "OK" to set the coordinate system.
        i. 

4. Next, under the "Catalog" tab, create a new folder connection (using the "Connect to Folder" button) and find the folder that holds all of your data.
    a. 

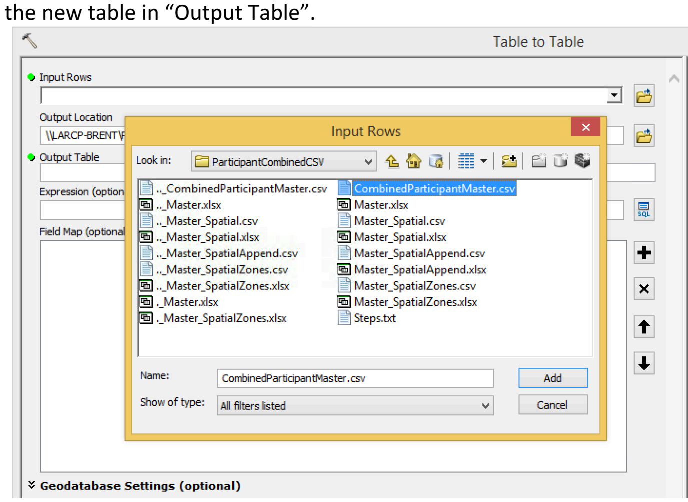
5. After connecting to the desired folder, expand the folder and create a new geodatabase.
    a. 

6. Once the geodatabase has been made, the next step is importing the "CombinedParticipantMaster" that was created in the previous appendix. Right-click on the geodatabase (file extension .gdb), select "Import" and then choose "Table (single)"



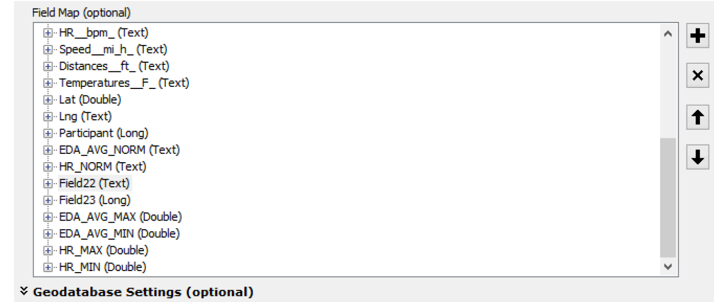
a.

7. A second window should open, allowing you to navigate out to find the "CombinedParticipantMaster" excel file. Click the browse button next to "Input Rows" to open up a browsing window. **MAKE SURE TO SELECT THE .CSV VERSION OF THE FILE.** Name the new table in "Output Table".



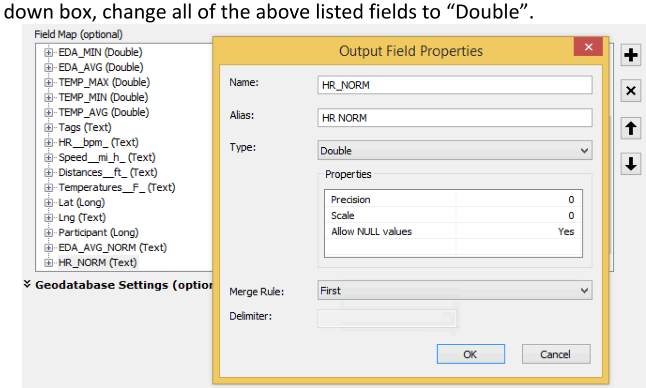
a.

8. Once the correct file has been selected for importing, under "Field Map" there will be some edits to do to the fields being imported.
   a. Scrolling to the bottom, notice that some fields have different properties (shown in parentheses). Some of these will have to be changed.

      i. 

      ii. Of the fields shown in the image above, start out by deleting: *Field22, Field23, EDA_AVG_MAX, EDA_AVG_MIN, HR_MAX,* and *HR_MIN*. This can be done by selecting the field and clicking the "X" to the right of the box.

      iii. Next, some of the field types will need to be changed. The fields to change are: *HR_bpm_, Speed_mi_h_, Distances_ft_, Temperatures_F_, Lng, EDA_AVG_NORM,* and *HR_NORM.* To do this, right-click on the field and select "Properties". A new window will open and from the "Type" drop down box, change all of the above listed fields to "Double".

         1. 

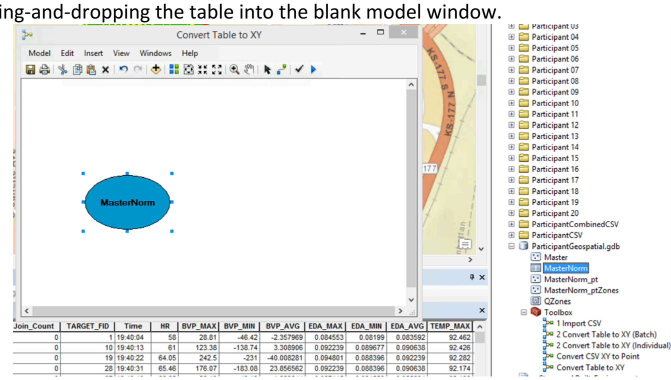
      iv. Once all the unnecessary fields have been deleted and the previously listed f

         1. 

      v. Make sure the output location of this new table is in the geodatabase you created. Use the browse-button next to "Output Location" to browse to your geodatabase. Once this has been done, click "OK" and the new table should appear in the geodatabase.

9. The next step is creating a model that takes the raw latitude and longitude coordinate data and creates points that maintain the physiological data at each lat/long point.
   a. After the new table has been created, within the geodatabase create a new toolbox by right-clicking on the geodatabase, going to “New”, and selecting “Toolbox”.
      i. Within this toolbox, create a new model. This is done by right-clicking on the toolbox, going to “New”, and selecting “Model”. Close the window. Rename the model to “Convert Table to XY”. Once the model appears in the toolbox, right-click, select “Edit”, and begin building the model.
      ii. When the model editing window opens, it will be blank. To begin, add the newly created table to the window by expanding the geodatabase and dragging-and-dropping the table into the blank model window.

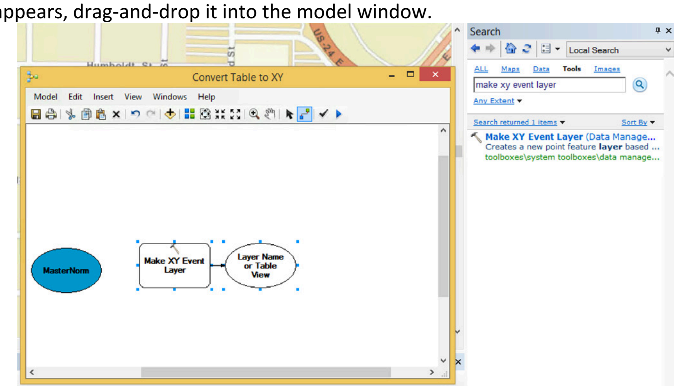
1.



a. *In this image “MasterNorm” is the title of the new table.*

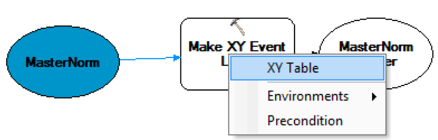
      iii. Next, open the “Search” tab again. In the “Search” tab, change the drop-down menu to “Local Search” and below click the “Tools” option for search criteria. In the text box, type in “Make XY Event Layer”. When the tool appears, drag-and-drop it into the model window.

1.



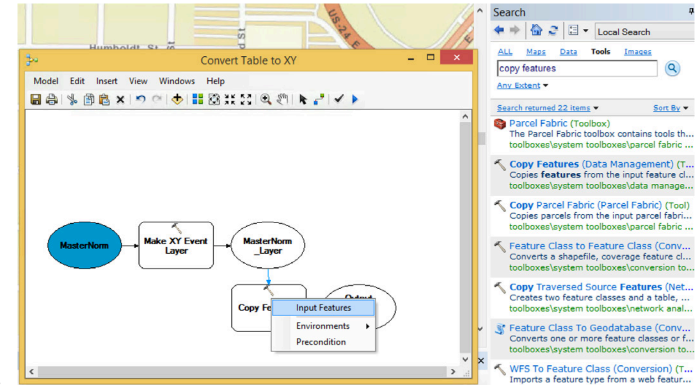
      iv. Now click the button that is highlighted blue in the model window in the image above (“Connect”). Connect the new table (“MasterNorm” in this window for reference) and then the “Make XY Event Layer” tool to link the two entities together. A small menu should appear after clicking on the “Make XY Event Layer” tool, click the “XY event” option.

1.



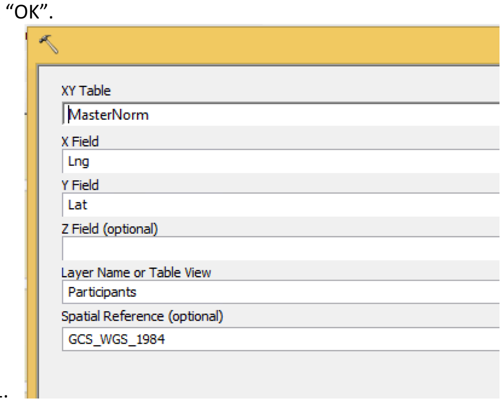
      v. Go back to the “Search” tab, and search for “Copy Features (Data Management)”. Drag-and-drop this tool into the model, and use the “Connect” tool to link the output of the “Make XY Event Layer” to the “Copy Features” tool. A similar small menu will appear, select “Input Features.”

1.



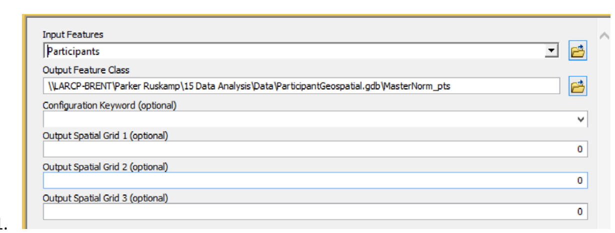
      vi. Double-click on the “Make XY Event Layer” tool to edit the inputs and outputs. Under “X Field”, click the dropdown and select “Lng” (longitude coordinates). If the “Y Field” doesn’t already show “Lat” (latitude coordinates), select “Lat”. In the “Layer Name or Table View” enter “Participants”. The “Spatial Reference” should already be set to the data frame’s coordinate system (WGS 1984 Web Mercator (auxillary sphere)). Click “OK”.

1.



      vii. Notice that the tools are now yellow in color and the outputs are green. Double-click on “Copy Features” and make sure the “Input Features” is showing “Participants”. In “Output Feature Class”, click the browse button and save the new feature class in the geodatabase with the name you desire.

1.



a. *For this example, the name of the feature class is “MasterNorm_pts”, indicating it is a master file with normalized data to be output as a point feature class.*

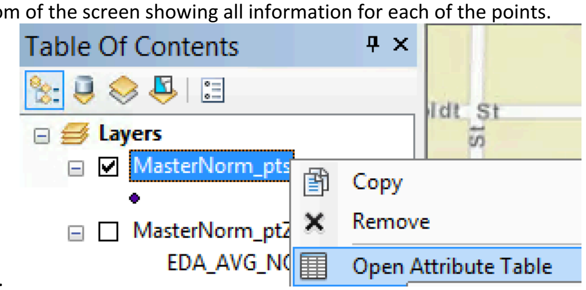
viii. Click the "Run" button (the blue arrow similar to a "Play" button). Once the model has finished running, the point feature class should appear in the geodatabase with the name given to it. Drag-and-drop the feature class into the model space and it should appear as numerous dots, with the name of the feature class and the symbology appearing under the "Table of Contents" tab.

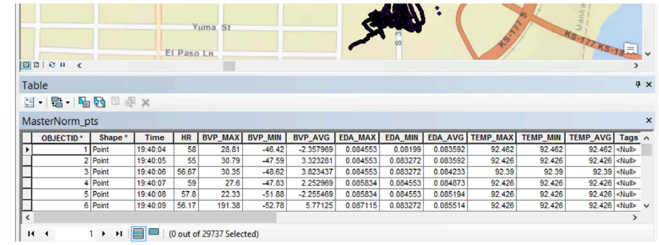
1. 

10. Editing the data for analysis.

a. With the new feature class created from the latitude and longitude coordinates, it can be formatted for easier reading and cleaned of any anomalies. In the image above, the GPS device gave strange results at the beginning of participant's walks. Additionally, some participants did not walk the correct route. These are two items that must be edited to get a more accurate reading for participants that did complete the correct route.

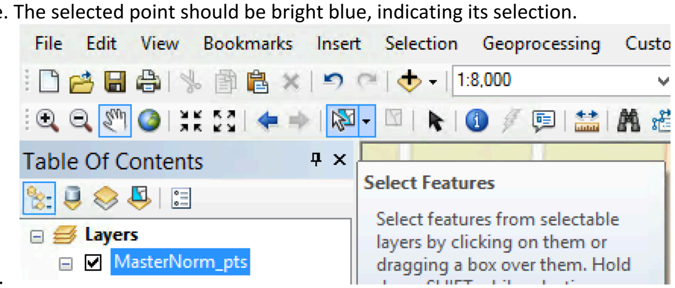
i. To begin, right-click on the feature class under the "Table of Contents" tab and select "Open Attribute Table". A table should appear at the bottom of the screen showing all information for each of the points.

1. 

2. 

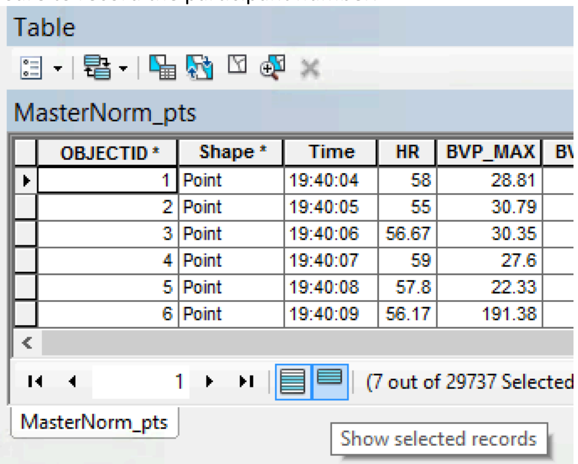
OBJECTID *	Shape *	Time	HR	BVP_MAX	BVP_MIN	BVP_AVG	EDA_MAX	EDA_MIN	EDA_AVG	TEMP_MAX	TEMP_MIN	TEMP_AVG	Tags
1	Point	19:40:04	58	28.81	-46.42	-2.357969	0.084553	0.08199	0.083592	92.462	92.462	92.462	<Null>
2	Point	19:40:05	55	30.79	-47.59	3.323281	0.084553	0.083272	0.083592	92.426	92.426	92.426	<Null>
3	Point	19:40:06	56.67	30.35	-48.62	3.823437	0.084553	0.083272	0.084233	92.39	92.39	92.39	<Null>
4	Point	19:40:07	59	27.6	-47.83	2.252969	0.085834	0.084553	0.084873	92.426	92.426	92.426	<Null>
5	Point	19:40:08	57.8	22.33	-51.88	-2.255469	0.085834	0.084553	0.085194	92.426	92.426	92.426	<Null>
6	Point	19:40:09	56.17	191.38	-52.78	5.77125	0.087115	0.083272	0.085514	92.426	92.426	92.426	<Null>

ii. identify the participants who walked the incorrect routes by using the "Select Features" button. Click on any point that is not along the desired route. The selected point should be bright blue, indicating its selection.

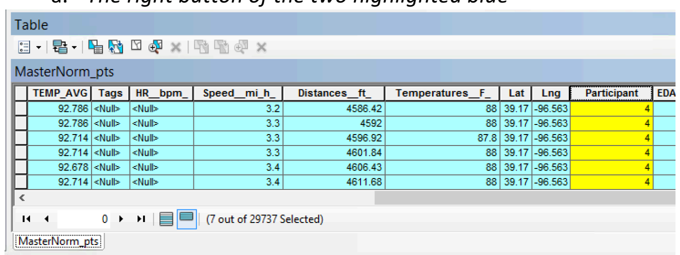
1. 

2. 

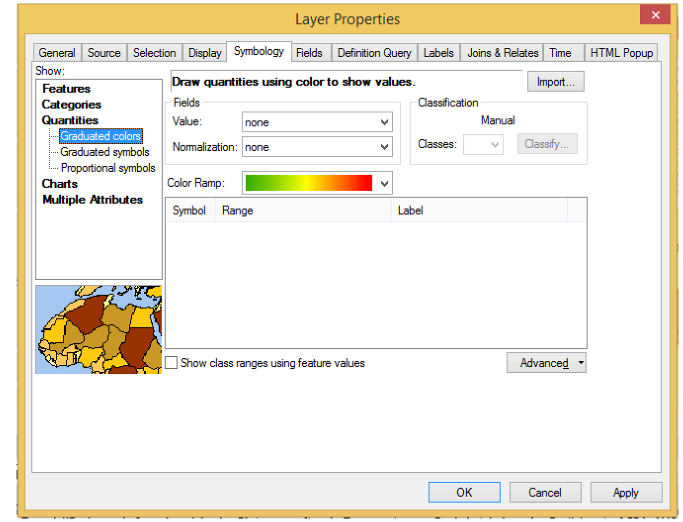
iii. From here, go to the table, and click on the button that looks like a series of bright blue colored bars ("Show selected records"). This button isolates the selected feature(s) in the attribute table. Scroll right and look for the column "Participant". Make note of the participant number (e.g, 1, 2, etc.). Repeat for all participants who did not walk the correct route, making sure to record the participant number.

1. 

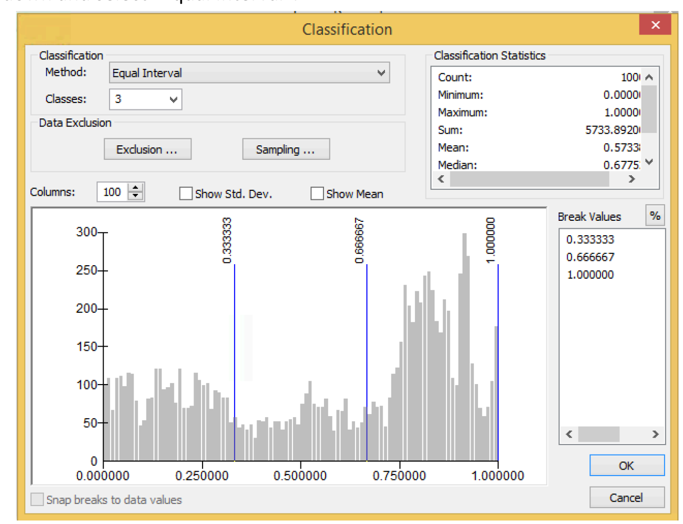
a. *The right button of the two highlighted blue*

2. 

iv. With all incorrect participants recorded, right-click on the feature class under the "Table of Contents" tab and select "Properties". When the new window opens, click on the "Symbology" tab. From the list on the left, selected "Quantities" then select "Graduated colors".

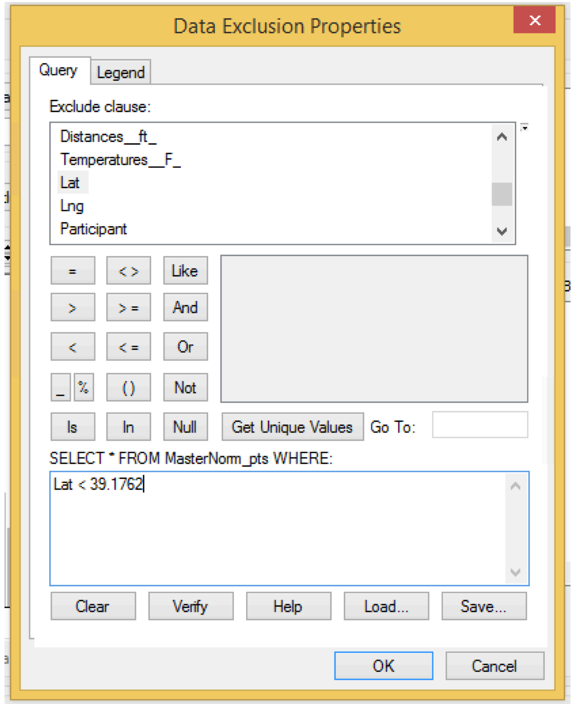
1. 

v. From the "Value" drop-down box, select either "HR_NORM" or "EDA_AVG_NORM" (both will be done, so it doesn't matter which is first). From the "Classes" drop-down box, select "3" and then click "Classify", which will open a new window. In the new window, click the "Methods" drop-down and select "Equal Interval".

1. 

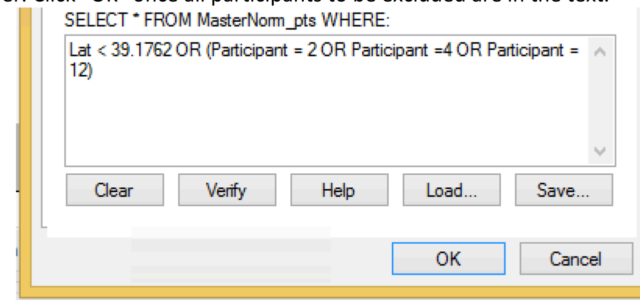
vi. While still in the “Classification” window, click “Exclusions”, opening another window. In this new window “Exclude clause” should provide a list of all the fields associated with the points. Double-click “Lat” (X-axis of points) making it appear in the text box below. From here, you will have to enter a latitudinal point to identify a designated cutoff.

1. **NOTE:** Any easy way to identify the desired cutoff is to go back into the model, use the “Select Features” button, and select points near the desired cutoff. Check the “Lat” field of the selected point in the attribute table and record it. Then, go back into the “Exclusions” window and enter “< or > XX.XXXX”. For a more precise cutoff, extend the decimal values as far as needed. The “< or >” depends on if the data is below or above the cutoff.



2.

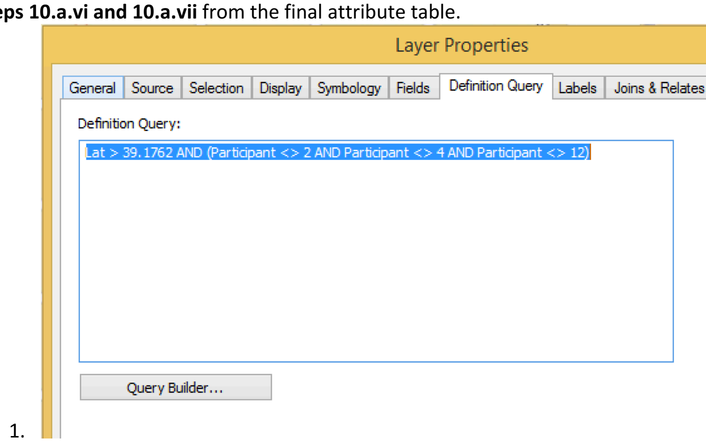
vii. Staying in the “Data Exclusion Properties” window, here you can exclude the participants that walked incorrect routes. In the text box at the bottom of the page, after the latitude coordinate enter “OR (Participant = XX OR Participant = XX OR Participant = XX)” where “XX” is the participant number. Click “OK” once all participants to be excluded are in the text.



1.

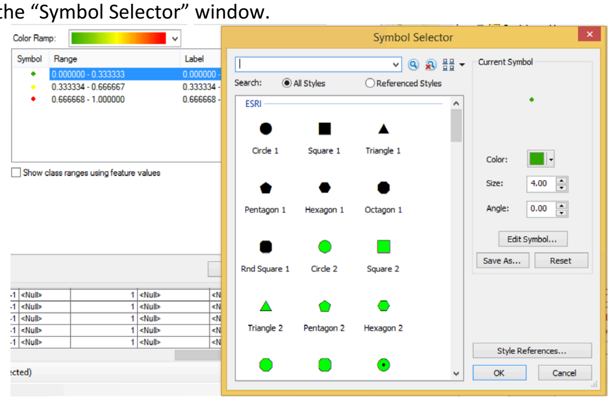
a. *For this example, Participants 2, 4, and 12 were excluded because of incorrect routes. If fewer or more participants need to be excluded, add or subtract “OR Participant = XX”*

viii. Go to the “Definition Query” tab and enter “Lat > XX.XXXX AND (Participant <> XX)”, where “XX.XXXX” is the selected “Lat” cutoff and “XX” is the participant number. For every additional participant to be excluded, enter “AND Participant <> XX” in the formula above before the final parentheses. This step will exclude all data that you identified in **steps 10.a.vi and 10.a.vii** from the final attribute table.

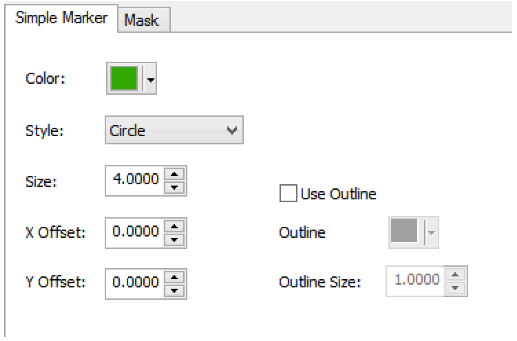


1.

ix. Click “OK” in the “Classification” window, bringing you back to the “Layer Properties” window. In this window, you can change the feature class’s symbology. Double-click on the symbol (in this case the colored dots) to open the “Symbol Selector” window.

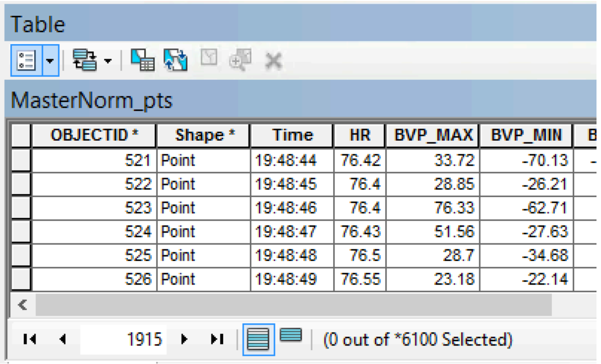
1. 

x. Inside the “Symbol Selector” window, click on “Edit Symbol”, opening the “Symbol Property Editor” window. Once in this window, uncheck the box that says “Use Outline”. This will make data much easier to read on screen and in any maps produced. Changes in color may be made in this window or in the “Symbol Selector” window.

1. 

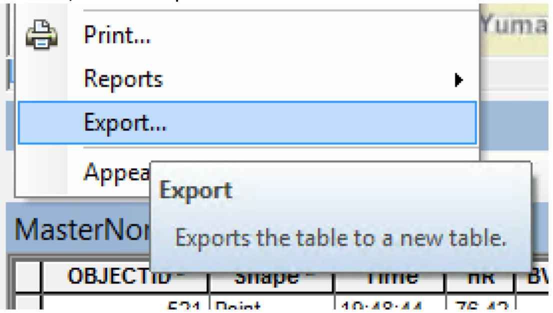
xi. Click “OK” through all windows once desired choices are made.
xii. Under the “Table of Contents” tab, perform a copy-paste operation on the layer that just went through editing. Right-click on the copied layer and select “Properties”.
xiii. Under the “Symbology” tab, note that most of the changes made to the previous layer remain in the copy. However, in this new layer, under the “Value” drop down, select whichever of “EDA_AVG_NORM” or “HR_NORM” you did not do in the previous operation.
xiv. Repeat **step 10.a.v.** to change the classification method to “Equal Interval” rather than “Natural Breaks (Jenks)”.
xv. The feature class symbologies should remain the same (no outline, desired color, etc.) from the copied file, the “Classes” drop-down should remain at “3”, all exclusions applied in the original layer should remain in the copy, and the definition query should remain as well. If this is not the case, repeat **steps 10.a.vi through 10.a.xi**.

11. Exporting final attribute tables
    a. Re-open the attribute tables of the two created layers (one should be for EDA_AVG_NORM and the other for HR_NORM).
    b. Click the drop-down on the upper-leftmost button in the table menu.

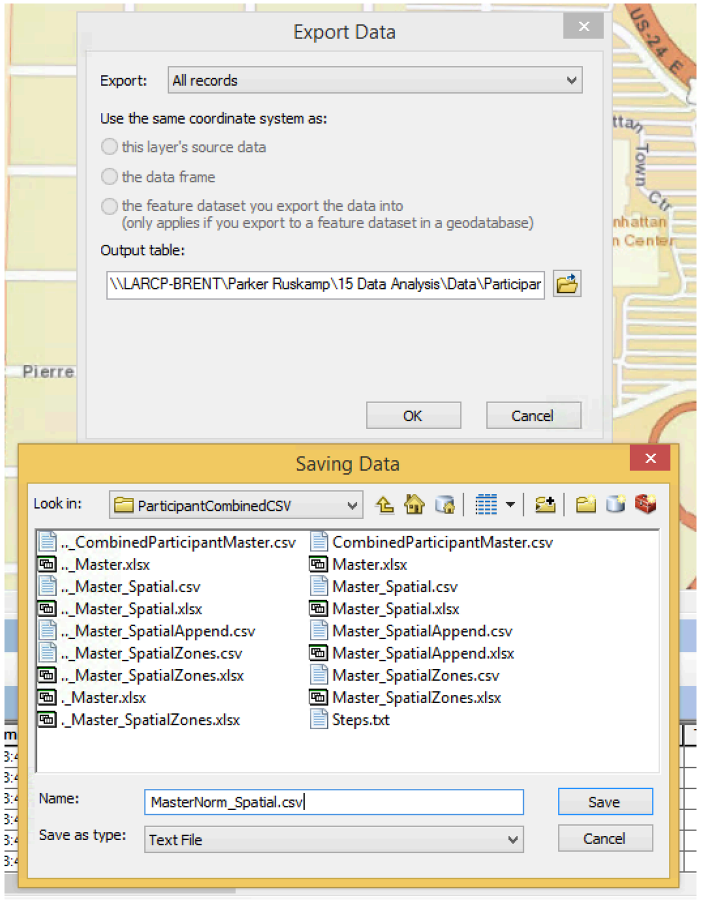
i. 

1. *The button is highlighted blue, directly under “Table”. Click the small down arrow immediately adjacent to it.*

    c. From this menu, select “Export”

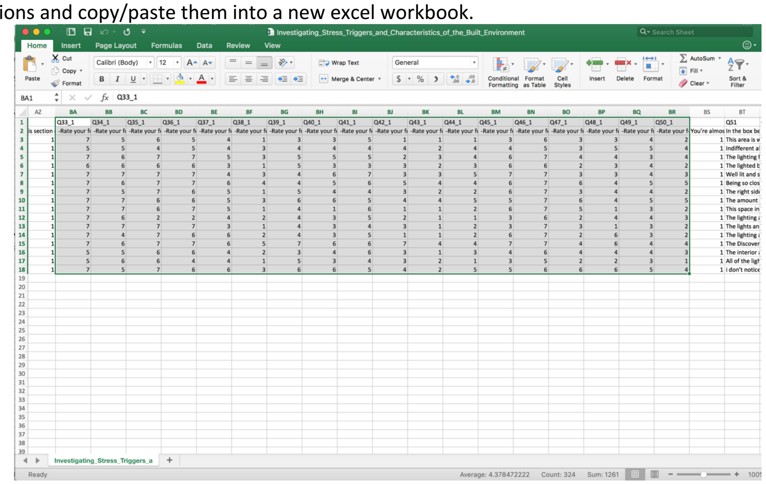
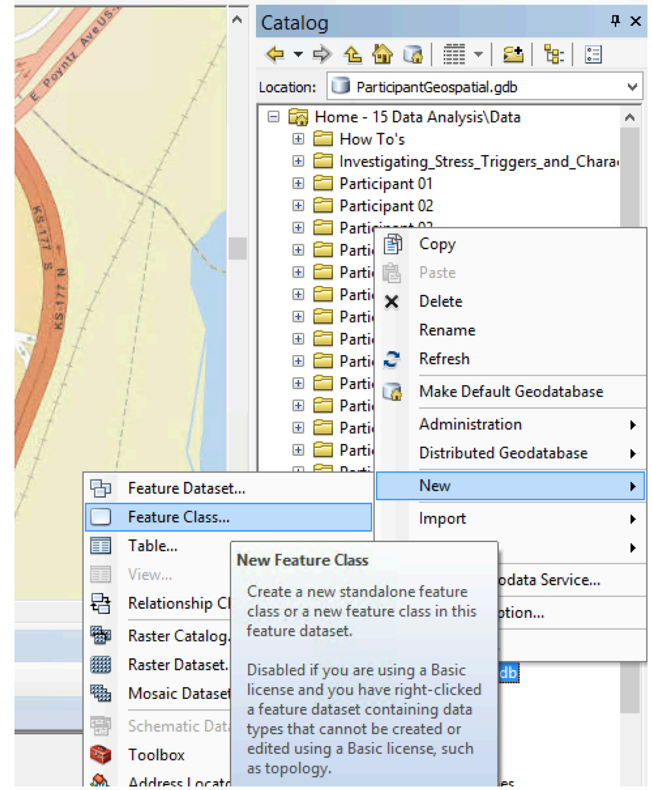
i. 

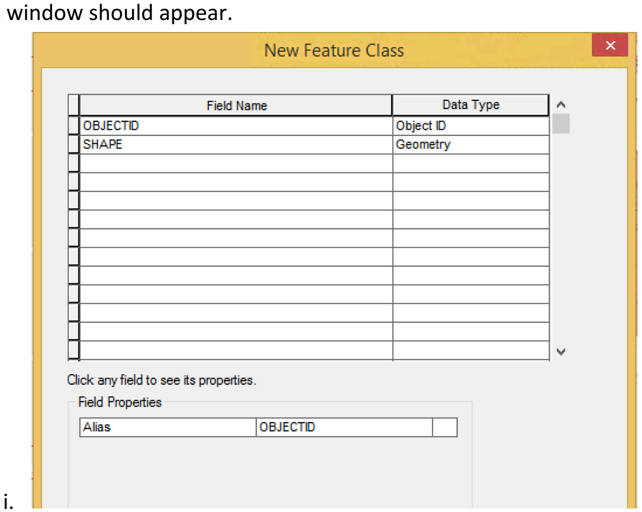
    d. A new window will appear. Click the browse button next to “Output Table”. A browsing window will appear allowing an export of the file in the desired destination. Change the “save as type” to **TEXT FILE** and selecting a name, give the file a **.CSV EXTENSION**. This is a very critical step, allowing the table to be opened in excel. Save the map document, and close out of GIS.

i. 
Export Data
Export: All records
Use the same coordinate system as:
this layer's source data
the data frame
the feature dataset you export the data into
(only applies if you export to a feature dataset in a geodatabase)
Output table:
\\LARCP-BRENT\Parker Ruskamp\15 Data Analysis\Data\Participar
OK
Cancel
Saving Data
Look in: ParticipantCombinedCSV
.._CombinedParticipantMaster.csv
.._Master.xlsx
.._Master_Spatial.csv
.._Master_Spatial.xlsx
.._Master_SpatialAppend.csv
.._Master_SpatialZones.csv
.._Master_SpatialZones.xlsx
._Master.xlsx
._Master_SpatialZones.xlsx
CombinedParticipantMaster.csv
Master.xlsx
Master_Spatial.csv
Master_Spatial.xlsx
Master_SpatialAppend.csv
Master_SpatialAppend.xlsx
Master_SpatialZones.csv
Master_SpatialZones.xlsx
Steps.txt
Name: MasterNorm_Spatial.csv
Save as type: Text File
Save
Cancel

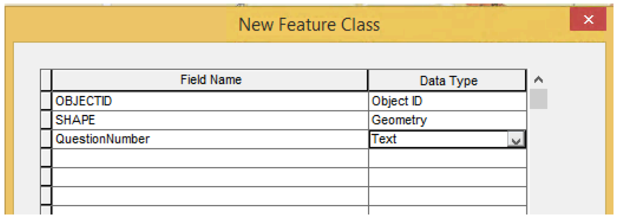
APPENDIX H - SICKMANN'S SIDEWALK WALKABILITY EVALUATION

APPENDIX I - COMPARATIVE ANALYSIS OF PHYSIOLOGICAL DATA AND IMAGE RATINGS

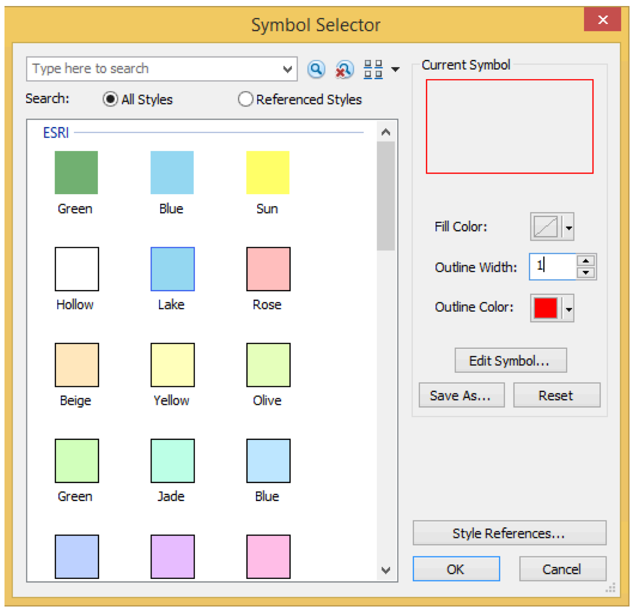
1. After a sufficient number of participants have completed the survey, export/download the results. (For this study, **Qualtrics** was the hosting service for the survey.)
   a. Select the **.CSV export option** if it is available.
2. Once the .csv file has been downloaded and saved in a desired location, open the file.
   a. In the file, identify which questions are the image ratings of the route. Select the questions and copy/paste them into a new excel workbook.
      i. 
   b. In the new workbook you paste the data into, rename the sheet to "Image Ratings".
3. Open the GIS document from the appendix "Viewing Participant Data in GIS for Analysis". To do this comparative analysis between GIS and the image ratings, points within the "zones" of images must be delineated and isolated. This step is rather qualitative, reference the images of the route used in the image ratings and identify "zones" where the character of the route matches the photos. These zones will be created as feature classes in GIS and joined with the physiological data.
   a. Under the "Catalog" tab, go to the geodatabase and right-click, and under "New" select "Feature Class".
      i. 

   b. When the new window opens, under "Name" enter "QuestionZones" and in the drop-down menu below select "Polygon Features". Hit the "Next" button at the bottom of the window.
   c. The proper coordinate system to select is "GCS_WGS_1984". Click the "Next" button.
   d. In the next two windows, do not make any alterations. Click the "Next" button. This window should appear.
      i. 

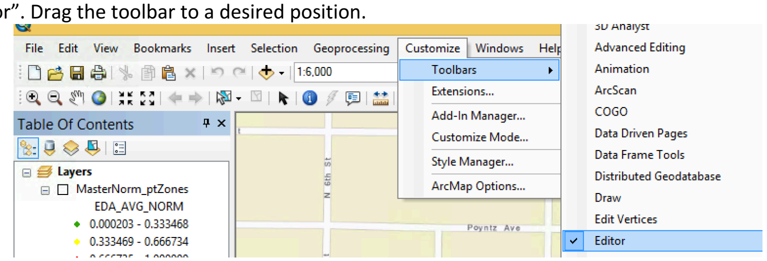
e. In a blank cell under "Field Name", enter "QuestionNumber" and under "Data Type" select "Text". Click the "Finish" button to finalize the feature class.

i. 

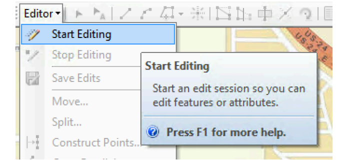
f. The new feature class should appear under the "Table of Contents" as a new layer. Double-click on the feature's symbology to edit it. Under "Fill Color", select "No Fill". Under "Outline Color" select a desired color (red is good for readability). Change the "Outline Width" to 1. Click "OK" to finish editing the symbology.

i. 

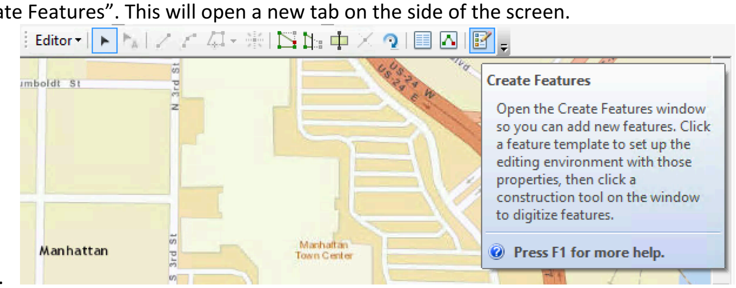
g. Under the "Customize" tab at the top of the screen, go to "Toolbars" and select "Editor". Drag the toolbar to a desired position.

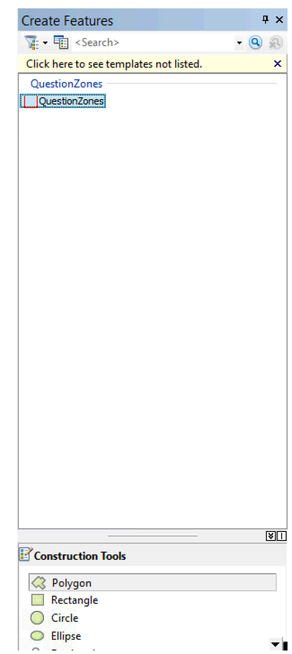
i. 

h. With the "QuestionZones" layers selected, go to the "Editor" toolbar, and click "Editor" and select "Start Editing".

i. 

i. A window may appear saying "Spatial reference does not match the data frame." Click "Continue". Go back to the "Editor" toolbar and click the last button "Create Features". This will open a new tab on the side of the screen.

i. 

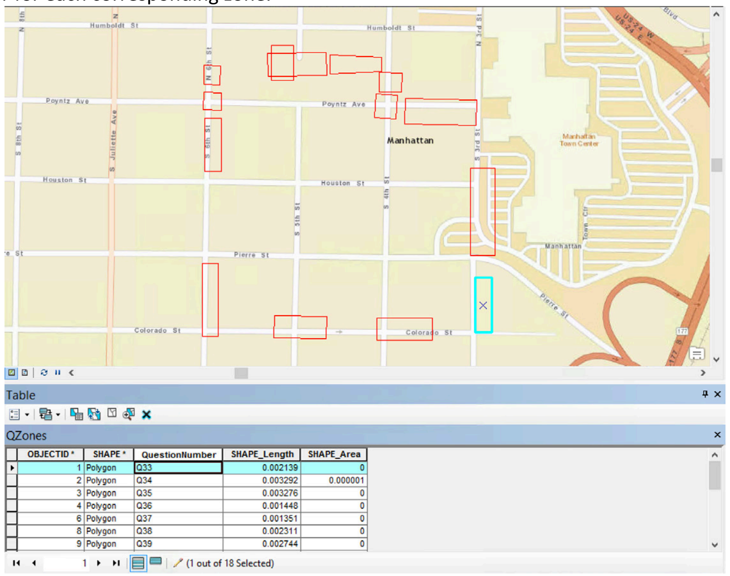
ii. 

1. Under this tab, select "QuestionZones" (layer needs to be turned on under "Table of Contents"). This will display the construction tools shown at the bottom of the image. Select "Polygon".

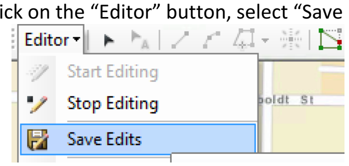
j. After selecting the "Polygon" construction tool, begin to delineate the images zones on the map. This is a subjective step, so use judgment based on the content of the image, and the surrounding context to delineate the zones.

k. Once each image has it's own zone, right-click on the "QuestionZones" layer under the "Table of Contents" and select "Open Attribute Table".

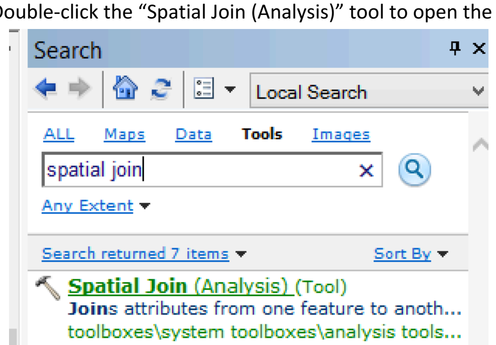
l. Under the field “QuestionNumber” in the attribute table, enter the question number for each corresponding zone.

i. 

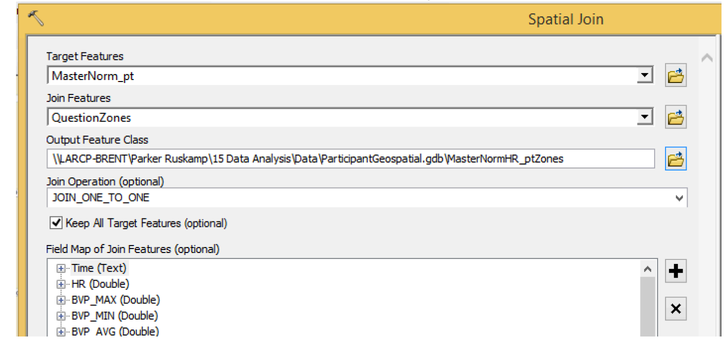
m. After adding a question number to each zone, go back to the “Editor” toolbar, and click on the “Editor” button, select “Save Edits”, then select “Stop Editing”.

i. 

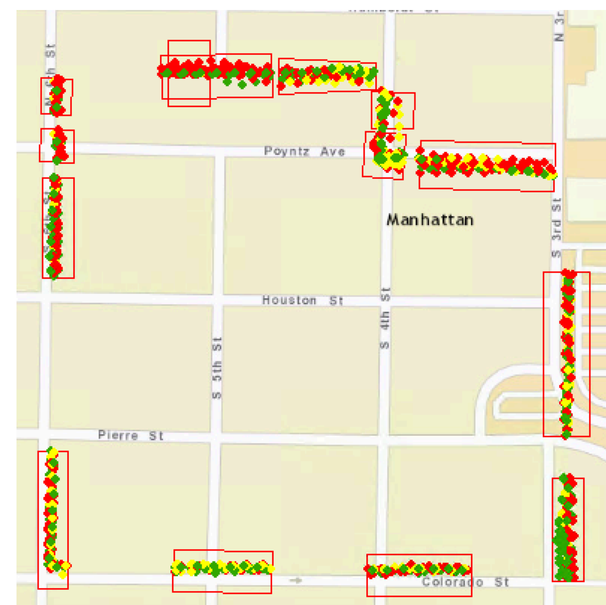
n. Under the “Search” tab, select the “Tools” subheading and search for “Spatial Join”. Double-click the “Spatial Join (Analysis)” tool to open the tool.

i. 

o. In the “Spatial Join” window, enter the physiological data layer under “Target Features”. Under “Join Features” select “QuestionZones”. Under “Output Feature Class”, click the browse button to the right, and save the feature class with the desired name. Click “OK” to run the tool operation.

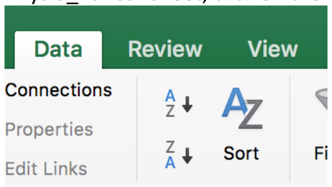
i. 

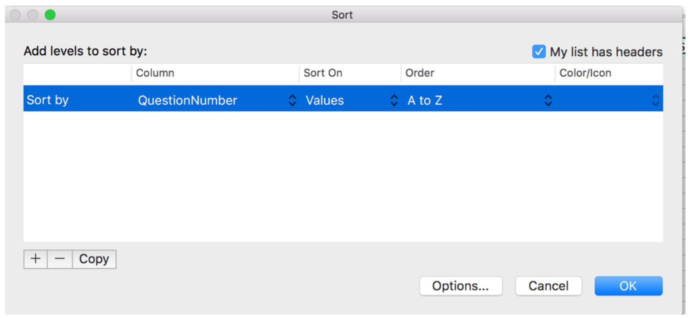
p. The points produced will be all one color. To change the symbology, refer to appendix “Viewing Participant Data in GIS for Analysis” and follow **steps 10.a.iv, 10.a.v, 10.a.ix, 10.a.x, and 10.a.xi** to format the points to look like the physiological data layers before running the “Spatial Join” operation. While still in the “Layer Properties” window for the newly joined layer, click on the “Definition Query” tab. In the text box enter “QuestionNumber <> ‘NULL’”. Make sure there is a single quotation mark on both sides of NULL. This will isolate the data and only show data within the zones. Click “OK” once complete. The image below shows how the result should look.

i. 

q. Under the “Table of Contents” tab, right-click on the newly joined layer and select “Open Attribute Table”.

r. From here, you will export the table as a **.CSV file**. Reference the appendix “Viewing Participant Data in GIS for Analysis” **steps 11.b.i through 11.d.i**

4. In Excel, open the .csv files of the normalized data in zones exported from GIS.
    a. Copy/paste all data into a new sheet in the Excel workbook with the image ratings data. Name this sheet “Physio_Zones”.
    b. In the “Physio_Zones” sheet, click on the “Data” tab and select “Sort”.
        i. 

    c. After clicking “Sort”, a new window will appear. Change the parameters to match those in the following image. This will sort the data by Question Number, so all question numbers are grouped together.
        i. 

    d. Create four new sheets titled: *EDA Zone Analysis, HR Zone Analysis, Image Rating Descriptive Stats, and Safety Rating Correlation*
    e. In sheet “EDA Zone Analysis”, manually enter what is shown in the following image
        i.

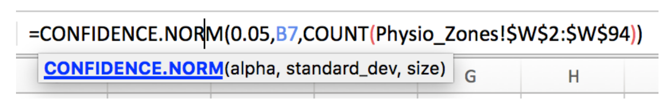
5	Question Image	Q33	Q3
6	Mean		
7	STDev		
8	Conf		
9			
10			
11			

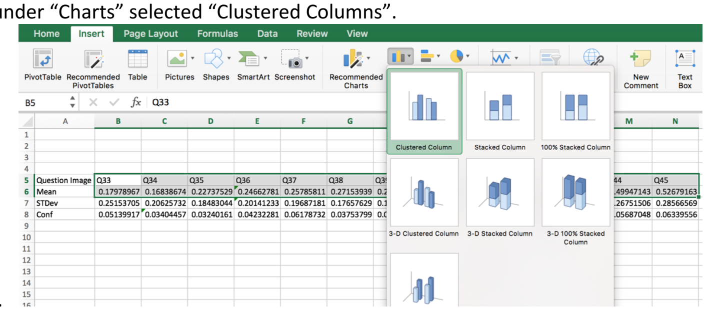
            1. *“Q33” indicates the first question in the survey that was an image rating question. This will vary depending on the survey. Add each additional question that is an image rating in the same row.*
    f. The three rows represent the mean results, the standard deviation (STDev), and the confidence interval (Conf). For the first question in the “Mean” row, enter the formula: “=AVERAGE(Physio_Zones!$W$2:$W$94)”
        i. **NOTE:** This function indicates that cells W2 through W94 were selected. In this demonstration, Column W contained the “EDA_AVG_NORM” data, and rows 2 through 94 related to question number 33. These will vary based on what column the “EDA_AVG_NORM” data is in, and which rows related to the question. Simply substitute out the “W”s and numbers in the formula above to match what is the table you are working with.
            1.

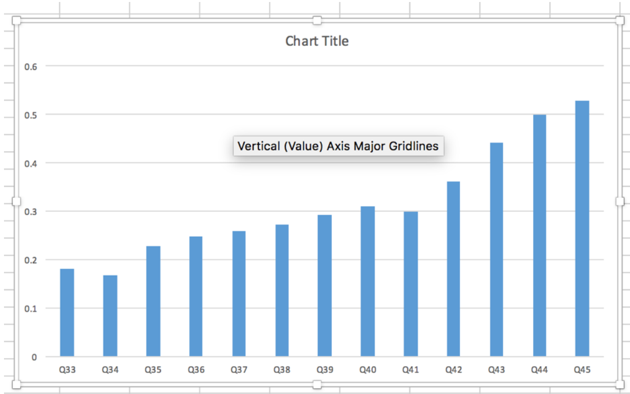
W	X	Y
EDA_AVG_N	HR_NORM	QuestionNumber
0.17964982	0.07607053	Q33
0.22156265	0.08194794	Q33
0.11975564	0.07103275	Q33
0.10179299	0.06347607	Q33
0.34730116	0.04047019	Q33
0.32335097	0.01427372	Q33
0.29341323	0.01595298	Q33

        ii. Repeat this process for the remainder of the image rating questions. The only variations in the formula above should be which rows relate to which questions (e.g., rows 95 through 194 relate to Q34, so the formula for Q34 would be “=AVERAGE(Physio_Zones!$W$95:$W$194)”)
    g. Once all “Mean” data is shown for each question, repeat the process for “STDev”. The formula for “STDev” is “=STDEV.P(Physio_Zones!$W$2:$W$94)”
        i. Repeat this process for the remainder of the image rating questions. The only variations in the formula above should be which rows relate to which questions (e.g., rows 95 through 194 relate to Q34, so the formula for Q34 would be “=STDEV.P(Physio_Zones!$W$95:$W$194)”)
    h. After entering all the standard deviation formulas, next is the confidence interval. The formula to enter for the confidence interval is “=CONFIDENCE.NORM(0.05,B7,COUNT(Physio_Zones!$W$2:$W$94))”.
        i. **NOTE:** In this formula, “B7” references the STDev for the particular question, while W2 and W94 is the range taken from the physiological data that corresponds with the question (in this case Question 33).
            1.

5	Question Image	Q33
6	Mean	0.17978967
7	STDev	0.25153705
8	Conf	$W$94))
9		

            2. 

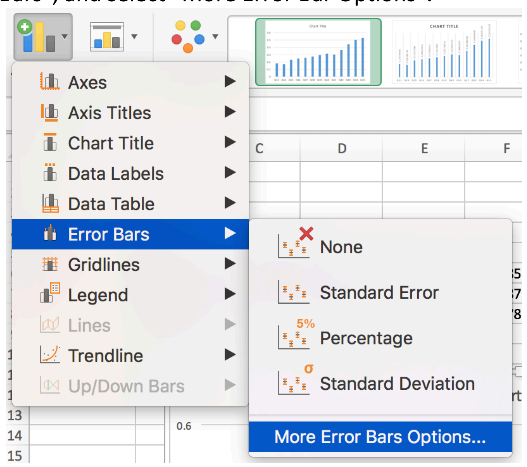
        ii. Repeat this process for the remaining questions.
    i. After filling out all means, standard deviations, and confidence intervals for the image rating questions, create a table to visualize the results.
        i. Select all question number and mean data, then go to the “Insert” tab and under “Charts” selected “Clustered Columns”.
            1. 



2.

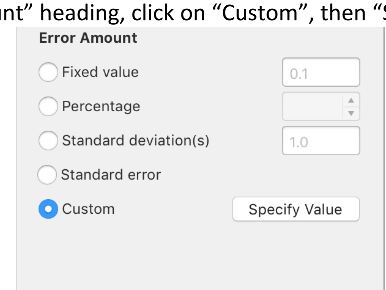
a. *The resulting chart should look like the image above.*

ii. Next, with the chart still selected, click on "Add Chart Elements", go to "Error Bars", and select "More Error Bar Options".



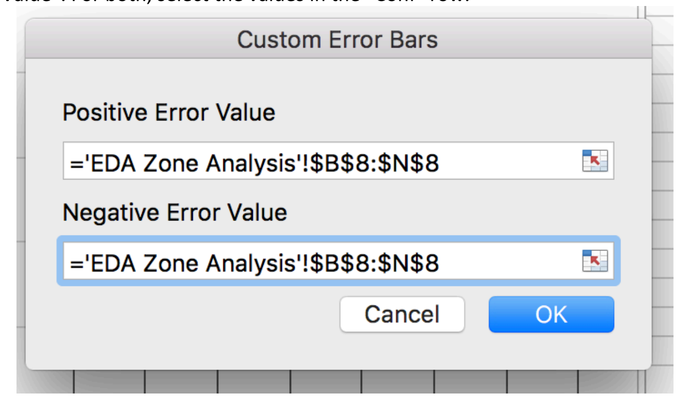
1.

iii. This will open window on the right side of the screen. Under the "Error Amount" heading, click on "Custom", then "Specify Value".



1.

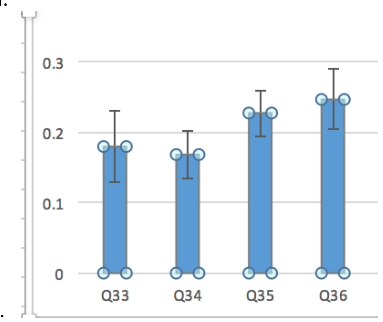
iv. A new window will appear, with "Positive Error Value" and "Negative Error Value". For both, select the values in the "Conf" row.



1.

a. **NOTE:** The values above may vary depending on how many questions you have and which row "Conf" is in.

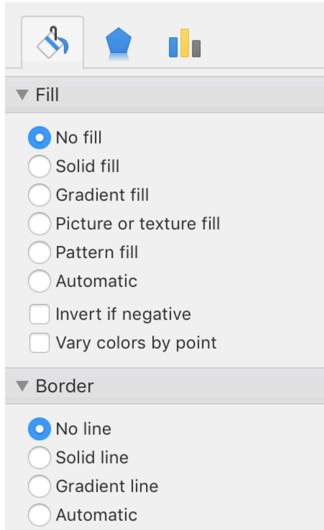
v. Once this is done, click "OK". Next, click on the bars in the table to format them.



1.

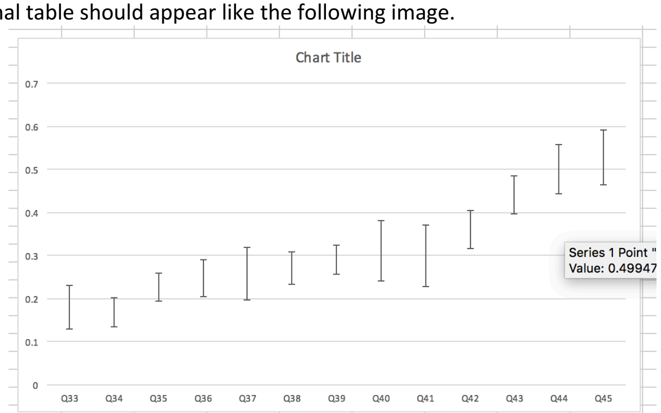
a. *The bars should have handles on the corners when selected*

vi. In the same window where the "More Error Bar Options" appeared, click on the paint bucket icon, and select "No fill" for Fill and "No line" for Border.

1. 

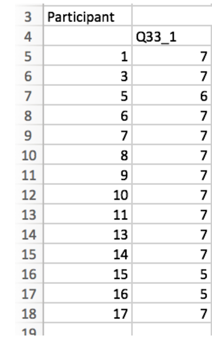
a. *Click "No line" may result in the program overriding the command, and switching it to "Solid line". Simply select "No line" again and it should work.*

vii. The final table should appear like the following image.

1. 

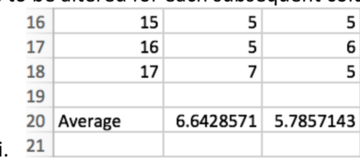
5. Repeat **step 4.e through 4.i.vii** in the sheet "HR Zone Analysis".
   a. The only differences in the "HR Zone Analysis" sheet would be selecting values in the "HR_NORM" column from the "Physio_Zones" sheet. **Note that all formulas for "Mean", "STDev", and "Conf" will need to have the column values altered**.
      i. *In this example, the formula* "=AVERAGE(Physio_Zones!$W$2:$W$94)" *would need to have the referenced column* (W) *changed to the column that contains the* "HR_NORM" *data in the* "Physio_Zones" *column.*

6. Go to the "Image Ratings" sheet, select all data.
   a. Copy/paste it into **cell B3** in the "Safety Rating Correlations" sheet.
   b. In colum A, add the participant numbers to each set of answers (most likely, the export will begin with participant 1).
      i. **NOTE:** It is important here to remove any participants who's physiological data was also removed/excluded from the GIS export. In this example, participants 2, 4, and 12 were excluded.

1. 

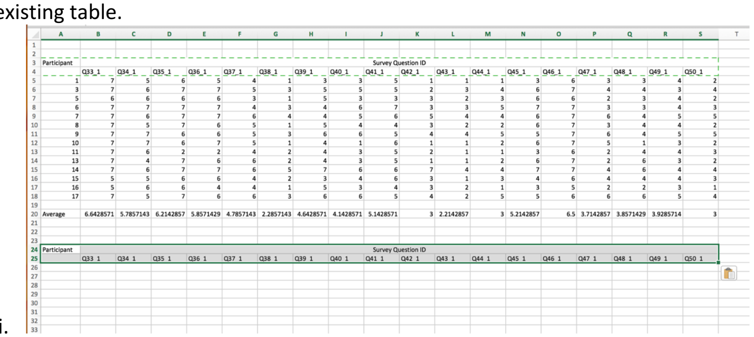
3	Participant		
4		Q33_1	Q
5	1	7	
6	3	7	
7	5	6	
8	6	7	
9	7	7	
10	8	7	
11	9	7	
12	10	7	
13	11	7	
14	13	7	
15	14	7	
16	15	5	
17	16	5	
18	17	7	

c. Next, get the average response for each question using the formula "=AVERAGE(B5:B18)" where "B" is the row of the first question. This formula will have to be altered for each subsequent column.

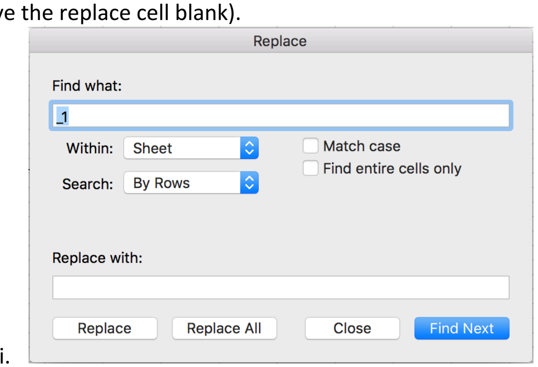
i. 

16	15	5	5
17	16	5	6
18	17	7	5
19			
20	Average	6.6428571	5.7857143
21			

d. Select the cells that have the question numbers and perform a copy/paste below the existing table.

i. 

e. Perform a find-and-replace command in this sheet and replace "_1" with nothing (leave the replace cell blank).

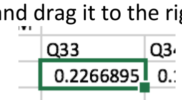
i. 

f. In the first cell immediately under the first question (in the case above, it would be cell B26), enter the formula "=AVERAGEIFS(Physio_Zones!$W:$W, Physio_Zones!$V:$V, 'Safety Rating Correlations'!$A5, Physio_Zones!$Y:$Y, 'Safety Rating Correlations'!B$25)".

  i. *In this example, column* "W" *in* "Physio_Zones" *represents* "EDA_AVG_NORM", *column* "V" *represents* "Participant (number)"*, which is matched to the participant number in the* "Safety Rating Correlations" *sheet cell* "A5". *Column* "Y" *in* "Physio_Zones" *represents* "QuestionNumber"*, which is matched to cell* "B25" *in* "Safety Rating Correlations" *sheet.*

    1. **NOTE:** This process will have to be done twice, with the formula changing slightly to reference "HR_NORM" instead of "EDA_AVG_NORM".

g. With this cell selected, click on the small square in the bottom-right corner of the cell, and drag it to the right to the end of the question range to autofill.

  i. 

h. Once all question blanks are filled across the first row, select all cells, click-and-drag on the small square in the bottom-right corner of the selection area, and drag down to complete the table for all participants.

  i. **NOTE:** There may be gaps in the data where no physiological data was recorded in the zone. This is normal.

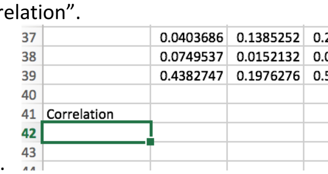
    1.

Survey Question ID

Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41
0.2266895	0.1077842	0.1723312	0.1417224	0.101793	0.1177637	0.1539849	0.1556996	0.1417224
0.0581521	0.0934558	0.1258521	0.1469353	0.1596593	0.1703029	0.1950933	0.2320843	0.249217
0.1683504	0.0764285	0.1009065	0.185471	0.2212976	0.2065252	0.2518887	0.0564432	0.102753
0.0024969	0.0129499	0.0390586	0.0614268	0.0752985	0.1020243	0.1372288	0.1956959	0.2116414
0.0508237	0.1557679	0.2077964	0.2541441	0.1823597	0.2020632	0.2197856	0.2326644	0.2408101
0.0381037	0.0401884	0.1484188	0.2229492	0.295776	0.3551257	0.3866852	0.4725446	0.489054
0.9047515	0.7005286	0.4357694	0.7457958	0.607867	0.4762721	0.3837736	0.2631088	0.2529706
0.0300234	0.2129321	0.4027219	0.4925481	0.5278685	0.5693158	0.6394693	0.7098991	0.7365327
0.007579	0.0087764	0.0095414	0.0214434	0.0180769	0.0419415	0.0426025	0.0525885	0.0398021
0.5477132	0.611764	0.6115202	0.6676457	0.6764699	0.64706	0.6196093	0.5045751	0.588234
0.0174393	0.0322479	0.106862	0.1192163	0.1324858	0.1944579	0.228304	0.2814678	0.2595568
0.0403686	0.1385252	0.2919557	0.2589	0.2325123	0.2052183	0.1956463	0.204162	0.205186
0.0749537	0.0152132	0.0337444	0.0794505	0.1722835	0.2787294	0.3756218	0.5749961	0.5558901
0.4382747	0.1976276	0.5039243	0.3997569	0.2268997	0.2414569	0.2162235	0.2133117	0.4633127

Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50
0.1736623	0.2395253	0.2065938	0.3812462	0.2266895	0.101793	0.1177637	0.1539849	0.2065938
0.2167317	0.2803722	0.4387341		0.0581521	0.1596593	0.1703029	0.1950933	0.4387341
0.0952543	0.064023	0.0702584	0.0476676	0.1683504	0.2212976	0.2065252	0.2518887	0.0702584
0.2439125	0.3677152	0.3238073	0.37601	0.0024969	0.0752985	0.1020243	0.1372288	0.3238073
0.2530128	0.2133111	0.1916428	0.2034576	0.0508237	0.1823597	0.2020632	0.2197856	0.1916428
0.5292781	0.7080738	0.9095276	0.9683626	0.0381037	0.295776	0.3551257	0.3866852	0.9095276
0.2446692	0.1025075	0.1837734	0.0894907	0.9047515	0.607867	0.4762721	0.3837736	0.1837734
0.7903097	0.8591093	0.751221	0.6143101	0.0300234	0.5278685	0.5693158	0.6394693	0.751221
0.1452842	0.6046768	0.7699392	0.5765476	0.007579	0.0180769	0.0419415	0.0426025	0.7699392
0.5823521	0.685293	0.7333323	0.4595586	0.5477132	0.6764699	0.64706	0.6196093	0.7333323
0.2793082	0.461595	0.5527691	0.8824056	0.0174393	0.1324858	0.1944579	0.228304	0.5527691
0.2005432	0.6022268	0.5910978	0.7980417	0.0403686	0.2325123	0.2052183	0.1956463	0.5910978
0.5908904				0.0749537	0.1722835	0.2787294	0.3756218	
0.6090831	0.5750683	0.6788936	0.7038058	0.4382747	0.2268997	0.2414569	0.2162235	0.6788936

i. Next, skip one row between the bottom of the table, then enter into column A "Correlation".

  i. 

j. In the cell in row B next to where "Correlation" was entered, enter the formula "=CORREL(B5:B18,B26:B39)". This formula identifies any correlations between the image rating data and the physiological data.

7. Repeat **steps 6.b through 6.j**, for whichever of "HR_NORM" or "EDA_AVG_NORM" wasn't selected in step 6.

  a. **NOTE:** The formula "=AVERAGEIFS(Physio_Zones!$W:$W, Physio_Zones!$V:$V, 'Safety Rating Correlations'!$A5, Physio_Zones!$Y:$Y, 'Safety Rating Correlations'!B$25)" will change, as noted in **step 6.f.i.1.**

  b. **NOTE:** The correlation formula in **step 6.j** will also be changed sligthtly to include the newly created table instead of the initially created table.