

SENTIENT SPACES: INTERPRETING BIOFEEDBACK INTO ENVIRONMENTAL SYSTEMS TO MITIGATE THE SEVERITY OF PHYSIOLOGICAL SYMPTOMS IN ANXIETY DISORDERS

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While anxiety disorders remain the most pervasive mental illness in the United States, few therapeutic solutions have incorporated strategies for dealing with both cognitive and physical symptoms. This is particularly challenging due to the often context-driven trigger of panic and the rapid and exponential onset of such physiological symptoms. With technological advancements for real-time physiological measurements becoming increasingly precise, along with new research highlighting their relationship to cognitive state, there lies great potential for current forms of treatment to be accompanied by real-time alterations to the qualities of our built environment. Sentient space is positioned at the intersection of psychophysiology, cognitive psychology, and environmental design, to put forth a study proposal that questions how spatial systems such as light, temperature, and air quality can be informed by individuals' physiological signals to, in turn, provide real-time relief to the physical symptoms associated with anxiety disorder.

Keywords: Anxiety disorder, psychophysiology, cognitive psychology, responsive environments, sensory stimuli.

INTRODUCTION

Anxiety disorders are the most common mental illness in the U.S., affecting 40 million adults, or 18% of the U.S. population. Even though anxiety disorders are highly treatable, only about 37% of those affected receive treatment due to forms of therapies being often associated with high monetary cost and social stigma, rendering them inaccessible or undesirable (ADAA 2021). Anxiety is characterized by the anticipation of a future threat and often results in chronic and persistent worry, which is multifocal, excessive, and difficult to control. Anxiety affects women twice as likely than men, and often is comorbid with stress, depression, insomnia, and other mental disorders. Featured most prominently with anxiety disorders are panic attacks, which represent a particular type of fear response. Additionally, the World Health Organization reports that anxiety disorders are the most common mental disorder globally and, along with depression, account for the leading cause of disability worldwide (WHO 2021). Several studies have identified both the psychological and physiological symptoms of anxiety disorders which span from signs of autonomic arousal, muscle tension, and insomnia to overthinking, indecisiveness, and inability to concentrate on a task (American Psychiatric Association 2013).

Currently, the most common forms of treatment for anxiety disorders include pharmacotherapy, such as benzodiazepines (e.g., Valium), selective serotonin reuptake inhibitors or serotonin-norepinephrine reuptake inhibitors (e.g., Prozac), and psychotherapy, such as cognitive behavioral therapy (CBT) which looks to treat anxiety through behavioral relaxation techniques and to reconstruct patterns of thinking that foster anxiety. Combined, these forms of therapy substantially improve quality of life in anxiety patients (Bandelow 2017). However, despite these treatments showing promising results around the long-term effects of anxiety disorder, little research has been conducted on therapeutic strategies for alleviating physiological symptoms, particularly those initiated by panic attacks or aggravated by environmental conditions.

Beyond the barriers of monetary cost and social stigmatization of anxiety disorder therapies is the absence of therapeutic strategies which address physiological traits associated with anxiety disorders, which often initiate or exacerbate the presence of cognitive-based symptoms. This is especially evident

in the presence of panic attacks, whose symptoms primarily are physiological: palpitations, accelerated heart rate, sweating, shaking, shortness of breath, chest pain, nausea, chills or heat sensation, and feeling dizzy. While physiological responses vary between episodes of panic attacks and anxiety disorders, several studies have identified that the most common symptoms are associated with autonomic arousal, and muscle tension (American Psychiatric Association 2013). Despite the tracking of these signals becoming increasingly easy to identify with wearable devices such as the Empatica E4 wristband or the Fit Bit Sense (Empatica 2021; Fitbit 2021), little has been studied in the use of such personal metrics in altering one's environment to alleviate symptoms of anxiety disorders and provide immediate support.

Many environmental triggers of panic attacks vary between patients and are often associated with personal stressors experienced throughout their life; however, some cues show repeated association with the induction of panic attacks within patients suffering from anxiety disorders.

It is important to note at this point that for this paper, the term "environmental cues" will be used to define qualities of our built environment, such as thermal comfort, light, noise, smell, and other spatial qualities. More specifically, we will look at the correlation between heat (Asnis 1999), light (Chinazzo 2021; Chamilothoni 2019; Verywell Mind), and air quality (Asnis 1999; Bandelow 2017; Verywell Mind 2021) and how the interpretation of our biosignals inform these environmental conditions to result in proactive alterations in our surroundings.

Positioned at the intersection of psychophysiology, cognitive psychology, and environmental design, this paper contributes to our knowledge of the role of sensory stimuli on mental health and, more specifically, in this case, to symptoms of anxiety disorder. It is hypothesized that by leveraging technological advancements in physiological signal tracking, more proactive spatial systems can be designed to mitigate the severity of symptoms and provide an alternate real-time therapeutic treatments.

1. BACKGROUND

1.1. PHYSIOLOGICAL SYMPTOMS

The Diagnostic and Statistical Manual of Mental Disorders (DSM), along with a number of papers, present a list of cognitive and physical symptoms associated with anxiety disorder and panic attack specifiers (American Psychiatric Association 2013, Bandelow 2017; Lader 1980; Katsis 2011). Some of the most common symptoms are skin conductance, heart rate variability, blood pressure, respiration, body temperature, muscle tension, and pupil dilation. The majority of these physical responses are directly triggered by one of our two branches of our nervous system. These two systems are our sympathetic nervous system (SNS), also known as our "fight or flight" response, and our parasympathetic nervous system (PNS), which controls our "rest and digest" response. The reason for physiological responses such as heightened heart rate, pupil dilation, heightened respiration rate, or peaks in skin conductance to appear during panic attacks is due to the fact that these systems are directly triggered by the sympathetic branch of our nervous system, which is the body's way to prepare for a threat, or emergency. This response from the SNS is fairly sudden and can rapidly escalate the magnitude of these physiological signals until communication from the parasympathetic branch kicks in to regulate the potential magnitude of such threat or stressor (APA 2012) (Figure 1).

Studies that look specifically at heart rate variability (HRV), which is a measure of how healthy one's communication between the SNS and PNS branches are, have shown a significant association between reduced HRV and anxiety disorder,

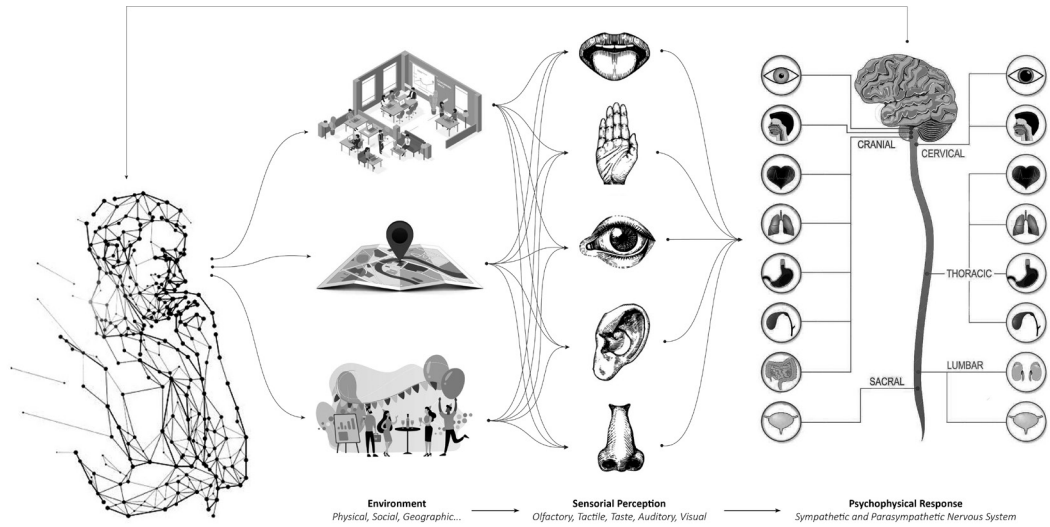


Figure 1: Diagram illustrating the feedback loop between environmental and sensorial cues that impact our nervous system and influences our psychophysiological response. Source: Author 2022.

suggesting that autonomic neurocardiac integrity is substantially impaired in such patients (Kim 2016; Chalmers 2014; Campos 2019). These findings shed light on a possible explanation of why those suffering from anxiety disorders, particularly those who also experience panic attacks, find it so difficult to calm down actively. Essentially, their nervous system is not processing the “rest and digest” appraisal of a scenario, allowing for physical symptoms to escalate and perpetuate. Despite cognitive behavioral therapy (CBT) showing promise in promoting calming strategies and modifying thinking patterns to soothe in-the-moment causal responses to panic or stress, we often see this falling short in new patients overwhelmed by the physiological symptoms (Otte 2011). This is especially true when such physical responses are being amplified by environmental conditions such as the severity of light in the space, thermal conditions, or air quality. In order to help mitigate the severity of physical symptoms, often due to an impaired autonomic nervous system, this study proposes to question the influence of external conditions on the amplitude of such physiological metrics, as well as patients’ perceived ability to cope in a stressful scenario.

1.2. ENVIRONMENTAL TRIGGERS

As seen in the section above, there is an undeniable link between mind, body, and our environment, yet the study of sensorial stimuli in the aggravation of symptoms related to anxiety disorder is greatly limited. Although one could arguably go through all aspects of our built environment and denote how each element, from scale to materiality, has some relative impact on our mental state, for the purpose of this study we will be looking at the effect of light, heat, and air quality in relationship with the physiological signals presented above (Figure 2).

The visual system is arguably the most pervasive sense in humans and on which we rely on to build the primary understanding of our surroundings (Pallasmaa 2012). Perhaps the most influential aspect of our visual system on well-being is our intake of light and its necessity in regulating our circadian rhythms and melatonin production. This correlation is crucial since difficulty sleeping is a comorbidity of every anxiety disorder and plays a significant role in how patients can manage both their cognitive and physical symptoms (Harvard

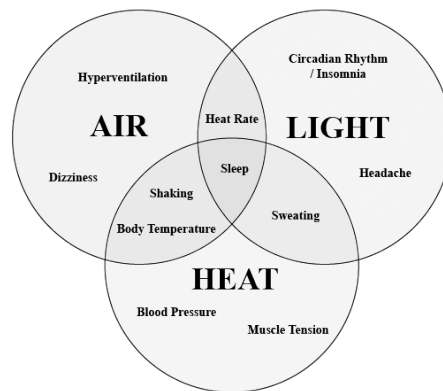


Figure 2: Diagram illustrating correlative symptoms of panic attacks and environmental conditions. Source: Author 2022.

2011; Kalmbach 2016). It was not until 2003 that scientists discovered the intrinsically photosensitive Retinal Ganglion Cells (ipRGC), which, unlike the other cells in the retina, are photosensitive and contain the photoreceptor chemical melanopsin (Berson 2003). Most importantly, these cells are what help humans synchronize their circadian rhythms with the solar day and are correlated with other behavioral and physiological responses to environmental illumination. Other than the highly influential role light plays on our sleep and, thus, overall health, light color, intensity, and spectral content have been seen to impact heart rate, skin conductance and even influence our perception of temperature (Chinazzo 2021; Chamilothoni 2019).

Secondly, the influence of light has been the impact of environmental conditions, such as room temperature, humidity, and air quality (levels of Co₂), which demonstrate not only detrimental effects on physical health, but also mental health. A study conducted by Asnis et al. found that patients with panic disorders described hot weather and humidity as potential triggers of their panic attacks (Asnis 1999). While several other studies have highlighted the link between air pollution and mental health, indoor air pollution contributes more and more to our daily exposure of Co₂ levels (Zhou 2021, Colligan 2021). Beyond the cognitive detriment poor air quality and severe temperature changes cause, is the contribution such factors can make to physiological symptoms of anxiety and panic. Rapid changes in skin temperature and sweat induction are two common occurrences during a panic attack which, depending on the conditions of the room itself, can either be aggravated further, or subtly alleviated. Additionally, one's rate of respiration is known to heighten when under panic, often referred to as hyperventilation, which can lead to low levels of carbon dioxide in the blood and other physical symptoms of dizziness, fainting, nausea, etc. If the air that one is rapidly inhaling is itself deficient in oxygen, or saturated by humidity, this will additionally cause further detriment to the person experiencing symptoms of panic.

With adults now spending 87% of their time inside buildings, it is impossible not to consider the enormous impact our environmental conditions have on mental health (Klepeis 2001). While we continue to live among these spatial qualities every day, with little thought behind their contribution to our mental well-being, it is time to not only recognize their impact on all facets of health, but additionally begin to consider their malleability as opportunities to promote emotionally conscious spatial experiences.

2. METHODS

2.1. SUBJECTS

Three Groups of Participants will be recruited for this study: Group A (subjects suffering from an anxiety disorder, with little indication of panic attacks), Group B (subjects suffering from anxiety disorders, and frequent panic attacks), and Group C (Random control - subjects exhibit no symptoms of anxiety disorder or panic attacks). These subjects will be recruited through association with the School of Psychology, and advertisements. Subjects must be 18 years of age or older. Subjects who meet the definition of anxiety disorder with or without the presence of panic attacks will be based on criteria from the fifth edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-5) (American Psychiatric Association 2013). Subjects that meet these criteria will additionally take the Beck Anxiety Inventory (BAI) to assess the intensity of physical and cognitive anxiety symptoms during the past week. Subjects with scores above 16 will be recruited for either Groups A or B (Beck 1988). To be sorted between Group A and B, these subjects will take an additional questionnaire assessing the comorbid presence of panic attacks based on symptoms for the panic attack specifier in the DSM-5. Subjects taking psychotropic medication such as antidepressants or benzodiazepines for the last seven days before the assessment will be excluded. Additionally, subjects will be excluded if taking any drugs that affect the response of their autonomic nervous systems, such as beta-blockers or anti-arrhythmic agents, or exhibited substance abuse or dependence. Healthy controls, Groups C, will undergo the same screening as Groups A and B and will only be recruited if exhibiting no psychiatric diagnosis associated with the DSM-5. A partial explanation of the study and its specific procedures will be given to all participants, and written informed consent will be obtained before proceeding.

2.2. PROCEDURE

The study will take place in a controlled space on campus. The controlled variables of this space will be light intensity and spectral content (blue or red light), room temperature, and air quality (humidity and levels of CO₂). These variables will be directly controlled by the interpretation of the subjects' physiological signals, which will indicate signs of autonomic arousal. Based on the findings from previous research highlighted in the literature review above, the alteration of the variables will depend on the associated desired physical response to these environmental conditions. For example, decreased blue light intensity when pupil dilation and heart rate is elevated from the participant's baseline.

Participants will arrive at the location, and before being briefed on the task, they will complete they put on the Empatica wrist device and are asked to wait calmly in a waiting room for 10 minutes (Empatica 2021). During this time, subjects will sit quietly in a soft chair in a sound-attenuated room, and asked to relax. This will allow for calibration of the device to occur and a per-subject baseline to be assessed. After the initial calibration phase, the subjects will be brought into the neutral room, which will be equipped with integrated systems for controlling light, temperature, and air quality. Subjects will be told not to worry about possible fluctuations they might notice in their environment since the room is equipped to change throughout the day. Once seated, participants will complete the first self-assessment evaluating their current levels of perceived stress, anxiety, and valence. Once done, subjects will begin the two-minute math test they are asked to perform, also referred to as the serial seven tests (Karzmark 2000; Hayman 1942). The test requires participants to continuously subtract 7 from an initial number as rapidly as they can for a time period of two minutes (e.g., initial number given= 86, -7 = 79, -7 = 72, -7 = 65, -7 = 58...). The participants are told when

their answers are incorrect and must alter their answers to continue. They are also informed of the time remaining every 30 seconds. After completing this task, participants will get two minutes to “recover” from the test before proceeding to the second phase, which is image stressors. In this section, subjects will be asked to imagine a personally stressful scene for two minutes. When done, participants will be presented with the second self-assessment report of their perceived levels of stress, anxiety, and valence.

2.3. PSYCHOLOGICAL EVALUATION

Subjects are required to fill out several questionnaires throughout the study. First, to determine eligibility to participate in the study, all subjects will fill out a questionnaire determining their symptoms associated with Anxiety disorder and Panic attacks based on the fifth edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-5) (American Psychiatric Association 2013). Additionally, subjects in Groups A and B will be asked to complete the Beck Anxiety Inventory (BAI) and will only be eligible for the study if their score is higher than 16 (Beck 1988). During the test, two questionnaires will be presented, one before the stress-inducing task, and one after. These questionnaires will be identical and follow the State-Trait Anxiety Inventory (STAI), specifically form Y, which evaluates subjects' current state of anxiety, asking participants how they feel “right now” (Julian 2011; Spielberger et al. 1983).

2.4. PHYSIOLOGICAL EVALUATION

In order to continuously collect a series of physiological data, the subject will be equipped with the FDA-approved Empatica E4 wristband, which allows for unobtrusive, long-term assessment of the physiological signals (Poh 2010; Empatica 2021). This device collects the raw signals of electrodermal activity (skin conductance) measured in microsiemens (μS), peripheral skin temperature measured in Celsius ($^{\circ}\text{C}$), blood volume pulse, and heart rate measured in beats per minute. Although other physiological signals, such as pupil dilation and respiration, will not be measured, they will be assumed correlated with the automatic response from the sympathetic nervous systems. For the analyses of changes in skin conductance, temperature, and heart rate, a mean value over a 5-second period will be evaluated to determine fluctuations that occur from the subject's initial baseline. Heart rate variability will be calculated through the SDNN time domain metric, the Standard Deviation of the normal beat-to-beat intervals (IBI) (Cacioppo 2007; Shaffer 2017). This time domain metric is measured in ms and represents short-term variability, in this case the most recent ten beats.

3. DISCUSSION

The prediction for this study rests on the assumption that subjects suffering from anxiety disorders, particularly those who suffer from panic attacks, have associated physiological symptoms. Although this is certainly the case for symptoms of panic attacks, this is not always the case with subjects suffering from anxiety. In fact, one study found little difference between participants with a generalized anxiety disorder (GAD) and healthy controls in their psychophysiological responses (Hoehn-Saric 1989). While another measuring physiological reactivity in patients with a social anxiety disorder (SAD) found that reactivity was dependent on the context of the subject's appraisal, suggesting that it is more a matter of reframing stress arousal as a positive coping tool (Jamieson 2013). These studies demonstrate that the fundamental component of anxiety disorders is the personal context. Beyond the evident unique qualities every person suffering from anxiety disorders face based on genetics, upbringing,

and social environment are those of skin conductance, sensitivity, external health conditions, physical activity and more. These all make the assessment particularly difficult for both psychological and physical symptoms appraisal and need to be accounted for as ulterior factors.

Another limitation of this study is the length for which participants undergo stress tests. Adding up to a total of four minutes, participants are unlikely to reach the extent of their physiological symptoms in such little time. Additionally, although the tasks at hand have demonstrated efficacy in inducing stress, this response is again highly dependent on a person's experience and might be beyond the scope of what triggers heightened anxiety in that particular subject. With this in mind, the study designs could incorporate a pre-study questionnaire in which participants indicate personal stressors so that the task can be catered more specifically to each participant.

Lastly, it is important to note that this type of sensory therapy is not looking to replace current forms of pharmacological and cognitive-based treatments but rather provide an additional antidote that would be integrated into individuals' personal surroundings to specifically address in-the-moment physiological cues of anxiety and panic. Being founded on the principle that our physical environment plays a significant role in our well-being, this work seeks to leverage the scale and subtlety of spatial qualities to offer a novel approach to biofeedback-informed therapy.

CONCLUSION

Although anxiety disorders are composed of both cognitive and physical symptoms, surprisingly little research has been done to mitigate the severity of physical symptoms at the moment of panic or induced stress. Therapy techniques such as CBT promote cognitive strategies for dealing with anxiety in the moment however are not always sufficient in successfully subsiding the amplitude of such physical sensations, which often are rapidly triggered and grow exponentially (Otte 2011). With technological advancements for real-time physiological measurements becoming increasingly precise, along with new research highlighting their relationship to cognitive state, there lies great potential for current forms of treatment to be accompanied by real-time alterations to the qualities of our built environment. This study looks to begin exploring this relationship between mental health and spatial systems to expand the potential for our built environment to respond proactively to one's cognitive state.

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