



**AN ANALYSIS OF BUILT ENVIRONMENT FACTORS IN RESIDENCES AND
THE ASSOCIATED EFFECTS ON MENTAL HEALTH SYMPTOMS OF
UNITED STATES VETERANS**

THESIS

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Abstract

Current awareness and statistics regarding negative mental health outcomes of United States Military and Veteran populations justify research into causes and methods to assist those afflicted. Growing academic research indicates connections between the built environment and the mental health of its occupants may be important. This research is intended to explore this relationship with a Veteran study group. Through the completion of a literature review, key built environment factors associated with various mental health conditions were identified. Mechanisms and pathways through which these factors can affect mental health conditions were explored. An analysis of residential built environment factors and Veteran mental health symptoms helps bring an understanding to design considerations that may be beneficial to individuals with military experience. Furthermore, a discussion into the applicability of results, as well as cost and benefits of military design for mental well-being is presented.

Acknowledgments

First and foremost, I want to express my sincerest appreciation to my wife and children. Everything I do in life is guided by your love and dedication. I cannot thank you enough for your endless support and understanding. You all make life worth living and work worth working. Also, an extra token of gratitude to my wife for holding it all together while I jettisoned around the country to warmer climates. To my advisor, Lt Col Hoisington, I am truly thankful. You allowed me to pursue my passion and provided just the right amount of push when it was needed. I hope you found my work at least half as exceptional as I found your leadership. To my sponsor and committee members, thank you for your guidance and time. You all played an indispensable role in me being able to complete this monumental academic effort. Finally, a huge thank you to all my classmates who made coming to class and work each day anything but dull.

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I. Introduction

Background

Promotion of mental health and well-being has been considered a worldwide priority by the United Nations [1]. Such a level of international attention is warranted given the impact of mental illness. In the United States (US), 44.7 million adults contended with a mental illness in 2016 alone, nearly 20% of the adult population [2]. Furthermore, earning losses for the US citizens afflicted by mental illness have been estimated as high as \$193.6 billion a year [3]. While considered a prominent national issue given these statistics, current rates point towards a greater mental health epidemic for United States (US) military members and Veterans. In 2014 it was reported that Army soldiers suffer from post-traumatic stress disorder (PTSD) and depression at 15 times and 5 times the civilian national average, respectively [4]. Similarly, one study of 103,788 US Veterans indicated that 31% of the sample received mental health or psychological diagnoses [5]. Potentially, the most publicized negative mental health outcome has been suicide. Psychological autopsies have indicated that as many as 90% of individuals who committed suicide had a diagnosable mental disorder at the time of their death [6]. Additionally, Department of Veteran Affairs (VA) statistics that have indicated Veterans commit suicide at 1.5 times the rate of US adult non-Veterans may also point towards an underlying mental health issue [7]. Research to better understand and assist US military members and Veterans contending with mental health disorders has become justified by these current trends.

The complexity of the public mental illness burden necessitates understanding of biological, social, psychological and environmental factors that influence individual mental

health. A growing research area regarding poor mental health is the built environment and its associated affects. Increased global urbanization [8] coupled with the fact that US citizens spend an average of 87% of their time in the built environment [9] is bringing people in contact more with buildings and other man-made environments. Homes, workplaces, and schools are being scrutinized for how and why they affect mental health of occupants. It follows that this built environment may impact the mental health conditions of US military members and Veterans.

Problem Statement

As the Department of Defense (DoD) and the VA continue to actively pursue a more comprehensive understanding of mental illness in the wider military population, research into factors that can influence mental health is necessitated. While factors such as combat exposure, traumatic brain injuries, and microbiology are actively being explored, no current research is addressing the role the built environment has on military and Veteran mental health.

Furthermore, current DoD design standards address engineering certain elements into the built environment for livability and quality of life purposes, but do not consider the improvement directly connected to the mental health of occupants. For these reasons a better understanding into the specific role of the built environment of military members in altering mental health is needed. Therefore, the purpose of this research is to determine which built environment factors influence Veteran mental health symptoms and to what degree.

Research Objectives

Given the intent of this thesis is to provide and understanding of the effect the built environment of Veterans has on their mental health, the research objectives are as follows:

1. To identify the built environment factors in current academic literature which have proven influential in occupant mental health and how they do so.

2. Develop the first survey given to US veterans to inventory the built environment with regards to mental health outcomes
3. To begin the process of determining how residential built environment factors in regards to living conditions among US military Veterans are related to mental health symptoms.

The Way Ahead

Due to the exploratory nature of the research objective, this thesis will follow a scholarly format. In Chapter 2, “Built Environment Factors and Associated Mental Health Outcomes,” a comprehensive review of current academic literature provides an understanding of which built environment factors have been tied to changes in occupant mental health. Particularly, this article is intended to educate building architects and engineers on design factors that may influence public mental health in developed countries. Mechanisms and pathways through which these factors act are explored, as well as ways to incorporate mentally healthy criteria into building design. Finally, Chapter 2 provides a discussion into current research limitations and potential ways to better future studies. The target journal for this paper is *Indoor and Built Environment*.

Chapter 3, “Influence of the Built Environment Factors on Mental Health in United States Veteran Residences,” provides details on a joint research study into the built environment of Veteran homes and associations to mental health symptoms. A self-reported survey was used to assess multiple factors of the residential environment and explore their association to psychometrically sound mental health measures for 92 Veterans. A discussion is had regarding factors that may be influential to understand how they affect mental health and potential means of design for healthier residential environments. The target journal for this paper is *Journal of Exposure Science and Environmental Epidemiology*.

In Chapter 4, “How Military Building Designers Can Aid Mental Well-Being,” an editorial is presented to military engineers into the influence building design choices can have on occupant mental health. Additionally, a discussion is had on the cost and benefit of incorporating those factors found to be most influential from Chapter 3 into current DoD design guidance. The target journal for this paper is The Military Engineer. Finally, conclusions and future work are presented in Chapter 5.

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II. Literature Review of the Built Environment and Mental Health Outcomes

Chapter Overview

The purpose of this chapter is to provide a comprehensive review of peer-reviewed literature connecting built environment factors and mental health outcomes. The article's target audience is building scientists and first explores the importance of mental health and the reasons why the built environment should be considered as an influencing factor. The research is organized into three larger constructs: connection to nature, personal control of the occupant, and indoor air quality. The article then aims to explain how various factors of built environment designs may influence the mental health of building occupants. Hypothesized psychological and neural pathways are discussed, as well as potential improvements that can be made to the built environment. Finally, the article ends on a discussion of the current limitations of research and opportunities for progress.

This chapter provides the foundation upon which subsequent chapters were built. Insight from this article led to the development of the built environment survey used for data collection in Chapter 3. Additionally, the understanding of the pathways through which the built environment affects occupant mental health enlightened discussions and conclusions throughout the thesis.

Publication Intention

Title: The Built Environment and Associated Mental Health Outcomes

Publication: Indoor and Built Environment

Review: The Built Environment and Associated Mental Health Outcomes

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Abstract

Global urbanization combined with evidence of increased prevalence of mental health disorders in urban environments highlights a need to investigate potential connections between the built environment and mental health outcomes. Accumulating research has identified three main constructs of the built environment that affect occupant mental health: 1) connection to nature; 2) personal control of the occupant; and, 3) indoor air quality. Contact with the natural environment is recognized for its physiological and psychological benefits, therefore increasing time without leads to negative mental health outcomes. The control an occupant has in regards to the built environment can alter the mental health of individuals through direct pathways, such as environmental stressors, and indirect pathways, such as social contact. Indoor air quality is connected to the mental health of built environment occupants, as particulate matter, malodorous irritants, and toxins have all been shown to alter mental wellbeing. Opportunities for architects and engineers to optimize buildings for occupant mental health include planned urban greenspace, enhanced sound-proofing, and design of adequate building ventilation. To understand optimization targets, improved interdisciplinary research utilizing controlled experiments will improve our current understanding of mechanisms underlying the association between the built environment and mental health.

Keywords

Built Environment, Mental Health, Personal Control, Nature, Indoor Air Quality

Introduction

In its most basic terms, the built environment is the physical environment constructed for human living and activities [1]. For the purposes of this review, the built environment is further defined as structures deliberately designed and constructed for humans to live, work, study, and interact to include: 1) residential buildings; 2) industrial buildings; 3) commercial buildings; and 4) schools. During the design process, conscious choices are made by architects and engineers, including, but not limited to, materials, layout, windows, lighting, floors, air quality parameters, temperature, and noise exposure. Since the industrial revolution, these aspects of the built environment have been studied for their influence on physical and cognitive health outcomes. Research in these two areas have led to the hypothesis that aspects of the built environment contribute to negative health outcomes including obesity [2, 3], diabetes [4], respiratory disease [3, 5], and impaired cognitive performance [6]. When incorporated, health-based design decisions on the built environment usually focus on improvements to the physical health of occupants. While understanding the impacts of the built environment is important, we argue that additional research is needed to evaluate the impacts of the built environment on mental health.

Currently, individuals in the United States (US) spend an average of 87% of their time indoors [7]. Globally, 55% of the population live in urban areas versus rural environments, an increase from the 30% of the population that lived in urban areas in 1950 [8]. Urbanization is expected to continue with 68% of the world's population living in urban environments by 2050 [8]. This increase in the global urban population centers has benefits including greater access to health care and education, as well as higher wages [9]. Negatively, urbanization reduces individuals' contact with the natural environment and likely increases the time spent in the built environment [7].

In 1946, the World Health Organization (WHO) declared mental well-being one of three fundamental components of health, along with physical and social well-being [10]. Global emphasis on mental well-being increased in 2013 with the release of the WHO's Mental Health Action Plan, which established mental health research as one of its goals [11]. Additionally, in 2015 the United Nations recognized the promotion of mental health and well-being as a health priority of the global development agenda effort [12]. The level of attention to mental health is warranted. In 2016, 44.7 million adults in the US, nearly 1 in 5, lived with a mental illness [13] and 44,000 individuals died by suicide [14]. Additionally, it has been estimated that in the US, mental illness results in \$193.2 billion of lost earnings for those afflicted [15]. Internationally, the WHO reported that neuropsychiatric disorders are the third-leading cause of disability-adjusted life years (DALYs) in Europe, behind only cardiovascular diseases and cancer [16]. A DALY is defined as one lost year of healthy life. For neuropsychiatric disorders, that equates to 44.7 million years lost for Europe or approximately 22 days lost per person.

Specifically, the burden of mental health conditions in developed societies and the growing emphasis on mental well-being awareness has given credence to a mounting production of research focused on the built environment and its impacts on mental health. Exploratory associations have been made between mental health and residential floor level [17], access to greenspace [18], and indoor air pollutants [19], to name a few. Comprehensive reviews that consider all of these factors are limited (Evans, 2003) and instead reviews tend to focus on a particular aspect of the built environment, such as greenspace and its effects on mental health [20]. Further hindering this research area is the complexity of psychological health outcomes with co-occurring mental health conditions in individuals.

The purpose of this paper is to synthesize peer-reviewed research on the built environments in developed countries and the relationship to mental health outcomes. Mental health outcomes considered are broadly defined psychologically as to include emotion, mood, psychiatric disorders, and cognitive performance. The review is organized into the three sections focusing on specific mechanisms through which the built environment affects the mental well-being of occupants: 1) connections to nature; 2) personal control of the built environment by the occupant; and 3) indoor air quality. Figure 1 provides a conceptual visualization of how each of these constructs interact with and affect the mental health of occupants. Included herein are initial thoughts on improvements to the built environment that could positively influence mental health and known research limitations.

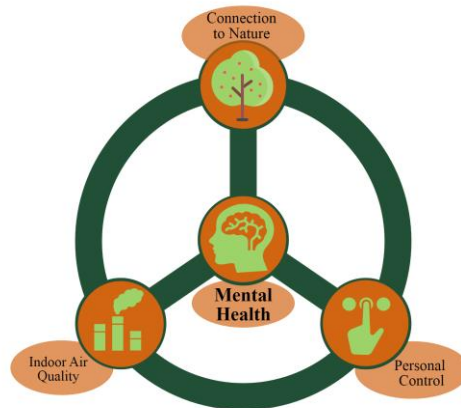


Figure 1: Proposed built environment factors that influence mental health

Connection to Nature

Human interaction with the natural environment has changed over time. Early in human history, individuals were hunters and gatherers, living their entire existence in the natural environment, which provided both shelter and sustenance. As society developed and population centers grew, individuals became increasingly disengaged from natural environments [21]. This

shift to a more artificial environment has resulted in a number of benefits for humans including safety, food predictability, and reductions in infant mortality. However, a growing section of research suggests that this shift has in some ways been detrimental to human well-being, as positive health influences from connections with nature have been established [22-29]. For this section, the connection to nature is analyzed at three physical levels: (1) viewing nature; (2) being in the presence of nature; and (3) seeking physical interactions with nature. Evidence of mental health benefits from nature are present at each of these levels.

First, researchers have shown that viewing nature through a window or represented in a picture or painting may improve mental health outcomes. Initial survey-based studies in the 1970's and 1980's suggested that having a window view in the built environment, no matter the content of the view, was preferred by occupants [30, 31]. Later research quantified those benefits from natural windows views that provide improvements in job satisfaction [32], less frequent use of health care services [24], increased attentional capacity of students [33], and positive effects on moods and emotions [34, 35]. More recently, researchers have relied upon the measurement of various psychophysiological responses to accurately quantify individuals' responses to natural views. For example, Chang and Chen (2005) observed office workers were less nervous and anxious with a natural window view as opposed to those with urban view or no window. Lack of a window in itself is associated with multiple negative mental health outcomes, including seasonal affective disorder, depression, and negative changes to mood and behavior [25, 37]. Indeed, current psychiatric practices employ bright light therapy as a treatment for major depression [38]. The importance of natural views are well-summarized in a WHO European housing survey that reported lack of daylight or having a poor view out of their window increased an occupant's chance of depression by 60% and 40%, respectively [39].

As previously mentioned, occupants can also get a positive mental health benefit through viewing simulated natural environments in pictures or paintings. One theory on why this is true suggests that viewing natural settings through any means including pictures and paintings may provide a restorative effect that improves mental well-being [26, 27, 40]. That is, after mental fatigue from a task that requires voluntary attention, exposure to natural environments leads to involuntary attention that allows for recovery from this mental fatigue [27]. For example, Ulrich (1979) showed that American college students exposed to pictures of undistinguished natural settings following a stressful final exam had significant increases in positive moods and feelings as opposed to viewing urban scenes. Additionally, that study indicated that the subjects' attention was better held by the natural scenes supporting the attentional restorative theory [41]. More recently, Berto (2005) discovered that individuals exposed to views of natural settings scored better on several tests designed to be mentally fatiguing. It is also possible that mental health benefits of viewing nature are tied to reducing stress through psychophysiological pathways [36, 42, 43].

The next level of natural interaction places individuals in the presence of nature. This level of physical interaction is incidental, in that the individual is participating in another activity or event without intent of engaging with nature. The most researched population of this level of interaction is children. For example, one study in New York found that 377 children with additional exposure to nature, as measured by type of yard, views from the home, and number of plants in the home, scored significantly better on two psychological distress questionnaires [44]. Further benefits from contact with nature have been indicated by cognitive measures. Such improvements indicate recovery from mental fatigue as hypothesized by the attentional restorative theory mentioned previously [27]. Indeed, prolonged mental fatigue may lead to

negatively affected psychological states. In an interventional study, Wells (2000) revealed that children with increased access to greenspace when moving to a new home had significantly improved scores on a standardized attention deficit disorder test. Similar results were observed in a recent study of preschool-aged children [29]. The aforementioned improvement in children from being in nature is likely to be similar in adults. For example, cognitive performance improved for college students walking through nature, while walks in urban environments had no significant impact on cognitive performance [45].

Physical interaction with nature can be difficult in urban environments but may not require city-wide investments into parks. To our knowledge, in the only interventional study utilizing cluster randomized trials in this field, it was shown that “greening” certain city landscapes resulted in improved mental health of nearby residents [47]. Within this study, South et al. (2018) identified 342 participants living near 541 vacant lots around the city of Philadelphia, Pennsylvania. These lots were placed into clusters that were then randomly assigned to one of three groups: greening, trash clean-up or control. By greening, the research team removed debris, graded the land, planted grass and performed regular maintenance on vacant lots within the cluster. Subjects were administered a self-reported mental health measure before and after the interventions. People living near the greened lots reported a 41.5% decrease in feeling depressed as compared to those living near the untreated lots, as well as a 62.8% decrease in self-reported poor mental health. This association between living in or near green areas and improved mental health has been consistently indicated in research [18, 48-50].

The closest connection with nature occurs during intentional interactions where individuals seek to physically interact with the natural environment. One studied area with relation to the built environment and mental health outcomes is community gardening, when a

parcel of land is assigned to be collectively gardened by residents who live nearby. Survey data has indicated that one of the primary reasons for peoples' participation in community gardens is the belief that it improved their mental health [52, 53]. Not only is gardening connected to perceived mental health effects, one study showed reductions in stress level and improvements in mood among individuals who gardened following a stress-inducing task [54]. Further engagement with nature, such as wilderness backpacking and watching wildlife, has been correlated to mental restoration and improved psychological measures [55, 56]. Benefits on intentionally seeking nature can also occur for children. Maller (2009) noted children who engaged in hands-on contact with nature had improved self-esteem and mental well-being.

Elucidating how interacting with or being in the presence of these natural environments improves mental health outcomes has proven difficult due to confounding variables, such as socioeconomic status, co-occurring mental health conditions, and genetic factors. However, two biological hypotheses attempt to explain the trends witnessed. First, nature exposure may modulate systemic inflammation by acting on the autonomic nervous system and reducing chronic stress, which has been shown in effects on biological markers [57]. Secondly, experiences in nature directly reduce activity in the subgenual prefrontal cortex of the brain [58]. Regardless of the mechanism, research converges on the connection to nature and its beneficial mental health outcomes.

Personal Control

Humans desire the ability to control their environment and maintain a sense of self-efficacy [59, 60]. The lack of personal control over one's environment has been associated with cognitive deficits and reduced motivation [61]. Therefore, it is unsurprising that mental health outcomes are connected to an individual's ability to control their physical self and their

surroundings [62-65]. The concept of induced or learned helplessness may help explain how a lack of control leads to negative mental health outcomes [65, 66]. For the purposes of this discussion, control in the built environment is broken into two categories: direct control and indirect control. Direct control is the physical ability of the occupant to alter their surroundings. Indirect control in this context is how built environment alters an aspect of daily life without direct participation of the occupants, such as social interactions or stress-inducing mechanisms. Aspects of indirect control in the built environment that influence mental health include levels of social interaction, noise, and housing quality.

Research in direct control of the surrounding environment is less robust and definitive compared to indirect control. Several researchers have hypothesized that a reduced-stress environment is dependent upon allowing individuals to physically manipulate the surrounding environment via changes to furniture, lighting and indoor temperature [67, 68]. However, empirical evidence of such a notion is inconclusive. In one study, the inability to control temperature within the work environment was correlated to worker dissatisfaction in the Netherlands [69]. Dynamic lighting, that is lighting that varies in color and illuminance during the day, was shown to improve employee satisfaction of office workers, which may indicate that the ability to control the lighting is important to occupants [70]. Neither of those two studies provide strong support for direct control corresponding to positive mental health outcomes. Actually, one study showed that office workers who were given choices concerning workplace lighting observed no differences in mood, performance, or health than those not given a choice in lighting [71].

A lack of social interaction negatively influences one's mental health [72, 73]. Consequently, it follows that aspects of the built environment that prevent or even reduce social

interactions may result in negative mental health outcomes. For example, occupants in high-rise housing have poorer social relationships [17], possibly related to consistent increases in psychological symptoms including anxiety, depression, and stress [74-76]. Additionally, living on higher floors has been shown to be negatively correlated with mental health symptoms [74], potentially from the lack of social interactions at higher floors [77]. Crowding also affects social connections. Evans and Lepore (1993) showed that college students living in crowded residences, as measured by residential density, were less likely to seek or offer support following a stressful situation. Amplifying the problem of not seeking support are findings that urban density limits social interaction, resulting in increased stress and negative psychological, cognitive, and behavioral outcomes [79-83]. The study of social interaction in the built environment is challenging due to confounding variables that include socioeconomic status, marital status, ethnicity, gender, family status, and location of the high-rise housing.

Another indirect control aspect is exposure to chronic unwanted noises. Such noise exposure is an environmental stressor that affects the cognitive development of children [6, 84, 85]. For example, chronic aircraft noise exposure for children aged 8-11 living near an airport has been associated with reductions in reading comprehension and attention capacity, along with higher levels of annoyance and stress when adjusted for socioeconomic factors [86]. Cognitive impairment is not the only reported mental health outcome related to chronic noise exposure. The annoyance associated with noise exposure has been positively associated with anxiety and depression [87]. When exposed to increased aircraft noise, London adults reported higher symptoms of irritability and depression [88]. Urban and traffic noise have also been associated with negative mental health outcomes [89]. Furthermore, similar outcomes of chronic noise exposure have been found in laboratory [90] and industrial settings [91].

Negative mental health outcomes can also be induced by inadequate housing quality or instability. While it has proven difficult to standardize the interpretation of inadequate housing, several measures have been employed such as deterioration and disarray. For example, Suglia et al. (2011) found that mothers from large cities in the United States experiencing housing disarray, which was subjectively measured by researchers, were more likely to screen positive for depression. Another study corroborated these findings by showing lower housing quality, as measured by independent assessments of structural quality, indoor climate, cleanliness, hazards, and privacy, was associated with poorer psychological health of rural United States children [93]. Moisture damage is another aspect of housing quality that may have detrimental mental health outcome as it has been correlated to systemic inflammation [94, 95]. In addition to housing quality and instability (moving multiple times in a defined period of time) has been shown to influence mental well-being. Suglia et al. (2011) further showed that housing instability, as defined by moving two or more times within the previous two years, was associated with greater incidences of anxiety and depression. Housing instability was also associated with more frequent mental distress and suicidal ideation in a study of 1,767 United States Veterans [96].

Indoor Air Quality

Poor air quality was first discussed in writing in 400 B.C. by Hippocrates who contended that particular “winds” led to diseases and ailments in cities [98]. One of the earliest researchers to investigate air quality was John Evelyn who wrote “Fumifugium” in 1661 by request of King Charles II of England. In that book, Evelyn chronicled London’s air pollution problems and offered health-based solutions. By 1850, John Griscom further advocated for indoor air quality in relationship to the health of occupants, recommending pointed improvements in ventilation

[100]. Despite Griscom's work, air pollution research concentrated on outdoor air until radon and formaldehyde health concerns occurred in 1960's and 1970's [101]. However, even today the majority of air research focuses on outdoor air pollution. Despite this fact, analogs between outdoor and indoor air can be assessed with several common fundamental chemical and physical processes. Occupants in the indoor environment are exposed to numerous pollutants originating from a combination of outdoor sources, materials used to construct homes and furnishings, and products used indoors [102]. The impact, in both types of pollutants and concentrations, is increasing due to decreased ventilation, mainly driven by a desire to reduce energy consumption [103]. Reductions in outdoor air ventilation may increase concentrations of pollutants in the built environment, even to concentrations higher than the outdoor air. Research indicates that negative mental health outcomes are correlated to multiple air pollutants [104-109].

Particulate matter is one of several pollutants of concern for mental health. The biological processes for particulate pollution exposure to promote negative mental health outcomes are still unclear. It is possible that exposure to fine particulate matter, which may also contain endotoxin, causes oxidative stress and systemic inflammation, which in turn induces anxious and depressive symptoms [110, 111]. Alternatively, particulate matter aggravates and promotes chronic disease, such as asthma, leading to decreased psychological well-being [112, 113]. Large cohort studies have indicated serious mental health outcomes are correlated with particulate matter exposures. In a study of over 71,000 female nurses, Power et al. (2015) found that exposure to fine particulate matter, specifically particles 2.5 micrometer or smaller ($PM_{2.5}$), was significantly correlated to increased anxiety with exposure occurring one and three months prior to testing. Similar findings for depressive and anxiety correlations to $PM_{2.5}$ were observed across multiple exposures [107]. Higher concentration of fine particulate matter in the air preceded suicide by 2-

3 days [105]. These studies mentioned above do not provide definitive associations with the built environment exposures because they used outdoor concentrations. The indoor and outdoor particulate concentrations are poorly correlated. However, research has shown that concentrations of particulate matter may be higher indoors. This is evidenced in a 2008 study, where indoor and personal PM_{2.5} exposure concentrations were higher than outdoor levels for elementary school students in rural, urban, and suburban areas of Ohio [114]. Indoor sources of particulate matter include smoking, burning of incense and candles, as well as cooking [115].

Malodorous irritants are another pollutant of indoor air shown to have negative mental health outcomes. Such pollutants irritate occupants and can lead to psychological distress through stress-inducing pathways [116]. Olfactory irritation from exposure to these compounds is hypothesized to trigger a stress reaction and negative emotional feelings [117]. In a study of Danish participants, it was revealed that chronic exposure to a malodorous pollutant, ammonia, was associated with higher odds of behavioral interference, perceived health risk, and annoyance [106]. Likewise, Radon et al. (2004) found that annoyance odors from livestock were significantly correlated to lower emotional quality of life scores through a standardized survey. Other studies have shown negative correlations between malodorous pollutants and annoyance [118], mood [109], and stress relationships [109, 119]. Volatile organic compounds (VOCs), are a leading source of malodorous irritants in indoor environments, as they are often found at two to five times the concentrations indoors as compared to outdoors [120]. Associations between VOCs and odor annoyance have been shown in a number of studies [121-123]. In one study on cyclohexylamine, a VOC recognized as a malodorant, researchers established that subjects experienced greater olfactory intensity and annoyance levels with increased concentrations [124]. Additionally, VOCs are irritants that may affect mucosal membranes and induce chronic

illnesses such as asthma or allergy symptoms [125, 126]. Chronic exposure may then also lead to psychological distress due to chronic illness. Measurements of the impact of malodorous pollutants on occupants can be difficult due to interpersonal variations of olfactory sensory levels and non-standard reaction to the smell [127-130]. Nevertheless, industries like the retail industry have already realized the importance of reducing malodorous pollutants to increase sales revenue [131], and future research in this area will likely be important in informing ventilation and building designs in different types of facilities.

Lastly, toxins can also be responsible for negative mental health outcomes in the built environment. Airborne toxins are distinguished from other pollutants because they can cause serious physical health outcomes [132]. Much of the research in this area has focused on exposure in the working environment—the only indoor environment that is regulated in the United States through the National Institute for Occupational Safety and Health. As an example, chronic exposure to airborne organic solvents in the workplace was significantly correlated with rates of clinical psychiatric disorders, particularly anxiety and mood disorders [133]. In that study, 71% of the individuals exposed to organic solvents met criteria for diagnosis of a psychiatric disorder, compared to 10% of the non-exposed control group [133]. Lead exposure has been shown to correlate with behavioral issues, such as aggression, in children and workers [134, 135]. These studies measure exposure by blood concentration and not source; therefore, means of exposure cannot be ascertained. However, typical lead exposure occurs through inhalation for adults and ingestion for children. Furthermore, several semi-volatile organic compounds (SVOCs) are known neurotoxins that are associated with negative behavioral outcomes [136, 137]. The connections between toxins and mental health outcomes are of particular concern in the indoor built environment where there is frequent use of household

cleaners and chemicals with such compounds, as well as, SVOCs that are in common building materials.

Improving the Built Environment

Ultimately, each of the three constructs presented in this paper (Table 1) provide opportunities for improvements to the built environment, in addition to expanded research. Providing a baseline understanding of how community and building designs affect peoples' mental health will enable architects and engineers to incorporate changes to designs and materials for greater public well-being.

Table 1. Constructs for Built Environment to Influence Mental Health Outcomes

Construct	Pathway	Result (reference)
Connection to Nature	Viewing	Occupant preference (31, 32)
		Improved job satisfaction (33)
		Less frequent use of health care services (25)
		Attentional capacity (29, 34, 42)
		Altered mood and emotion (26, 35, 36, 38, 42)
		Reduced nervousness and anxiety (37)
		Seasonal affective disorder (26, 38)
		Depression (26, 38, 40)
	Incidental contact	Stress (37, 43, 44)
		Psychological distress (45)
		Increased attentional capacity (30, 47)

		Cognitive outcomes (46)
		Improved general mental health (18, 48-51)
		Depression (48)
		Perceived mental health benefits (53, 54)
		Stress reduction (55)
Occupant Control	Interacting	Altered mood (52, 55)
		Improved psychological measures (56, 57)
		Mental well-being (52)
	Direct	Worker dissatisfaction (69)
		Occupant preference (70)
Occupant Control	Indirect	Social relationships and interactions (17, 76-78)
		Psychological distress/symptoms (74, 76, 91, 96)
		Depression (75, 76, 81)
		Stress (76)
		Cognitive outcomes (6, 79, 80, 84-86)
		Altered behavior (82)
		Stress (86, 89, 91)
		Anxiety (87, 92)
		Depression (87, 88, 92)
		General mental health (89)
		Systemic inflammation (94, 95)
		Suicidal ideation (96)

		Anxiety (105, 108, 111, 112)
	Particulates	Depression (108, 111, 112)
		Suicide (106)
		Stress (110, 117, 118, 120)
		Altered emotion (118)
Indoor Air	Malodorous irritants	Altered behavior (107)
		Altered mood (110)
		Annoyance (107, 119, 122-125)
		Anxiety (134)
	Toxins	Mood disorders (134)
		Altered behavior (135-138)

Interactions with nature have been associated with beneficial mental health outcomes. Further longitudinal and interventional research studies are needed to define the exact importance nature plays in the built environment. While many of the existing results are compelling, common terminology on what images of nature, which views from windows are important, and how to measure if a built environment is near a greenspace are warranted. Designers, engineers, and architects can likely positively influence the public health of occupants by focusing efforts across any one of the levels of nature connection. Interventions can include planned urban greenspace or inclusion of natural design elements, both of which must target diverse cohorts of the population. Communities unable to access greenspace should investigate artwork depicting natural scenes and community shared green areas (i.e. parks and gardens) to

improve occupants' connection to nature. Finally, concerted efforts to maintain clean vacant and public areas can lead to positive mental health outcomes for the community.

Understanding how personal control for occupants in the built environment is related to mental well-being can also provide pathways through which designers may influence occupants' mental health. Designs that limit environmental stressors can conceivably reduce the mental health burden on individuals. Utilization of better sound proofing insulation or improved windows may provide one opportunity for reducing the stress of chronic noise. This was exemplified in an interventional study in a daycare center where preschool-aged children scored better in letter-number-word recognition and were less susceptible to a feeling of induced helplessness when they were in sound-proofed rooms [138]. Furthermore, implementing measures that allow for beneficial social interaction may also help improve occupant mental health outcomes. For example, it has been shown that walkable, mixed-use neighborhoods encourage enhanced levels of social engagement [139]. Additionally, providing a better sense of control over social contact may be accomplished in designs of space that allow for users to choose between socialization and isolation, a concept that is supported by previous research [140, 141]. Finally, while not directly tied to mental well-being, the ability to physically manipulate one's environment has consistently been deemed important to occupants. This in turn may lead to long-term satisfaction and ultimately mental health benefits. Thus, designs in work environments that allow for window, climate, and lighting manipulation in residences should be considered.

In regard to indoor air pollutants, designers and engineers should incorporate better countermeasures for reducing them. Limiting the use of products in construction containing toxins or emitting VOCs and SVOCs should be considered. Better filtration may be feasible for

some facilities, but may prove impossible in residential homes with inadequate air handling systems that would become overwhelmed with the increased pressure drop. Design of residences and facilities with adequate ventilation and the ability to open windows is a promising intervention to improve mental health. Building homes with increase outdoor air ventilation is challenging due to the negative consequences for energy consumption, so alternative designs that reduce energy could assist this effort. Finally, encouraging little to no use of particulate creating activities, such as smoking and burning candles/incense, would likely improve the mental well-being of occupants.

Research Limitations

Difficulties facing the current research must be addressed to further the understanding between the built environment and mental health. For example, connecting mental health outcomes to the built environment is confounded by a multitude of variables that may be difficult to assess or variables that might not even be known. Mental health disorders do not always occur independently, meaning multiple issues may be present among those living with these conditions. Therefore, it is likely that the built environment is one of many factors that contributes to psychiatric distress. An additional problem is the presence of socioeconomic factors. Studies in lower socioeconomic cohorts have greater rates of mental illness [142]. Expanding the research into higher socioeconomic populations may improve validity of findings and strengthen our understanding of the relationship between the built environment and mental health. Studying higher socioeconomic populations may eliminate some influences of socioeconomic stressors, such as monetary strain and poor social support. Similarly, the theory of social drift may give rise to doubt about the influence the built environment plays on mental well-being. Social drift is when an “individual develops a serious psychiatric disorder they

become less able to maintain stable social relationships or hold well-paid employment” [143]. This may confound the notion that occupants are mentally unhealthy because of their built environment. Rather the inverse is true, individuals who are mentally unhealthy live and work in poor quality-built environments.

While causation is difficult due to the innumerable potential independent variables, controlled interventional studies that include social scientists, architects and engineers might be helpful. More effort to control extraneous variables in the built environment, such as materials, climate, and stressors, may also lead to strengthened understanding in the field. Finally, improvement in utilizing subjective measures that are standardized and validated for both built environment and mental health variables can assist future research. This is demonstrated in research on housing quality. A lack of detailed and direct assessments of home quality undermines results as meaningful conclusions are difficult to ascertain. Directed efforts to study narrowly defined aspects and mental health outcomes will improve future research.

Conclusion

It is evident there is a need for research into the built environment and its effects on mental health outcomes. Applying an interdisciplinary team approach with both social scientists, engineers, architects, and building scientists will aid in generating research that improves understanding in the field. Utilization of controlled experiments, animal models, and interventional studies can help generate more meaningful results that can be applied for impactful public health consequences. Additionally, expansion of research into post-occupancy alterations can help researchers identify how occupants alter the built environment in ways that prove important to mental well-being. Not only can built environment research inform architectural and engineering design policy, it may also advise health care professionals and

occupants on housing choices, and occupational, academic, and household alterations that optimize mental health.

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III. Examining Built Environment Factors of Veteran Residences and Associated Mental Health Symptoms

Chapter Overview

The purpose of this chapter is to specifically analyze factors of Veteran residential environments as they are related to five psychometrically sound mental health measures. Through collaboration with the Rocky Mountain Mental Illness Research, Education and Clinical Center (MIRECC), a survey assessing residential factors was administered to 92 Veterans enrolled in a larger microbiome study. These factors are then compared to symptom scoring across five measures, to include PTSD, depression, and insomnia. Odds ratios and mean comparison tests provide insight into those factors most influential on Veteran mental health symptoms. From this, potential design factors are investigated for their role in associated mental health changes and mechanisms through which they act.

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Influence of the Built Environment Factors on Mental Health in United States Veteran Residences

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Abstract

Awareness of Veteran mental health conditions have been poignant since the start of the Global War on Terrorism. While research on how to best diagnose and assist Veterans with mental illness abounds, little is known about their residences and the related impacts on these illnesses.

Growing research is indicating multiple ways in which the built environment affects occupant mental health. For these reasons, a joint research study into the built environment of Veteran homes and the associated mental health outcomes was undertaken. Currently there is not a set measurement for analyzing the built environment in terms of mental health outcomes.

Therefore, the team developed a self-reported survey of residential quality. In this paper we present the survey and discuss preliminary results that were compared against five psychometrically sound measures of mental health conditions, to include depression, post-traumatic stress disorder, and insomnia. Although further analysis is forthcoming with additional survey respondents is planned, this analysis includes the first 92 Veterans. Preliminary results show that a lack of nature pictures or paintings in the home significantly increased odds of severe mental health symptoms across all measures. Additional aspects of the built environment, such as water damage to the home, poor air quality, and low ceiling height, were also associated with negative mental health symptoms validating current academic literature. Further studies between interdisciplinary teams of social scientists and building designers should focus on longitudinal effects of exposures to built environment factors and interventional studies to more completely understand how these factors influence mental health.

Keywords

Veteran, Mental health, Built environment, Nature, Indoor air

Introduction

A Veteran is an individual who served in the active military, naval, or air service, and was discharged or released under conditions other than dishonorable [1]. Current statistics indicate that United States Veterans contend with mental illnesses at a disproportionate degree as compared to the civilian national population [2-5]. According to one study of 103,788 Veterans, nearly 31% of Veterans returning from conflicts after 2001 received mental health or psychosocial diagnoses [3]. Of those, 56% had two or more distinct mental health diagnoses [3]. Suicide, while not exclusive to individuals with mental illness, it is estimated that 90% of individuals who took their own life had a diagnosable mental health condition [6]. Suicides are of specific concern for Veterans as they die by suicide at 1.5 times the rate of US adult non-Veterans from 2005 to 2016 [5]. Coupling the statistics regarding Veteran mental health with the size of the current US Veteran population, nearly 20 million individuals [7], the public health issue becomes evident. Research on why Veterans are diagnosed with mental illnesses [2, 8, 9] and the most beneficial ways to assist them [10, 11] is on-going. However, one area of research to our knowledge that has yet to be sufficiently explored is the built environment of Veterans and how it may affect their mental health.

The built environment is the structures deliberately designed and constructed for humans to live, work, study, and interact. People are in contact more with this built environment today than ever before in human history. Urbanization has steadily increased and is expected to continue. For example, in 1950 only 30% of the world's population lived in urban areas [12]. This had increased to 50% in 2016 and is expected to rise to 68% by 2050 [12]. Additionally, US citizens spend 87% of their time in the built environment [13]. This means individuals are in contact with these man-made structures more often. These environments have been documented

to affect the physical health of individuals in contact with them [14-17]. Furthermore, people associate buildings and urban spaces with moods and emotions with phrases such as “this room is an inviting and happy space.” It follows that these environments may play a role in shaping the mental well-being of humans interacting and living within them, Veterans being no different. Indeed, a plethora of research identifies the built environment affecting occupant mental health [18, 19]. Through a previous literature review [20], impacts on mental health induced by the built environment in this paper were considered part of three constructs: a connection to nature, personal control of the occupant, and the indoor air quality of the environment.

The benefits of maintaining a connection to nature in the built environment have been documented [19, 21-23]. Incorporating natural elements into built environment can be accomplished through a number of methods to include: (1) views of nature in pictures, paintings, and windows; (2) abundant natural lighting, (3) having access to greenspace; and (4) direct physical interactions with natural environments (i.e. community gardens, nature walking paths). Natural aspects integrated into the built environment have been tied to multiple beneficial psychological outcomes, such as, reduction in occupant depression [24-27], stress reduction [28-31], and improved mood and emotion [32, 33]. Another construct, control of the occupant, modulates the ability of occupants to regulate social interactions or environmental stressors, such as noise exposure and poor built environmental quality. The lack of control has been shown to be tied to negative mental health outcomes to include increased depression [34-36], anxiety [37, 38], and stress [35]. The final construct, indoor air quality, is relevant because indoor pollutants such as particulate matter, odors, and toxins are common in buildings and lead to increased stress [39-42], depression [43-45], and behavioral issues [46-48] in occupants.

Given the rising evidence of the built environment affecting the mental health of occupants and the mental health burden, exploratory research into the built environment of Veterans and its effect on their psychological well-being is warranted. As such, the present joint study by building and social scientists at the US Department of Veterans Affairs (VA) hospital in Denver, Colorado was conducted. The objective of the study was to explore associations between Veteran homes and scores from five psychological measures. Built environment data was collected through a survey of 92 Veterans. To date, this is the only known study examining the built environment of Veterans and its implications on their mental health.

Methodology

Study Design and Data Collection

This study was as subset of the United States-Veteran Microbiome Project (US-VMP) study occurring at the Rocky Mountain Mental Illness Research, Education and Clinical Centers (MIRECC) in Denver Colorado [49]. The study was voluntary and open to all Veterans eligible to seek care within the VHA. All participants were former military Veterans, who provided informed consent to participate. Data was collected via multiple modes to include clinical interviews, self-reported measures, and access of individual's electronic medical record.

The start of enrollment into the US-VMP was May 2016. Beginning in March 2018 consented participants were re-sampled at 6-month intervals and the built environment measure was added to the study. At the baseline assessment, participants were administered the self-reported measures shown in Table 1 and are discussed in more detail below. During every 6-month subsequent assessment, participants were re-administered each measure. This design tied each measure to an instance in time, removing longitudinal effects from the data set. Therefore,

participants who were seen at the baseline appointment and those seen at the 6-month follow-up were not subset from each other.

Table 1. Self-reported study measures. Post-Traumatic Stress Disorder (PTSD) Mental Illness Research, Education and Clinical Centers (MIRECC)

Measure	Time to administer (minutes)	Condition(s)/Factor(s) of Interest
PTSD Checklist for DSM-5 (PCL-5)	5	PTSD symptoms
Insomnia Severity Index (ISI)	5	Insomnia symptoms
Patient Health Questionnaire (PHQ-9)	5	Depression symptoms
Outcome Questionnaire-45 (OQ-45)	10	Psychological distress
Short Form Health Survey (SF-36)	10	Functional health and well-being
Rocky Mountain MIRECC Demographics Questionnaire	5	Personal and military characteristics
Housing, Occupancy, Materials, and Environment (HOME) Survey	5	Built environment factors that influence mental health

Mental Health Measures

All assessments utilized in this study were self-reported. The Rocky Mountain MIRECC Demographics Questionnaire, was administered to obtain standard demographic and military history information. Investigators chose five psychometrically sound tools frequently used to assess the mental health of participants. Each of these measures provide a quantitative score related to symptom severity of different mental health conditions of interest. The main conditions investigated included insomnia, depression, PTSD, and functional mental health. The following measures were used to assess the mental health of the cohort:

- 1) PTSD Checklist for DSM-5 (PCL-5): a 20 item self-report measure used to assess PTSD symptom severity, based on DSM-5 diagnostic criteria [50].
- 2) Insomnia Severity Index (ISI): a 7-item instrument assessing the nature and severity of insomnia symptoms [51].

3) Patient Health Questionnaire (PHQ-9): a self-administered depression measure which scores each of the 9 DSM-IV depression criteria [52].

4) Outcome Questionnaire-45 (OQ-45): a 45-item questionnaire that is designed to measure psychological distress associated with three key areas (symptom distress, interpersonal relations, and social role) [53].

5) 36-Item Short Form Health Survey (SF-36): a multi-purpose, health survey that provides an 8-scale profile of perceived health and well-being [54].

The mental health measures were used to provide a comprehensive assessment of participant's overall mental well-being. To focus analyses, only the interpersonal relations score from the OQ-45 and the emotional well-being, social functioning, and general health score from the SF-36 were analyzed in this study.

Built Environment Measure

In order to assess the built environment of the Veterans, a self-reported Housing, Occupancy, Materials, and Environment (HOME) survey was developed by the research team (Appendix A). There has been no known survey of the built environment with mental health outcomes considered for Veterans. This survey was established after a literature review to assess aspects of the current home of participants and potential correlations to mental health. Questions ranged from type of home to in-home activities (e.g. smoking) to Likert scaled responses on ability to adjust the indoor climate.

Several built environment factors were grouped together to produce proposed constructs of the built environment. First, the factors of smoking any substance in the home, burning candles or incense, and water damage to the home were combined. If two of these three factors were present, then the home was considered to have poor air quality. Next, the factors of living

near greenspace, having at least 50% of windows look upon a natural setting, having pictures or paintings of nature in the home, and having good overall natural lighting in the home (indicated by a Likert response above 6) were combined. If less than three of these four factors were present, then the home was considered to have a poor connection to nature. Further analysis will be needed to confirm the existence of these constructs. Since personal control in the environment can be measured by several independent means, it was not combined into a single construct. Rather, personal control was assessed by questions regarding ability of occupants to adjust climate to their liking, ability to open windows, and whether homes were rented or owned. These questions generated independent measures of control within the built environment.

Statistical Methods

Descriptive statistics were used to summarize demographic and mental health responses in JMP® Pro Statistical Discovery™ Version 13.0.0 (SAS Institute Inc., Cary, North Carolina). An alpha of 0.05 was used for statistical significance. Correlational testing was applied to the questions on the HOME survey to assess validity. This was accomplished through three tests dependent upon the data type being compared as shown in Table 2. For example, if two yes/no responses were being compared, then the Pearson chi-square test was used to assess the relationship between the residential aspects.

Table 2. Means of statistical comparison between variable assessed on the Housing, Occupancy, Materials, and Environment (HOME) survey.

Data Types	Statistical Means of Comparison
Categorical to Categorical	Pearson chi-square test
Categorical to Continuous	Wilcoxon rank-sum test
Continuous to Continuous	t-test

Linear correlation analysis was utilized to further determine relationships between all continuous variables from the study. The continuous variables related to the built environment included the number of residences lived in over the last 10 years, number of people living in the home, the size, age, and ceiling height of the home. These were compared against demographic variables of the sample (age, time of service, and number of deployments), as well as, the scores from the psychological measures. Using a t-test, statistical significance was determined for linear correlations.

Further analysis was accomplished with the assumption of meeting several limitations. First, the HOME survey was not validated. While the above means of comparison amongst HOME survey responses helped assess relatedness between aspects of the built environment, the small sample size did not allow for complete validation of the survey. Furthermore, the small sample size resulted in a lack of statistical power for the study. Both of these limitations can be met with more participants being assessed. This will occur as the study continues. Finally, the study lacked a true control group. While individuals may have been assessed to be asymptomatic on the psychometric measures, these assessments did not indicate clinical diagnoses or the lack of any mental health disorder. Taking these limitations into account, several statistical methods were used to produce preliminary analysis.

First, the Wilcoxon rank-sum test and two-sample t-test were utilized to determine if there were significant changes in the psychometric scores for exposed and non-exposed individuals. The scores of the mental health measures were analyzed for normalcy using a Shapiro-Wilk goodness of fit test. If the scores followed a normal distribution, then a one-tailed t-test was employed to determine if the mean of exposed individuals differed from those of non-exposed individuals. If the scores did not follow a normal distribution, the Wilcoxon rank-sum

test was used. This is a one-way chi-square test to determine difference in the means [55]. Since built environment factors were compared against all seven mental health measures, a Bonferroni adjustment was applied which lowered the alpha of significance to 0.0071.

Next, odds ratios (OR) were utilized to assess the connection between aspects of the built environment and the presence of mental health outcomes. The OR represents the odds that a mental health outcome will occur if a group of individuals are exposed to a particular aspect of the built environment, compared to the odds of the same outcome in the absence of that aspect [56]. This is calculated via a two by two contingency table as shown in Figure 2. Equation 1 and Equation 2 indicate how the OR is calculated, as well as, the 95% confidence interval (CI). An OR greater than one indicated that the exposure to a given built environment factor was associated with higher odds of having a specific mental health outcome. The greater the value of the OR, the greater the odds. Statistical significance was ascertained from the likelihood ratio chi-squared (χ^2) test. Moreover, the Fisher's Exact test was utilized to accommodate the small sample size on calculating significance for OR.

		Mental Health Outcome	
		+	-
Exposure to Built Environment Aspect	+	a	b
	-	c	d

Figure 2. Two by two contingency table example

Where

a = Number of exposed individuals with mental health outcome

b = Number of exposed individuals without the mental health outcome

c = Number of non-exposed individuals with the mental health outcome

d = Number of non-exposed individuals without the mental health outcome

Equation 1. Odds ratio calculation [56]

$$OR = \frac{a/c}{b/d} = \frac{ad}{bc}$$

Equation 2. Odds ratio confidence interval calculation [56]

$$95\% CI = e^{\left[\ln(OR) \pm 1.96 \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}} \right]}$$

In order to calculate the OR, a control group (e.g. those without the mental health outcome) was determined by individuals who had non-significant or subthreshold scores for all five psychometric measures. Table 3 shows the criteria for the control group. In total, there were 19 control participants, 20.7% of the entire sample. Only the scores for PCL-5, ISI, PHQ-9, and the OQ-45 Interpersonal Roles were considered in calculating OR because they have validated cutoff values for symptom severity. The control group and the participants with scores that indicated the highest level of symptom severity were compared. For example, the control individuals, n = 19 (20.7%), were used in conjunction with the individuals with PHQ-9 scores of 20 and above (e.g. those considered to have severe depression symptoms), n = 10 (10.9%), for various built environment factors.

Table 3. Control group criteria used for comparisons. In order to be classified in the control group, subjects had to have scores on all five tests that met the cut-off criteria stated. Cut-off criteria has been tested and validated for the PCL-5 [57], ISI [58], PHQ-9 [52], and OQ-45 [53]. The cut-off for the SF-36 was determined by the research team for the purposes of this study.

Measure	Control Group Score Criteria
PCL-5	< 33
ISI	< 15
PHQ-9	< 5
OQ-45	Total Score < 63

Results and Discussion

Veterans

The correlational analysis indicated that each mental health measure was significantly related to each other. While this comorbidity is backed within literature, it does complicate further findings. Due to the interrelatedness of the psychometric variables, it becomes unclear whether significant relationships between built environment aspects and mental health symptoms exist. For example, it is unclear if someone contending with high depressive symptoms is due to their lack of nature pictures or paintings in their home or if it is because of their high insomnia symptoms.

There were 92 total Veterans, and while the sample was relatively diverse, many of the major demographics of the sample match those reported in the 2010 National Survey of Veterans, Active Duty Service Members, Demobilized National Guard and Reserve Members, Family Members, and Surviving Spouses (NSV) [59]. Most of the individuals were male (83.7%) and Caucasian (73.9%). Participant age ranged from 22 to 85 years old with an average

age of 47.9, a majority of participants younger than 50 years old. This differs slightly from the NSV, in which the majority of Veterans (64.0%) were above 55 [59]. This may be attributable to the fact that 9 years have passed since the NSV was conducted and therefore the Veteran population has become younger. Furthermore, the education level of the sample was overall higher in the present study compared to the NSV with only 14.1% reporting a high school education level or below as compared to nearly 31% for the NSV [59]. Additional statistics, such as marital status and employment status, were similar to those reported in the NSV. Notably, 46.7% of the present study population reported having been homeless in the past. Three individuals reported being currently homeless, however they did provide HOME survey responses and were therefore, still analyzed with the rest of the cohort. One of the three individuals indicated his living situation to be a group home/sober house. The other two individuals did not specify their current type of residence. However, since they did provide details on the place they currently reside, their results were analyzed accordingly. The full demographic characteristics are summarized in Table 4.

Table 4. Veteran sample characteristics

Variable	N (%) or Mean $\pm$ SD
Total	92
Age	47.9 $\pm$ 13.3 (22-85)
AGE CATEGORIES	
20-29	7 (7.6%)
30-39	22 (23.9%)
40-49	22 (23.9%)
50-59	20 (21.7%)
60-69	15 (16.3%)
70+	6 (6.5%)
GENDER	
Male	77 (83.7%)
Female	15 (16.3%)
RACE	
Caucasian	68 (73.9%)
African American	9 (9.8%)
Multiracial	9 (9.8%)
Other	5 (5.4%)
ETHNICITY	
Hispanic	12 (13.0%)
Non-Hispanic	79 (85.9%)
MARITAL STATUS	
Married	39 (42.4%)
Single	21 (22.8%)
Cohabiting	7 (7.6%)
Separated/Divorced	22 (23.9%)
Widowed	3 (3.3%)
SEXUAL ORIENTATION	
Heterosexual	83 (90.2%)
Gay/Lesbian/Queer	5 (5.4%)
Bisexual	4 (4.3%)
EDUCATION LEVEL	
No High School Degree	1 (1.1%)
High School Degree	12 (13.0%)
Some College	30 (32.6%)
Associate Degree	13 (14.1%)
Bachelor Degree	23 (25.0%)
Master's Degree	12 (13.0%)
Doctoral Degree	1 (1.1%)
EMPLOYMENT STATUS	
Employed Full-Time	20 (21.7%)
Employed Part-Time	8 (8.7%)
Unemployed Seeking Job	10 (10.9%)
Unemployed Not Seeking Job	25 (27.2%)
Retired	28 (30.4%)
STUDENT STATUS	
Not in School	77 (83.7%)
Full-Time	9 (9.8%)
Part-Time	5 (5.4%)
CURRENTLY HOMELESS	
Yes	3 (3.3%)
No	89 (96.7%)
Number of Times Ever Homeless	1.1 $\pm$ 1.7 (0-10)

While military service history of the cohort varied, 90.2% of the sample were enlisted in rank. The time spent on Active Duty service ranged from 6 to 312 months and 38 (41.3%) individuals served at some point on Reserve Duty. Additionally, the sample represented each of the four major branches of the military, Air Force, Army, Marine Corps, and Navy, the only exception being the Coast Guard. Most of the cohort had been on at least one deployment (67.4%) and had been to a combat zone (54.3%). The latter statistic may indicate a sample with a propensity towards PTSD symptoms as combat exposure has been associated with PTSD in past research [60].

Scoring for the mental health measures are summarized in Table 5. Participant scores on the five mental health measures spanned a wide range. Categories for the PCL-5, ISI, PHQ-9, and OQ-45 follow standard practice scoring manuals for the VA found in Supplementary Information. The SF-36 does not have standard scoring categories therefore, a subjective score of 50 was used to separate significant from not significant scores. Significant correlations existed between all of the mental health measures. Additionally, age of the participant was significantly negatively correlated to PCL-5 ($p = 0.0025$), ISI ($p = 0.0222$), and OQ-45 IR ($p = 0.0186$). This means that as participant age increased, these scores decreased, thus younger patients reported more symptom severity. This is also true of the SF-36 emotional well-being score which was positively correlated ($p = 0.0011$). Since higher scores indicate less distress in the SF-36, this result suggests that younger participants reported more distress for this measure.

Table 5. Mental health measures scoring summary

Psychological Measure and Categories	N (%)
PCL-5 (PTSD)	
Not Present	55 (59.8%)
Present	37 (40.2%)
ISI (INSOMNIA)	
Not Significant	31 (33.7%)
Subthreshold	23 (25.0%)
Moderate	26 (28.3%)
Severe	12 (13.0%)
PHQ-9 (DEPRESSION)	
Not Significant	32 (34.8%)
Mild	21 (22.8%)
Moderate	21 (22.8%)
Moderately Severe	8 (8.7%)
Severe	10 (10.9%)
OQ-45 (INTERPERSONAL RELATIONSHIPS)	
Not Significant	48 (52.2%)
Significant	44 (47.8%)
SF-36 (SOCIAL FUNCTIONING)	
Not Significant	68 (73.9%)
Significant	24 (26.1%)
SF-36 (EMOTIONAL WELL-BEING)	
Not Significant	68 (73.9%)
Significant	24 (26.1%)
SF-36 (GENERAL HEALTH)	
Not Significant	48 (52.2%)
Significant	44 (47.8%)

HOME Survey Assessment

In assessing the relationship between built environment factors, the correlation matrix of Figure 3 was generated. This matrix displays the p-value from the tests used to compare the different built environment factors assessed on the HOME survey. Those displayed in red indicate statistical significance. From this, there are logical relationships between built environment factors. For example, individuals who owned their home are more likely to have remodeled the home versus those who rented. Similarly, having a dog is significantly related to the type of home the Veteran. Further data is needed to fully validate the HOME survey as an accurate means of residential built environment measurement.

	Number of Residences	Number of people in home	Size of home	Age of home	Ceiling Height	Smoke	Burn incense or candles	Dogs	Remodeled	Open windows	Windows look on nature	Near highway	Near greenspace	Adequate privacy	Basement	Water damage	Nature pictures	Own the home	Type of home	Natural light rating	Climate adjustability
Number of Residences																					
Number of people in home	0.914																				
Size of home	0.221	0.700																			
Age of home	0.033	0.604	0.779																		
Ceiling Height	0.239	0.915	0.257	0.820																	
Smoke	0.461	0.339	0.073	0.612	0.226																
Burn incense or candles	0.745	0.104	0.949	0.545	0.666	0.021															
Dogs	0.953	0.002	0.003	0.796	0.634	0.331	0.225														
Remodeled	0.001	0.979	0.016	0.011	0.868	1.000	0.701	0.842													
Open windows	0.982	0.540	0.386	0.982	0.566	0.851	0.716	0.593	0.149												
Windows look on nature	0.201	0.248	0.523	0.127	0.865	0.161	0.232	0.714	0.071	0.059											
Near highway	0.760	0.443	0.519	0.906	0.263	0.233	0.845	0.738	0.037	0.015	0.476										
Near greenspace	0.387	0.916	0.262	0.432	0.300	0.323	0.087	0.860	0.510	0.432	0.062	0.757									
Adequate privacy	0.776	0.045	0.171	0.732	0.857	0.993	0.389	0.157	0.249	0.225	0.245	0.400	0.107								
Basement	0.026	0.002	<0.001	0.005	0.641	0.084	0.044	0.100	0.062	0.055	0.755	0.502	0.041	0.331							
Water damage	0.238	0.744	0.075	0.043	0.091	0.167	0.012	0.711	0.062	0.219	0.995	0.066	0.114	0.823	0.001						
Nature pictures	0.541	0.880	0.384	0.506	0.523	0.531	0.358	0.859	0.306	0.142	0.143	0.360	0.095	0.619	0.203	0.291					
Own the home	0.001	0.236	<0.001	<0.001	0.751	0.182	0.142	0.005	<0.001	0.046	<0.002	0.996	0.005	0.166	<0.001	0.011	0.052				
Type of home	0.116	<0.001	<0.001	0.114	0.834	0.069	0.413	0.001	0.014	0.166	0.140	0.107	0.390	0.327	<0.001	0.209	0.481	<0.001			
Natural light rating	0.332	0.958	0.031	0.711	0.906	0.469	0.460	0.821	0.649	0.865	0.014	0.037	0.012	0.690	0.118	0.295	0.015	0.859	0.192		
Climate adjustability	0.776	0.714	0.086	0.580	0.271	0.655	0.323	0.991	0.543	0.208	0.032	0.660	0.013	0.214	0.568	0.311	0.002	0.242	0.150	<0.001	

Figure 3. Correlation Matrix for built environment factors assessed on the Housing, Occupancy, Materials, and Environment (HOME) survey. P-values are displayed for the statistical test used. Those highlighted red are the reported p-values below the alpha of 0.05 and represent statistical significance in the relationship between factors.

Preliminary Findings

Several limitations to the research should be noted. A relatively small sample size made statistical significance difficult to attain. For the OR this led to large 95% confidence intervals. Furthermore, this small sample size may attribute to the skewing of negative mental health symptoms for younger participants. Additionally, each measure utilized relied upon self-reporting from the Veterans. This can lead to inaccuracies in assessing the home environment or the psychological measures which may artificially inflate or deflate scores. The limited data also made did not support the validation of the two proposed built environment constructs, air quality and connection to nature. While these limitations apply to the current study, preliminary analysis was accomplished and served a two-fold purpose: (1) allowed for a more complete and meaningful discussion into study data and (2) provided potential analysis techniques for researchers once limitations have been addressed.

For those individuals with severe depression symptoms as reported on the PHQ-9, 13 exposures resulted in OR above one. The only exposure that led to the significantly higher odds of severe depression was having no nature pictures in the home ($\chi^2 = 18.080$, $p < 0.0001$). The next highest OR resulted from exposures to no remodel of the home, poor privacy, and water damage, respectively. In total, 39 exposures were identified to have OR above one. Four OR were statistically significant as indicated by a p-value of less than 0.05 and each was due to an exposure of having no nature pictures in the home.

Means comparisons were also utilized to determine if statistically significant differences in the means of the mental health scores existed between exposed and non-exposed groups. Each set of scores for the mental health measures were tested for

normalcy. The only measure that followed a normal distribution was the OQ-45 IR (W-statistic = 0.985, $p = 0.351$). Results from the two-sample t-test and Wilcoxon rank-sum test are presented in

Table 6. For PHQ-9 scores, three exposures resulted in statistically significant mean scores: gender (male), lack of nature pictures, and a poor nature connection in the home. Men had higher PHQ-9 scores than women, indicating more depressive symptoms in the males of this sample. Not having nature pictures in the home also led to higher PHQ-9 scores, as did the combined construct of poor nature connection. Only the lack of nature pictures was statistically significant when accounting for the Bonferroni corrected alpha value.

For OQ-45 IR symptom scoring, nine exposures resulted in increased odds of having clinically significant symptoms. The only statistically significant OR resulted in an exposure to no nature pictures in the home ($\chi^2 = 12.582$, $p = 0.0004$). Not being near greenspace, having poor privacy in the home, and having water damage to the home also resulted in higher odds of significant IR symptoms. As OQ-45 IR scores were the only ones to follow a normal distribution, a one-tailed t-test was used to compare means between exposed and non-exposed groups. This measure had the greatest number of exposures that significantly affected mean scores with six, and it was the only mental health measure to be affected by low ceiling height (<8 feet) and poor climate adjustability (Likert response < 7). Similar to the PHQ-9 scores, only the no nature pictures in the home resulted in a p-value below that of the Bonferroni adjusted alpha value.

Individuals with severe insomnia had eight exposures that resulted in OR above one. As previous measures, the only exposure with significantly higher odds of severe insomnia was a lack of nature pictures in the home ($\chi^2 = 11.267$, $p = 0.0008$). Poor privacy and burning incense or candles in the home also resulted in relatively high OR. An OR was not calculable for exposure to no remodel as no individuals with severe insomnia had remodeled their home. Only one exposure resulted in statistically different mean ISI scores, no dogs in the home. Additionally, this exposure resulted in better (lower) ISI scoring, that is Veterans without dogs in their home had reduced insomnia (as reported in ISI scores) than those who did have dogs.

The only exposure resulting in statistically significant higher odds of having clinical symptoms of PTSD was not having nature pictures in the home ($\chi^2 = 9.210$, $p = 0.0024$). Another nine exposures resulted in higher odds of clinically significant PTSD symptoms with poor privacy and water damage being the next highest odds aside from no nature pictures. In general, higher PCL-5 scores were seen by those exposed to no nature pictures, poor air quality in the home, and water damage as indicated from the Wilcoxon rank-sum test.

As there is not a standard cutoff score for the SF-36, OR were not calculated for this measure. However, the Wilcoxon rank-sum chi-square test was used determine which built environment factors resulted in different mean scores between exposure groups. Across all three of the functioning categories, no nature pictures resulted in lower scores for those exposed. In the case of emotional well-being and general health, not having nature pictures was statistically significant (with Bonferroni correction). Males had lower

social functioning scores than females. Lastly, individuals determined to have a poor nature connection in their home had lower general health scores.

Table 6. Mean comparison results. Each of the scores were tested for a normal distribution This was only present for the OQ-45 IR scores which means the exposures were the only ones tested via a one-tail t-test. All other exposures were tested using a Wilcoxon rank-sum test. Bolded exposures indicate proposed built environment constructs. Highlighted p-values are those below the Bonferroni corrected alpha of 0.0071. The * denotes the only exposure which resulted in a negative effect on scoring, that is, being exposed to no dogs was associated with lower (better) ISI scores.

Exposure	χ^2 or t-statistic	p-value
SF-36 Emotional Well-Being		
No Nature Pictures	10.525	0.0012
SF-36 Social Functioning		
Gender	4.609	0.0318
No Nature Pictures	4.762	0.0291
SF-36 General Health		
No Nature Pictures	10.59	0.0011
PCL-5		
Water Damage	4.056	0.0440
No Nature Pictures	6.681	0.0097
ISI		
No Dogs*	4.684	0.0304
PHQ-9		
Gender	5.069	0.0244
No Nature Pictures	18.452	<0.0001
OQ-45 Interpersonal Relationships		
Water Damage	1.978	0.0256
Low Ceiling Height	2.019	0.0232
No Nature Pictures	2.771	0.0034
Poor Climate Adjustability	2.154	0.0170

While multiple built environment factors were associated with higher odds of the mental health distress per the four tested measures, not having nature pictures in the home resulted in the only statistically significant OR and spanned multiple exposures in mean comparison analysis. The OR for not having nature pictures in the home is

significantly greater than any other built environment exposure ranging from 12.272 for PTSD symptoms to 72 for severe depression symptoms. Furthermore, using the Fisher's Exact test, it was the only exposure found to be significant across each mental health measure. These findings indicated that this exposure is influential on the mental health of the sample.

The increased odds of mental distress due to the lack of nature pictures or paintings in the home has been hypothesized to result from attentional restoration [61]. This idea theorizes that views of natural environments leads to involuntary attention that allows for mental fatigue recovery. While this theory may help explain why having no nature pictures decreases mental well-being, it is not intuitive why ISI scores did not reflect the same significant change. According to the attentional restoration theory, it would appear most likely that insomnia would improve with more natural connections in the home. The Biophilia hypothesis is yet another idea that give credibility to these findings. This hypothesis states that humans have a natural affection for other life [62]. Therefore, homes lacking pictures or paintings of nature can cause mental distress for occupants. However, it is not immediately clear why the other measures of nature connections in the home, natural window views and access to greenspace, were not as strongly related to psychological distresses. This may point to an economic disparity in the sample. Individuals who are able to afford to place nature pictures in their home may belong to a higher socio-economic status (SES) and are therefore less susceptible to psychological distresses. Additionally, individuals who are experiencing greater symptoms of distress across the measures may be less prone to actively seek nature artwork to place in their home, therefore causation is difficult to place.

This study did feature certain strengths, as well. The research team was able to assess multiple built environment factors through a single survey. This means more exposures could be discussed and analyzed for their influences. Additionally, the psychological measures provide scaling of severity of symptoms. By evaluating in this manner, the research team was able to discern which factors resulted in the greatest influence on psychological distress. Finally, this study allows for continuation of data collection. As participants are re-evaluated at six-month intervals, their residences may change and differences between their psychological symptoms between residences can be evaluated.

Conclusions

Veteran mental health conditions appear related to their home environment. It remains unclear if the home environment leads to increased mental health symptoms or if mentally ill Veterans are seeking out unhealthy living conditions. While causation is difficult to deduce, further steps in the research can assist. Developing more standardized measures of the built environment can help eliminate confounding variables and more accurately assess the environment. Similarly, all efforts should be made to compliment psychological measures with psychiatric diagnoses to obtain a comprehensive mental health picture of participants. Furthermore, interventional studies that assess the effects of changing aspects of the built environment on the mental health symptoms of individuals can aid in explaining variance. Post-occupant alterations may also affect mental health conditions and should be considered in further research. Finally, increasing interdisciplinary research that involves teams of building and social scientists can help

identify those variables most important in understanding how to optimize living environments for mental health benefit.

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Appendix A

Housing, Occupancy, Materials, and Environment Questionnaire

Baseline

1. How many residences have you lived in over the last 10 years?

2. How many people currently live in the home with you? _____

3. How large in approximate square feet is the home you live in? _____

4. What year was your home constructed? _____

5. How tall are the ceilings in your home (in feet)? _____

6. Do you or anyone smoke any substance in the home you live in (e-cigarettes included)?

☐ Yes

☐ No

7. Do you burn incense or candles in your home daily?

☐ Yes

☐ No

8. Do you have any dogs that are regularly in your home?

☐ Yes

☐ No

9. Have you in the last 5 years done any of the following: replaced more than 50% of the carpet, applied paint to more than 50% of your home, remodeled, or replaced the roofing of your home?

☐ Yes ☐ No

10. Do you have the ability to open the windows in your home whenever you would like?

☐ Yes ☐ No

11. Do 50% or more of the windows in your home look upon a natural setting (e.g. not man-made structures)?

☐ Yes ☐ No

12. Do you live within 1 mile of a highway or interstate?

☐ Yes ☐ No

13. Do you live within 0.5 miles of open greenspace (park, playground, field, hiking trails, etc.)?

☐ Yes ☐ No

14. Do you feel you have adequate privacy in your home?

☐ Yes ☐ No

15. Does your home have a basement?

☐ Yes ☐ No

16. Has your home ever had water damage?

☐ Yes ☐ No

17. Do you have any pictures or paintings of nature in your home?

☐ Yes

☐ No

18. Do you own or rent the home you live in?

☐ Rent

☐ Own

19. What type of home do you live in?

☐ Detached Single Family:

If yes, what size is the lot upon which your home sit?

☐ <0.25 acres

☐ 0.25-0.5 acres

☐ 0.5-1.0 acres

☐ >1.0 acre

☐ Apartment:

If yes, what floor do you live on?

☐ Multiple Dwelling Unit (condo, townhouse, etc.)

☐ Other:

If yes, please specify:

On a scale of 1-10 (1 being poor and 10 being excellent), please rate the following aspects of your home:

20. The overall natural lighting in your home:

1 2 3 4 5 6 7 8 9 10

21. Your ability to adjust your indoor climate to your liking:

1 2 3 4 5 6 7 8 9 10

IV. Incorporating Research into Military Building Design

Chapter Overview

The purpose of this chapter is to provide an informed commentary on how to apply previous findings of beneficial built environment factors to military building design. As a culmination piece, the intent is to discuss the challenges facing military engineers in designing with mental well-being in mind and potential offsetting benefits. Several design factors are discussed along with associated mental health outcomes backed by literature and research from Chapters 2 and 3. This chapter is meant as an editorial striving to bring awareness to the military engineering community on the mental health benefits of certain built environment designs.

Publication Intentions

Title: How Military Building Designers Can Aid Mental Well-Being

Publication: The Military Engineer

How Military Building Designers Can Aid Mental Well-Being

Cody Beemer, Capt, USAF

Capt Cody Beemer is an Air Force Civil Engineering Officer and currently pursuing his master's degree at the Air Force Institute of Technology in engineering management.

Capt Beemer is one of several students researching mental health and the built environment under a new initiative by AFIT assistant professor, Lt Col Andrew Hoisington. This research would not have been possible without the guidance and assistance of Dr. Lisa Brenner and her team at the Department of Veteran Affairs Rocky Mountain Mental Illness Research Education Clinical Center (MIRECC).

Mental illness is a prevalent issue in today's society. Worldwide and national statistics indicate that mental illness is a robust public health problem and this issue especially is of concern for United States (US) Military members and Veterans. Current academic literature and Department of Veteran Affairs (VA) research has revealed the extent of negative mental health outcomes with airmen, soldiers, sailors, and Marines experiencing depression, post-traumatic stress disorder (PTSD), and other problems. Aside from the human suffering of these mental health outcomes, further issues abound, such as, reduced war-fighter readiness and economic burdens. Meanwhile, the mental

health issues are complicated by the historical apathetic culture of armed forces members towards diseases and wounds that are non-visible. Fortunately, this plight is being actively researched to improve outcomes in nearly all areas. Social scientists continue to make progress in understanding and treating mental illnesses experienced by the Military and Veteran populations. One area of growing research in combating negative mental health outcomes being conducted by building scientists, engineers, and architects.

In general, most associate the buildings we use with emotions and feelings. Everyday vernacular includes phrases such as “this room makes me happy” or “that is a depressing building.” We recognize the role that the man-made environment around impacts our emotional and likely mental state. Some people even make lifestyle choices, such as selecting a new job, based on pleasing aesthetics of the facility and improved mindsets created by certain built environments. Couple this with the fact that the average adult in the US spends a nearly 90% of their time indoors, and it is evident the built environment might be a prime target for improving mental health. Therefore, scientists are working towards discovering ways that the built environment might be associated with mental health outcomes. To date, research studies have correlated items in the built environment to mental health outcomes including depression, anxiety, mood, and cognitive function. Specifically for the team at the Air Force Institute of Technology (AFIT) Engineering Management program, growing interest in this field has led to a collaboration with the Rocky Mountain Mental Illness Research, Education, and Clinical Centers (MIRECC) at the Denver Veteran Affairs hospital in an attempt to provide meaningful changes that can be made in military facilities and residences of active duty members and Veterans.

Through engineering and architectural decisions, literature points towards three primary constructs that the built environment might influence mental health: connection to nature, personal control of the occupant over their surroundings, and indoor air quality. Architects and engineers can incorporate nature through the use of natural elements in the built environment. Specifically, measures include improving natural light, providing windows with views of natural landscapes, and integrating nearby greenspace into built environment designs. Another construct, personal control, refers to the ability of the occupant to physically manipulate their surroundings or indirectly manipulate them through regulation of social interactions or environmental stressors, such as unwanted noise. In buildings, this is altered by giving control to the occupant for climate and lighting, designing open, mixed-use spaces that encourage social interactions, or using quality insulation to reduce noise related disturbances. Even allowing individuals to alter their environment through hanging of pictures on walls or paint might be important for the feeling of control of the environment. Finally, chemical and particulate pollutants, as well as, annoying odors influence air quality in the indoor environment. Indoor air quality can be altered by engineers through heating, ventilation, and air conditioning (HVAC) design and limiting use of construction material which emit pollutants. Each of these constructs have been already been correlated to negative mental health outcomes for the occupant such as increased risk of depression and other psychiatric disorders.

The MIRECC and AFIT partnership set out to better understand how the homes of Veterans may contribute to mental illness symptoms. The initial interest in the topic began when psychiatrists thought it pertinent to ask questions about how the physical surroundings of residences may affect the poor mental health of Veterans who had

attempted suicide. From this line of inquiry, a survey was developed by AFIT that inventoried home living conditions and objects in the home. The Housing, Occupancy, Materials, and Environment (HOME) survey was developed through a review of current academic research, and garnered information on veteran homes including age and type of the home, views from windows, proximity to greenspace, climate adjustability, indoor air quality, and natural lighting. From this preliminary survey, investigators were able to analyze the various aspects of the home and how they were related to symptom severity scores across five psychometrically sound measures. Veterans provide a useful study population as they share demographics and experiences with active duty and reserve Military populations. Additionally, Veterans may be more apt to report accurate negative mental health outcomes that may have otherwise been censored by active military members fearful of retribution or stereotyping.

While further data and validation are required, preliminary analysis from this study are revealing potential opportunities for building designers to improve occupant mental health via relatively simple and affordable avenues. For example, preliminary data suggests the presence of nature pictures or paintings in the home was related to mental health benefits. Veterans who did not have nature artwork or pictures in their home were shown to be more susceptible to severe depressive symptoms, PTSD symptoms, severe insomnia, and issues with interpersonal relationships. These pictures and paintings of natural settings may be important as they provide a connection to nature in the home that is not otherwise possible via window views or proximity to greenspace. Hypotheses abound as to the reasons a connection to nature is important for human mental health, regardless veteran mental health may also be influenced by this aspect. However, these

results are preliminary and not having nature pictures could be a proxy for the ability of individuals to modify their surroundings. Also, adequate privacy may hinder their ability to regulate social contact and induce stress both of which can lead to degraded mental well-being. Finally, living in a home with water damage was associated with increased psychological symptoms. Aside from being detrimental to home aesthetics, water damage degrades the indoor air quality and negatively alters the mental and physical health of occupants. While other home aspects can influence mental health, these three provide opportunities for building designers to positively influence and should have additional research. At the present, this research is preliminary so current military design guidelines directly incorporate these issues.

Engineers and architects are limited in design and construction by a finite budget. Suggestions to alter designs or spend more money to make buildings more mentally friendly is likely to be met with uncertainty as most individuals are unaware of this field of research. Some of these sentiments towards military buildings have been quelled by the more recent pushes towards sustainable design and construction means. However, even these initiatives are founded from financial incentives and political policy. Therefore, incorporating design features to help improve occupant mental health must be backed by sound fact and science. While some measures may require deliberate design with significant economic impacts for a project, others can be implemented with relatively minor financial investment and effort. Ensuring natural artwork is a part of final design may be beneficial in combatting multiple mental health outcomes. This particular design consideration is also possible for current facilities. Other efforts, such as improving air quality and providing adequate privacy may require more robust design

considerations. Nevertheless, many of the incurred cost can be offset by including privacy measures or more intensive air filtration systems early in design processes similar to sustainability concepts. Furthermore, economic incentive realized from improving mental health via these means and others may ultimately overcome the upfront investment into these designs. Keeping military members working, increasing productivity, and reducing the use of mental health treatment can lead to such economic gains.

Current efforts in treating mental health for both military members and Veterans are robust and ever-changing. Increased awareness campaigns aim to destigmatize mental afflictions and encourage use of mental health treatment options. While important, many of these efforts are passive, in that they can only be given once poor mental health symptoms are experienced and help is sought. Building designers can play a crucial role in changing this work to an active narrative. By altering buildings through often low-cost and reasonable design considerations, engineers and architects may combat mental illness as it occurs. Much research remains in understanding how the built environment affects mental health, but it is clear that engineers and architects play an important role in furthering this knowledge.

V. Conclusions and Recommendations

Conclusions of Research

In examining the influence of the built environment on occupant mental health outcomes, the purpose of this research strived to address the following three research objectives:

1. To identify the built environment factors in current academic literature which have proven influential in occupant mental health and how they do so.
2. Develop the first survey given to US veterans to inventory the built environment with regards to mental health outcomes
3. To begin the process of determining how residential built environment factors in regards to living conditions among US military Veterans are related to mental health symptoms.

In answering the first question, a thorough literature review of current and historical academic research is required. This is accomplished in the article “Built Environment Factors and Associated Mental Health Outcomes,” where the evidence points towards three constructs by which built environment factors can affect occupant mental health: (1) a connection to nature, (2) personal control of the occupant, and (3) indoor air quality. Hypotheses as to the mechanisms that enable these factors to alter mental health of occupants vary and include social, psychological, and biological means. The mental health outcomes observed are many and include, but are not limited to depression, anxiety, altered mood, behavioral changes, and cognitive interference. While this current literature is expansive, some common limitations apply. A majority of

research relies on cross-sectional studies which contend with confounding variables, such as socio-economic status and extraneous built environment variables. Furthermore, studies in this field often rely on subjective measures of the built environment, for example housing quality, which makes drawing impactful conclusions difficult. Through controlled experiments, animal models, and interventional studies conducted by interdisciplinary teams of social scientists, engineers, architects, and building scientists more meaningful results can be obtained.

The second and third objectives are accomplished in the article “Influence of the Built Environment Factors on Mental Health in United States Veteran Residences,” in which 92 Veteran residences were surveyed and residential built environment aspects were analyzed for their influence on five psychological symptom distress measures. From this research, several built environment factors are identified as influential. Most significantly, participants with no nature pictures in their home have greater odds of severe depressive, insomnia, and PTSD symptoms, as well as more reported issues with interpersonal relationships. This finding is consistent with academic literature which connects views of nature to various mental health outcomes [1, 2]. This result may be attributed with the Biophilia hypothesis which states that humans gain a natural benefit from exposure to other life [3], therefore homes with no such exposure can lead to mental distress. Additionally, water damage in the homes was tied to increased psychological symptoms along with poor privacy as indicated by the occupant. Such results indicate that the aspects of the homes of Veterans are tied to mental health conditions. This may provide insight for further research and ultimately means of intervention for Veterans contending with poor mental health.

Furthermore, the third objective is addressed in the final article, “How Military Building Designers Can Aid Mental Well-Being.” This article provides an overview of those built environment factors found to be influential that lend themselves to being readily changed in current buildings and design guidelines going forward for the DoD. Including natural artwork and pictures is the easiest change to incorporate at little or no cost which may improve occupant mental well-being. Further updating design guidelines to consider privacy and securing buildings against water damage can lead to more mentally healthy facilities. Finally, considering designs which limit exposure to environmental stressors, such as poor air quality and unwanted noise, can lead to reduced stress for occupants. Cost-benefit analysis can help identify the most practical and economic changes which provide the greatest influence on occupants.

Significance of Research

With the current Veteran and Military mental health epidemic, new avenues for improving mental well-being must be explored. While much research has indicated built environment factors are linked to negative mental health outcomes, no current literature exists for this type of connection for Military members and Veterans. Given the unique nature of the mental health of the Military and Veteran populations, a thorough understanding of how their current home environments affect them is necessary. This research has begun such exploration into this realm and found potential residential aspects that are influencing Veteran mental health. By introducing initial exploration into this important topic, this research will provide the foundation upon which further research will lead to a greater understanding of the influence the built environment plays

in the mental health of Veterans. Furthermore, through a review of current research on the topic, avenues of change to the built environment are presented. Some prescribed changes can be made with low effort and at little cost by the DoD to potentially improve mental well-being of the active Military population. This research may also provide opportunities for intervention in the treatment and care of Veterans afflicted with mental illness. By introducing some of the measures discovered in this analysis into the homes of Veterans, care givers may be able to induce a healthier environment that leads to improved mental health symptoms. While not a comprehensive treatment of mental health conditions, this research when coupled with other psychiatric practices may provide new avenues for Veteran mental health assistance.

Recommendations for Future Research

This research was impacted by time constraints leading to a limited number of Veterans having completed the HOME survey at the time of analysis. Given the procedure is still in place, the first direction for future research is to continue to collect Veteran residential data and complete the same analysis seen in Chapter 3. This will bring greater statistical power to results and identify factors truly influential to the mental health symptoms of Veterans. Collection of a larger sample size will also allow for the validation of the current HOME survey. Also, backing the current psychological symptom measures with psychiatric diagnoses would help identify true control groups and validate results. Finally, through the current practice of resampling Veterans at six-month intervals, a subset of participants whose residences have changed can be analyzed.

This will allow future researchers to see how changing built environment factors translates into reported mental health symptoms.

Another consideration is to develop an interventional study based on the factors identified as influential to Veteran mental health symptoms. Making in-home alterations and monitoring the associated changes in mental health symptomology may help bring causal evidence to the research effort. Additionally, such a study design helps control extraneous variables that may be influencing mental health outcomes. Along these same efforts, changing from a self-reported survey to a researcher-based analysis of the home environment of Veterans will help with subjectivity and consistency issues. Lastly, narrowing the scope of research into a more defined aspect of the built environment, for example natural lighting, may lead to a more comprehensive understanding what the aspect is, how to measure it, and how it is influencing the mental health of the Veteran. While this research has begun the understanding of Veteran homes and corresponding mental health outcomes, by refining research strategies a more complete understanding can be generated.

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