The Hopeful Expect to be Comfortable: Exploring Emotion and Personal Norms Related to Sustainable Buildings in the United States

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Abstract

Sustainable buildings are designed to reduce energy use and other environmental impacts and to provide indoor environmental conditions that maximize well-being and satisfaction among building occupants. However, occupants' comfort in and satisfaction with such buildings has been inconsistent. Evidence indicates occupants’ *expectations* of indoor building environments influence their perceptions of climatic conditions (e.g., temperature) and comfort while in buildings. Accordingly, it is important to better understand a priori expectations associated with sustainable buildings. An online experiment examined the influence of exposure to a depiction of a sustainable vs. a conventional building on a priori expectations of indoor environmental conditions/quality (IEQ) as a measure of anticipated comfort. The study also examined the extent to which personal norms moderated and the emotion of hope mediated the influence of building type. Results indicated more positive expectations of IEQ associated with the sustainable building, but such effects were largely explained by mediating effects of hope, indicating an important role of discrete, goal-directed hope in predicting expectations of conditions in sustainable buildings. Personal norms did not moderate the effects of building type on hope or expectations. IEQ expectations were also correlated with less anticipated need to use personal appliances or make personal adjustments in order to stay comfortable in the building.

Keywords: sustainable buildings, hope, personal norms, comfort, expectations, environmental conditions

1. Introduction

Buildings are responsible for 31% of energy consumption worldwide and have the highest potential for emissions reduction relative to the cost of such improvements [1]. Sustainable buildings are designed to reduce the energy use and other environmental impacts of building construction and daily operation as well as to provide indoor environmental conditions that maximize well-being and satisfaction among building occupants [2]. Some research indicates that building occupants have a generally favorable disposition toward sustainable buildings [3,4]. However, the long-term performance of sustainable buildings with respect to occupants' satisfaction seems to be inconsistent [2]. This is potentially problematic because building occupants' satisfaction with indoor environmental conditions can be associated with workplace productivity [5,6] and well-being [7].

Across building types a mismatch between the predicted occupant perceptions of indoor environments (thermal, e.g., too hot or too cool, and air quality) and occupants' reported satisfaction has been widely observed and studied [8,9]. Evidence indicates that occupants' expectations of the indoor climate (e.g., expectations of the temperature and air quality in a given building) influence their actual comfort while in the building [10], and when positive expectations of the indoor environment are not met, occupants' reported comfort decreases. Dissatisfaction with the indoor environmental conditions can lead to an increased use of building systems (e.g., heating, air conditioning, lighting), thus offsetting potential energy saving [11]. Consideration of occupant satisfaction with the indoor climate plays a substantial role in the design of indoor spaces and building services, especially in sustainable buildings. Accordingly, research is needed to better understand and predict individuals' expectations of conditions in sustainable buildings as such expectations could, in turn, influence perceptions of and satisfaction with indoor conditions once they are in such buildings.

Research on motivated reasoning [12] suggests that individual differences and biases among humans can influence their perceptions of environmental conditions, and such differences could also be associated with a desire among some occupants to tolerate or be satisfied with a wider range of indoor conditions. Understanding occupants' motivations to expect favorable conditions and to tolerate environmental conditions can help building designers and operators identify solutions to enhance occupant satisfaction with indoor conditions. Such understanding could additionally improve forecasts of occupant actions, which can strongly influence energy consumption. Accordingly, we examined the extent to which individuals' motivations (i.e., personal norms) were associated with expectations of indoor environmental conditions (thermal and air quality) in a sustainable building as compared to a conventional building. Additionally, because human emotions (e.g., fear, hope) can predict and motivate responses to environmental problems and opportunities [13,14], we also examined the extent to which the emotion of hope might mediate the influence of individuals' psychological motivations on such expectations.

Although prior studies have examined occupant responses to and expectations of sustainable buildings, little work has examined how differing psychological motivations of occupants might influence those expectations and responses. Thus, this study examined the intersection of the type of building (sustainable vs. conventional) and the potential role of motivational variations across individuals on expectations of indoor environments in buildings. Given that human motivations have been found to be associated with estimates of measurable phenomena such as air quality and outdoor temperature, we suggest that such motivations have the potential to influence expectations of indoor environmental conditions. As noted above, those expectations, in turn, could predict perceptions of indoor environments among building occupants while in a given building and concurrently influence their energy-related behavioral adjustments.

2. Literature Review and Hypotheses

2.1 Buildings and occupant expectations and satisfaction

Sustainable building construction optimizes the use of resources (energy, materials), minimizes waste and environmental impacts (both at the construction and at the operational stages), seeks to maximize comfort and well-being of occupants, and attempts to minimize energy consumption [15]. Of particular importance is the potential improvement of indoor environmental quality (hereafter IEQ) as well as an understanding of occupants' responses to the indoor environment of sustainable buildings in order to optimize the final energy performance of buildings while maintaining occupant comfort.

Occupants' exposure to different indoor environmental stimuli directly impacts their perceptions of comfort in their environment [16]. The experience of occupants with their indoor environment can be defined along different domains, including the thermal and indoor air quality (IAQ) domains [17]. Low levels of thermal comfort and perceptions of IAQ can negatively impact occupants' satisfaction and increase coping strategies [e.g., behavioral coping (environmental adjustments, such as changing the thermostat setting or using a personal heater or fan, or personal adjustments, such as wearing lighter or heavier clothing) or psychological coping (managing one's attitudes and emotions regarding the situation)] within the built environment [18–20]. Two common parameters used to evaluate the thermal environment are *thermal comfort* (occupants' ratings of the indoor temperature from "very uncomfortable" to "comfortable") and *thermal sensation* (rating the space from "hot" to "cold"). IAQ is usually assessed in terms of *perception of air quality* (for instance, Gunnarsen

& Fanger [21]: “clearly acceptable” to “clearly not acceptable”). Satisfaction with indoor environmental conditions has been associated with a variety of factors, such as IAQ perceptions [22], emotions (e.g., joy, boredom) experienced by occupants [23], and physiological factors, such as skin temperature and heart rhythm [24]. Research has focused on understanding occupants’ perceptions of the indoor climate to provide acceptable indoor environments through building operations [25,26].

However, building performance and occupant satisfaction with indoor conditions are not always correlated [27], and some argue that unmet expectations of building performance can lead to dissatisfaction with indoor conditions. Several studies [28–30] have found that occupant expectations of indoor conditions can be influenced by previous thermal experiences, such as differences in occupants’ thermal sensation and acceptance after moving to a different climate zone or after being exposed to different outdoor conditions or to air conditioning. These studies identified a relationship among occupants’ expectations and their thermal and overall satisfaction as well as between occupant expectations and acceptance of indoor environments. For example, Schweiker et al. [10] identified an effect of occupants’ expectations of the indoor environment on their thermal satisfaction: if the mismatch between expected thermal conditions and actual thermal sensation is big enough, displacement of thermal perception can occur, whereby occupants either increase or decrease their thermal acceptance. Consequently, if the experienced thermal conditions are close to occupants' expected conditions of a particular space, they will likely psychologically minimize any minor thermal discrepancy and accept the actual conditions [10]. These findings suggest that positive expectations of the indoor environment could influence IEQ acceptance in buildings. Accordingly, it could be helpful to better understand the expectations occupants hold before they experience or interact with a building as well as the potential psychological or motivational drivers of those expectations.

Expectations in prior studies have been conceptualized and/or measured in different ways[1], but all studies known to the authors have measured expectations retroactively -- after occupants or research participants had just entered or had been in the building for some time. Retroactive measures of expectations could be biased by occupants' current or recent experiences within the building or by the experience of answering other questions related to the building or current IEQ. Accordingly, in this study the main interest is in the *a priori* expectations of IEQ occupants have before they enter a building. Although IEQ pertains to thermal, visual, and acoustic comfort, as well as IAQ, in this study, we have only focused on thermal comfort and IAQ factors, and hereafter, the term IEQ specifically accounts for these two factors.

2.2 The case of sustainable buildings and occupant expectations and satisfaction

Research suggests the type of building itself might influence expectations of and responses to indoor environmental conditions. A recent international survey [31] found fairly widespread public support for reducing energy use in buildings, indicating favorable attitudes toward green or sustainable buildings. Additionally, a "green" label can evoke psychological

[1] Schweiker et al. [10] asked participants right after they entered a workspace - either in the laboratory or at their normal workplace - if the encountered thermal conditions were in line with the expectations they had before entering the space. If conditions were not congruent with expectations, participants were asked if conditions were cooler or warmer than expected. In a different approach, Brown & Cole [35] measured expectations through a "forgiveness" factor by comparing mean ratings of overall comfort with mean rating of other comfort indicators. Monfared and Sharples [22] conceptualized expectations as occupants' previous knowledge about sustainability and their perceptions of sustainable buildings in general and compared those with their evaluations of the green office buildings in which they currently worked. Jailani et al. [38] took a similar approach to assess occupants' expectations and satisfaction with a post-occupancy survey and interviews. In all studies reviewed here, expectations were either directly measured or inferred from other measures after occupants experienced the thermal conditions in the buildings.

associations (i.e., a preference bias) for green buildings [3,32] and lead to greater forgiveness/tolerance of less-than-ideal conditions in green buildings [33]. For example, occupants were more ‘forgiving’ of conditions in green buildings when other building features they valued were present, such as more natural light; when they received more/better information about the building design and management [34]; or if they perceived the building to be more, rather than less, “green” [35]. Several studies [36] have indicated that occupants in “green” buildings were likely to be more satisfied with IAQ and reported favorable thermal perceptions compared to conventional buildings [37]. However, occupants’ satisfaction with green buildings can sometimes be lower than expected [22,38]. A recent review of studies comparing green and conventional buildings found that occupant satisfaction with green buildings varied geographically [2]. Accordingly, with some exceptions, occupants seem to have generally favorable responses to green or sustainable buildings, and research suggests that individual differences among occupants could further predict those responses via occupant expectations of indoor conditions.

2.3 Occupants’ psychological factors influencing environmental perceptions

Research on motivated reasoning finds that environmental conditions can be perceived in a manner consistent with individuals’ existing attitudes, beliefs, or ideologies [12]. For example, several studies have found that U.S. citizens’ personal values and/or political ideology (beliefs) influenced their perceptions of outdoor temperature, air quality, and recent weather patterns [39–42]. Moreover, these individuals’ recall and perceptions of outdoor environmental conditions were often at odds with verifiable weather and air quality data.

Because psychological factors such as human values and beliefs have been found to determine perceptions of outdoor environmental conditions, the current study investigated whether similar factors might influence expectations of indoor environmental conditions. A review of a small number of initial studies suggested that, in addition to the already established environmental and physiological predictors of thermal sensation and comfort, psychological factors such as building occupants' knowledge and attitudes could influence their thermal comfort [43]. More recent research has found that personality factors (e.g., openness to experience, extraversion) as well as beliefs about personal control over the indoor environment can predict thermal sensation and thermal preferences [44] and that cultural differences can predict thermal comfort [5].

Given the documented influence of existing motivations on outdoor environmental perceptions as well as the influence of other psychological factors on indoor environmental perceptions, it should be possible to identify particular groups of occupants who would likely expect indoor conditions in sustainable buildings to be more acceptable than others. In short, some occupants might have more positive expectations and be more tolerant of indoor conditions in sustainable buildings because of their overarching, personal goals. For example, those whose behaviors (such as pro-environmental or energy-related behaviors) have a strong moral basis tend to be more motivated than others to make sacrifices in order to conform to their own standards of conduct [45,46]. Moral motivations to perform pro-environmental behaviors are called personal norms. Pro-environmental personal norms reflect feelings of personal obligation and strong motivations to take action in order to protect the environment, and they are generally correlated with performance of pro-environmental behaviors [47].

Pro-environmental personal norms are typically activated by an awareness of the potential impact of one's actions on the environment along with beliefs about the extent to which one's actions to protect the environment can make a difference [48]. If individuals with strong pro-environmental personal norms learn that they will soon or currently do work in a sustainable building and are informed about or reminded of building features designed to protect the environment, their personal norms should be activated and subsequently motivate them to act – or perceive the situation - in a manner that is congruent with those norms. One possible behavior in this context would be finding a way to be comfortable in a sustainable building, because doing so gives them the opportunity to act on their norms. But before that opportunity to adapt occurs, another option would be to expect to be comfortable: based on existing values and beliefs, these individuals should be likely to engage in motivated reasoning that would lead them to expect and report favorable environmental conditions in a building that reflects their important values and goals. Given findings described above that indicate a general desire for and positive responses to "green" buildings it is reasonable to predict that many individuals will have positive expectations of indoor environmental conditions associated with such buildings, based on motivated reasoning processes that stem from their existing positive predispositions toward green buildings. However, we suggest that such effects will manifest more strongly among those who are intrinsically motivated to envision a value- or attitude-congruent experience in those buildings – individuals with stronger, rather than weaker, personal norms to protect the environment and save energy. Accordingly, we tested the following hypothesis:

H1a-b: After receiving information about a building and being asked to envision working there (a) more positive expectations of indoor environmental quality (IEQ) will be reported by participants asked to envision working in a sustainable building than by participants asked to envision working in a conventional building, (b) especially among participants with greater existing personal norms to protect the environment and save energy.

Although general motivated reasoning processes could lead to a direct influence of building type (and its potential interaction with norms) on expectations of IEQ as proposed in H1a, research suggests another path by which more positive expectations could occur:

emotional responses to the information about the building and to envisioning working in it. Human emotions are important predictors of responses to environmental problems and opportunities [13,14] and have been found to be associated with perceptions of IAQ [23]. Emotions contribute a sense of urgency to more abstract issues such as environmental impacts and are experienced when individuals consider the possible goal-relevant outcomes of a given situation [49]. Of particular interest in the current context is the positive and goal-directed emotion of hope. Feelings of hope have been found to influence energy-related and pro-environmental behaviors [42,50,51], as well as support for energy and climate-change related policies [52]. Accordingly, we examined the role of hope as an alternative or complementary path of influence of building type and personal norms on a priori expectations of IEQ.

Hope arises when we face negative, goal-relevant circumstances and are then presented with an opportunity for things to improve or to make progress toward important goals [53,54]. Those who are concerned about environmental problems or climate change, should, therefore, feel hopeful when presented with an opportunity to mitigate such problems. This should especially be the case for individuals with high levels of personal norms to protect the environment, as they are typically aware of environmental problems (such as pollution or climate change) and are motivated to make sacrifices in order to mitigate or alleviate the problem [48]. Therefore, presenting individuals who have high levels of pro-environmental personal norms with the possibility of working in a sustainable building should lead them to experience hope. This is because working in a sustainable building should be perceived by those individuals as a relevant pathway [55] by which to make progress on their goals or fulfill their moral obligations to help protect the environment or at least to limit their contributions to environmental harm. Accordingly, we tested for an interaction of building type and personal norms on feelings of hope:

H2: After receiving information about a building and being asked to envision working there, participants in the sustainable building condition with greater existing personal norms to protect the environment and save energy will report greater hope than participants with lower levels of personal norms and than participants in the conventional building condition.

Research on hope and motivated reasoning (as well as on hope and related processes such as confirmation bias and biased processing of information) suggests that the more those who are hopeful feel a yearning for goal-congruent outcomes the more subject they are to seeing what they want to see. Those who are hopeful that a goal-relevant outcome is possible are proposed to generate more positive evaluations of related information, events, or objects (such as consumer products) and to more readily accept evidence that indicates a greater (rather than lesser) possibility of achieving the desired outcome [56–58]. For example, intense levels of yearning for a goal-congruent outcome is proposed to make individuals particularly sensitive to the potential benefits associated with a goal-relevant consumer product [59]. Therefore, those with high levels of hope should be especially motivated to expect that sustainable building conditions will be sufficiently suitable or favorable to allow them to achieve their goals of environmental protection. Accordingly, we tested the following hypothesis:

H3: Greater hope elicited by envisioning working in a sustainable building will be associated with more positive expectations of environmental conditions in that building.

Finally, although the primary outcome of interest in this study is expectations of IEQ, such expectations likely have implications for energy use. In general, perceived comfort in an indoor space should be associated with perceived need to change environmental conditions in order to feel comfortable, such as interacting with/use of building systems (e.g., a thermostat), using personal appliances (e.g., a portable heater), or making personal adjustments (e.g., wear warmer or lighter clothes). Importantly, occupants' use of such systems, appliances, or personal adjustments can affect the actual amount of energy saved in a sustainable building. Use of systems, appliances, or personal adjustments are an attempt to restore comfort: when discomfort increases, the likelihood of system use or adjustments increases [60,61]. Therefore, an expected state of comfort should reduce the perceived need to perform an action that is "comfort-related". Accordingly, we tested the following hypothesis:

H4: More positive expectations of environmental conditions will be associated with less anticipated need to make adjustments and to interact with building systems in order to stay comfortable.

3. Materials and Method

3.1. Overview of procedure

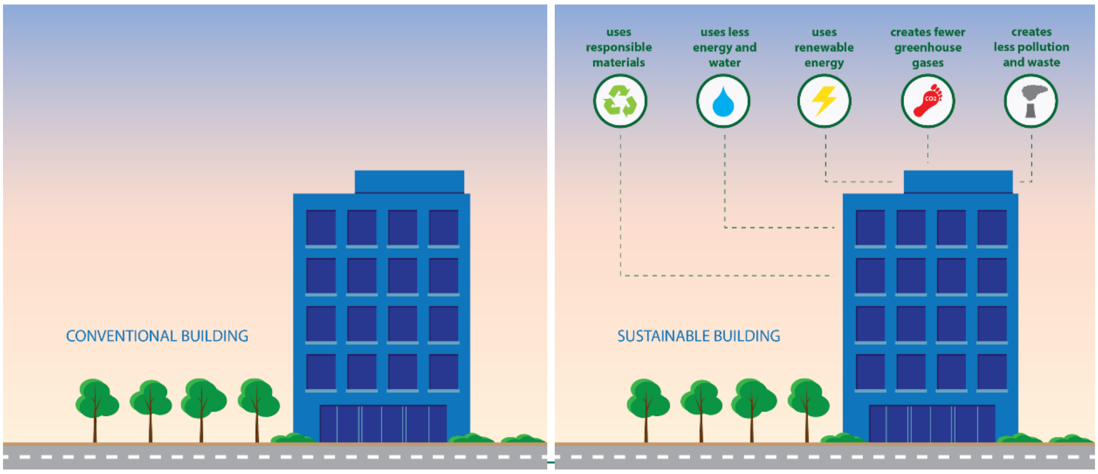
An online experiment was conducted using the Qualtrics platform and its panel participants during the period between April and May 2021.

Data for the study were collected in two phases. In phase 1 participants completed a pretest questionnaire that measured their individual characteristics (e.g., values, beliefs, demographics) (see 3.3., Table 2 for details). Two weeks after the pretest, participants completed the experimental phase of the study (phase 2), during which they were randomly assigned to one of two research conditions (asked to imagine working in a conventional building vs. in a sustainable building). The two groups were then asked to report their expectations of IEQ (thermal and air quality) in that building; the emotions they felt when imagining working in that building; and their perceived need to adjust the environment in order to stay comfortable. To rule out the potential influence of their current environmental conditions, participants were asked to report the type of building they were currently in (including home as a possible answer) as well as the indoor and outdoor temperature at the location where they completed the study. Additionally, because the study was conducted during the Covid-19 pandemic, participants were asked to report to the extent to which they would be concerned about exposure to Coronavirus in the building, how much they thought about that concern while answering the questions in the study, and how much they thought their concern about exposure to Coronavirus in the office building influenced their answers to the questions in this study. Answers to these questions were designed to be used as control variables if they differed by research condition. [Note: these data were collected in late April/early May 2021 in the United States, when vaccinations were available to most adults, and Covid-19 infection rates were temporarily declining.]

3.2. Stimuli/Independent Variable

This study included two research conditions in the experimental phase/phase 2. In the sustainable building condition, participants were instructed to "Imagine how you would feel about working in a sustainable office building now or in the near future. By sustainable building, we mean: a building that is designed to use less energy and resources than other similar buildings or that is designed to reduce or eliminate negative impacts on the climate and natural environment." Participants in this condition were concurrently shown a simple, illustrated graphic of the exterior of a building with common features of sustainable buildings listed in text bubbles around the outline of the building: uses less energy and water, uses renewable energy, generates less pollution and waste, uses responsible materials, and generates fewer greenhouse gasses (see Figure 1 for illustrations). These features were based on the World Green Building's definition of sustainable buildings (https://www.worldgbc.org/what-green-building). In the conventional building condition, participants were instructed to "Imagine how you would feel about working in a conventional office building now or in the near future." Participants in this condition were concurrently shown the same, simple illustrated graphic of the exterior of a building that was shown to participants in the sustainable building condition but this graphic was only a building with no features listed or described. After reading the building descriptions and viewing the building graphic, participants were asked an attention/manipulation check question that required them to correctly indicate what they had just read about. Data from participants who did not correctly answer this question were screened out by Qualtrics and not included in our final dataset. Participants were then asked about their feelings (especially the emotion of hope) and expectations about working in the building that was depicted and described to them.

Figure 1: Illustrations of buildings shown to research participants



Note. One of the above illustrations with related, accompanying text (see Method section) was randomly assigned to each participant.

The average duration for completing each phase of the study was 11 minutes. All participants were required to consent to completing the questionnaire at the beginning of each phase of the study, following university Institutional Review Board guidelines. Participants were recruited and compensated by Qualtrics.

3.3. Measures

Responses to questionnaire items were used to measure variables in the study hypotheses. Descriptions, along with descriptive and reliability statistics, for the following variables appear in Table 1: personal norms, hope, a priori expectations of IEQ, and anticipated need to make comfort-related adjustments.

Table 1: Key variables, items, scale reliability, and descriptive statistics

Measure	Description of items	Response categories	Scale reliability	Mean (M)	Standard Deviation (SD)
Personal norms*	I feel a personal responsibility to use less energy, I feel a moral obligation to use less energy, I feel a personal responsibility to help protect the environment I feel a personal moral obligation to help protect the environment	1 = *strongly disagree*, 7 = *strongly agree*	α = .92	5.52	1.10
Hope**	Feeling of *hope* (as a resultof working in this building) Feeling of *optimism* (as a result of working in the building).	0= *none at all*; 5 =*a great deal*	*r* = .71; *p*< .05;	3.54	1.25
Indoor environmental condition (IEQ) expectations**	What do you think the indoor temperature would bein this building?	Original responses codedas ranging from *much too cold* = -3; *neither toocold nor too warm* = 0; *much too warm* = 3, withscale folded/recoded as ranging from *neither too cold nor too warm* = 0 to either *much too cold* or *much too warm* = 3	α = .82	1.97	.87
	How comfortable do you expect to be with the indoor temperature?	*very uncomfortable* =1; *very comfortable* = 7			
	How would the air feel?	*very stuffy* = 1; *very fresh* = 7			
	How comfortable would yoube with the indoor air?	*very uncomfortable* =1; *very comfortable* = 7			
	How acceptable would theair quality be?	*very unacceptable* = 1; *very acceptable* = 5			
	How much would you want to change the temperature inyour workspace in the building?	original responses codedas ranging from *make it much colder* = -3; *no change* = 0; *make it much warmer* = 3, with the scale folded/recodedto range from no change = 0, to most desired amount of change, either*much colder* or *much*			

		warmer = 3			
Anticipated need to use personal appliances**	How likely do you think it is that you would need to: Use a personal fan; Use a personal heater… to stay comfortable in this building?	*Not at all likely* = 0; *Extremely likely* = 6	$r = .63$; $p < .001$	2.62	1.72
Anticipated need to make personal adjustments**	How likely do you think it is that you would need to: Adjust your clothing (for example, put on or take off a jacket or sweater; wear lighter or heavier clothing); Drink a warm or cool beverage… to stay comfortable in this building?	*Not at all likely* = 0; *Extremely likely* = 6	$r = .67$; $p < .001$	4.07	1.52
Anticipated need to interact with building systems**	How likely do you think it is that you would need to Adjust the thermostat if possible; adjust the blinds, if possible; open or close the windows, if possible… to stay comfortable in this building?	*Not at all likely* = 0; *Extremely likely* = 6	$\alpha = .84$	3.64	1.52

*Note. *Measured in pretest; ** measured after exposure to building information.*

In order to test for adequacy of random assignment to condition/equivalence of participant groups in the two research conditions, during the phase 1 pretest we also measured the following key variables that commonly predict pro-environmental behaviors or that could predict thermal or air quality perceptions (variable descriptions along with descriptive and reliability statistics shown in Table 2): biospheric values (the belief that protecting the environment is an important goal or guiding principle in one's life), environmental concern, climate change beliefs, political orientation, existing personal norms to protect the environment and use less energy, participants' concern about being exposed to Coronavirus while working in the building described, and the extent to which they thought that concern influenced the way they answered the questions in the study were also measured. We also confirmed that pretest levels of personal norms were positively correlated with these variables, as would be expected:

biospheric values, *r* = .69; *p* < .001; environmental concern, *r* = .35; *p* < .01; and climate change beliefs, *r* = .52; *p* < .001.

Table 2: Variables used as controls and to determine equivalence of research conditions

Measure	Description of items	Response categories	Scale reliability	Mean (M)	Standard Deviation (SD)
Biospheric values*	Respecting the earth, unity with nature; protecting the environment; and preventing pollution	*-1 = opposed to my values; 7 = of supreme importance*	α = .89	4.68	1.05
Environmental concern*	15-items, New Ecological Paradigm scale (Dunlap, VanLiere, Mertig, & Jones, 2000)	1 = *strongly disagree*, 7 = *strongly agree*	α = .67	4.66	.73
Climate change beliefs*	I believe that the climate is changing; I believe that the climate is changing, and that to a large extent the change is due to human action	1 = *strongly disagree*, 7 = *strongly agree*	*r* = .75; *p* < .05	5.66	1.43
Political orientation*	In terms of politics today, how would you classify yourself?	1 = *very conservative*; 7 = *very liberal*		3.94	1.67
Coronavirus exposure concern **	If you were to work in the building described at the beginning of this study, how concerned would you be about exposure to coronavirus?	1 = *not at all*; 4 = *a great deal*		Conventional building: 1.26 Sustainable building: 1.04	Conventional building: 1.09 Sustainable building: 1.04
Perceived influence of coronavirus concern**	How much do you think your concern about exposure to coronavirus in an office building influenced your answers to the questions in this study?	1 = *not at all*; 4 = *a great deal*		Conventional building: 0.91 Sustainable building: 0.67	Conventional building: 1.07 Sustainable building: 0.87

*Note. *Measured in pretest; ** measured after exposure to building information.*

The pretest questionnaire also collected the following data in order to determine equivalence of participant groups in each research condition: participants' prior experience working in office buildings (both conventional and sustainable), whether they were currently going to work in an office, and their general type of occupation.

Finally, study participants were asked to check and then (if possible) report both the indoor and outdoor temperatures for the location in which they completed the experimental phase of the study. They were provided a link to an online weather service to help them report outdoor temperature at their location.

3.4. Sample, Validation, and Checks on Random Assignment

The study was completed by 319 participants. Data from both questionnaires/waves of the study were examined for the amount of time it took participants to complete each phase, in order to screen out cases for which participants moved too quickly through either questionnaire (indicating an attention problem) or who spent too much time on the questionnaire for the experimental phase of the study (indicating a possibility of having forgotten the stimulus information to which they were exposed at the beginning of the questionnaire). Based on data gathered during initial piloting of the study (n = 53) that indicated reasonable amounts of time required to complete each questionnaire, data from participants who spent too much (> 30 minutes) or too little (< 3 minutes) time (n =24) were not analyzed, leaving a sample of 295 participants. The remaining participants were between 18 and 41+ years old (M = 36.79, SD = 6.77) with 48% identifying as female, 52% as male, and 0% as other. The majority of participants, 72.2%, self-reported their race or ethnicity as White, 10.1% reported Hispanic or Latinx, 8.1% reported Black/African American, 6.4% reported Asian/Pacific Islander, and the remaining participants reported other races or ethnicities.

Before testing the hypotheses we verified equivalence of participant groups in the two research conditions using *t*-tests and Chi-square analyses (see Appendix for results of equivalence tests). Participants in the two research conditions did not differ in terms of: environmental concern, biospheric values, political orientation, personal norms, climate change beliefs, prior or current experience working in an office building (including prior or current experience working in a sustainable building), age, education level, or type of occupation. Participants in both conditions also reported equivalent indoor and outdoor temperatures in the place in which they completed the experimental phase of the study. Participants in the two conditions did vary significantly in terms of concern about being exposed to Coronavirus while working in the building described as well as the extent to which they thought that concern influenced the way they answered the questions in the study. In particular, participants in the conventional building condition reported greater concern, $M = 1.26$; $SD = 1.09$; $t = -1.52$; $p < .05$, and greater perceived influence of that concern, $M = 0.91$; $SD = 1.07$; $t = -2.13$; $p < .05$, than did participants in the sustainable building condition, $M = 1.04$; $SD = 1.04$; and $M = 0.67$; $SD = 0.87$, respectively. There was also a significant difference in gender identity between the two conditions, with more participants who identified as female in the sustainable building condition than in the conventional building condition, χ^2 (1, $N = 295$) = 4.85, $p = .03$. Accordingly, we controlled for Coronavirus concern, perceived influence of Coronavirus concern on question answering, and gender identification by entering them as covariates in the tests of H1-H3.

Hypothesis H1a was tested via linear regression in order to identify a possible significant total effect of research condition on the outcome variable. The moderation and mediation hypotheses (H1b-H3) were tested with conditional process analysis [62] using Hayes' PROCESS model 8 of moderation and mediation for SPSS with 20,000 bootstrap samples and with the personal norms variable mean-centered. Because a priori expectations, rather than perceived need to make adjustments, was the main outcome variable for which we intended to provide theory-based predictions and estimates of effects size/variance explained, we did not include perceived need to make adjustments in the moderation/mediation model. Rather, the relationships among those perceived needs and a priori expectations (H4) were tested with separate correlation analyses.

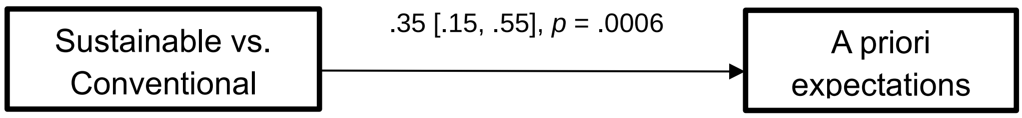
3.5. Data availability statement

The data for this study are available in the project's OSF repository [https://osf.io/3s8jk/?view_only=cf42e725b02c4c1589d8872c43c4aef1].

4. Results

H1*a* predicted more positive a priori expectations of indoor environmental quality (IEQ) would be reported by participants asked to envision working in a sustainable building than by participants asked to envision working in a conventional building. In order to test this hypothesis, we examined data from the total effect model (which tests the simple effect of the independent variable/research condition along with any control variables on the outcome variable). H1*a* was supported, with the sustainable building condition being associated with significantly more positive a priori IEQ expectations, F (4, 294) = 5.72, p < .001, R^2 = .07 (see Figure 2 for coefficients and confidence intervals). The control variable of concern about Coronavirus exposure was also a significant predictor of expectations, with greater concern being associated with less positive expectations.

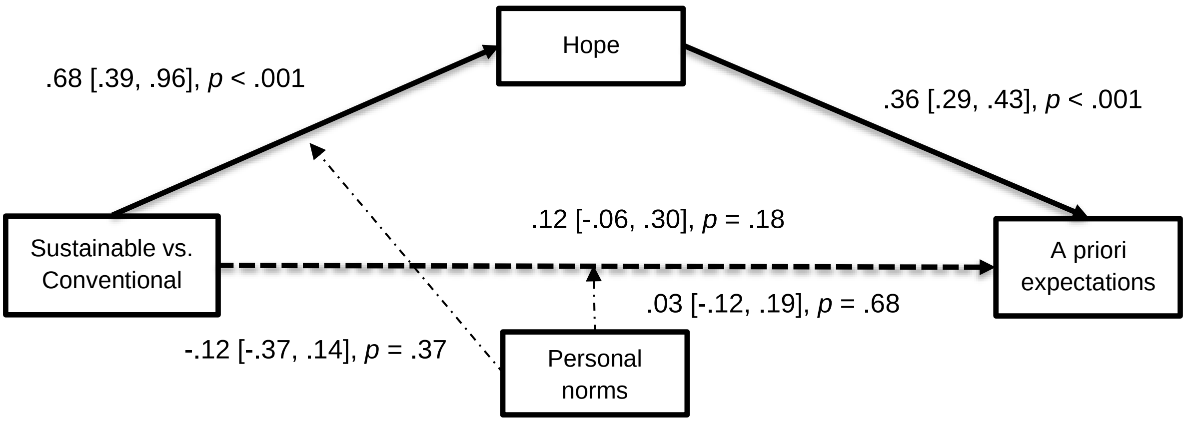
Figure 2: Total effect model of influence of research condition on expectations



Note. *n* = 295. Unstandardized coefficients shown. Conventional building condition coded as 0; sustainable building condition coded as 1. Control variable concern about exposure to Covid-19 in the building influenced expectations, -.14* [-.24, -.02]. Control variables of gender and perceived influence of Covid-19 concern on answers to questions did not significantly influence expectations.

H1*b* predicted that the effect of building type on a priori expectations of IEQ would be especially strong among participants with greater existing personal norms to protect the environment and save energy. This hypothesis was not supported (see Figure 3 for coefficients and confidence intervals for tests of H1*b*-H3 and Table 3 for bivariate correlations among continuous and control variables in the model). The effect of building type on expectations did not vary depending on existing personal norms of the participants.

Figure 3: Model of mediating effects of hope and moderating effects of personal norms on expectations



Note. n = 295. Unstandardized coefficients shown. Dotted lines indicate nonsignificant relationships. Conventional building condition coded as 0; sustainable building condition coded as 1. Personal norms did not significantly moderate the effect of building condition on hope or a priori expectations. Control variable of perceived influence of Coronavirus concern on answers to questions influenced hope, .23* [.07, .39]. Control variable concern about exposure to Coronavirus in the building influenced expectations, -.11* [-.21, -.02]. Control variable of gender did not significantly influence any variables in the model.

Table 3: Bivariate correlations among modeled variables shown in Figure 3

	Hope	Personal Norms	IEQ Expectations	Exposure Concern	Concern Influence
Personal Norms	-.02				

IEQ Expectations	.52**	.06			
Exposure Concern	-.01	-.04	-.19**		
Concern Influence	.14	.06	-.06	.43**	
Gender Identity	.03	.12*	.01	.03	-.001

Note. *p < .05, **p < .01. Gender identity coded as 0=male; 1=female; no other identities indicated by participants.

H2 predicted that participants in the sustainable building condition who had greater existing personal norms to protect the environment and save energy would report greater hope than participants with lower levels of personal norms than participants in the conventional building condition. This hypothesis was not supported. However, building type had a significant, positive effect on hope, such that those in the sustainable building condition reported greater hope than those in the conventional building condition. The control variable of perceived influence of Coronavirus concern on question answering was positively associated with hope, but the other two control variables of concern about Coronavirus exposure and gender identification were not significantly associated with hope.

In support of H3, greater reported hope was positively associated with a priori expectations of IEQ. The indirect effect of research condition (building type) on a priori IEQ expectations via hope was significant, B = .24, SE = .06, CI [.14, .36], indicating that hope mediated the effect of building type on expectations of IEQ. The control variable of concern about Coronavirus exposure was also a significant predictor of expectations, with greater concern being associated with less positive expectations. Neither of the other two control variables was significantly associated with a priori expectations of IEQ. The full moderation/mediation model shown in Figure 3 was significant, $F\ (7, 287) = 18.96$, $p < .001$, $R^2 = .32$.

Although data from the test of the total effect model for H1a (Figure 2) identified a significant effect of building type on expectations, this effect was non-significant in the moderation/mediation model that included hope[2] (Figure 3). Such findings indicate that the mediating variable of hope was necessary to explain any effects of building type on IEQ expectations. Additionally, the variance explained in the total effect model (which estimates only the effect of building type and the control variables on expectations) was much less ($R^2 = .07$) than that explained by the full model that included the variable of hope ($R^2 = .32$).

With respect to H4, more positive IEQ expectations were associated with less anticipated need to use personal appliances (personal fan or heater), $r = -.29$, $p < .001$, and to make personal adjustments (e.g., wear warmer or lighter clothes), $r = -.11$, $p = .03$, in order to be comfortable in the building. Expectations were not associated with perceived need to interact with building systems (e.g., adjust the thermostat or open a window), $r = -.02$, $p = .73$. Accordingly, H4 received substantial, but not complete, support.

5. Discussion, Limitations, and Conclusion

This study examined the extent to which expectations of indoor environmental quality (IEQ) were influenced by information about and being asked to envision working in a sustainable building (as compared to in a conventional building) and how existing motivations – personal norms to save energy and protect the environment – might moderate the effects of

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[2] In contrast to tests of the total effect of a predictor variable on an outcome variable, which do not consider/account for effects of any mediating variables (Figure 2), tests of direct effects (the bottom path from building type to expectations shown in Figure 3) reflect the influence of a predictor variable on an outcome variable while holding any mediating variables constant.

building type on those expectations. The study also examined the extent to which the emotion of hope might mediate the influence of building type and individuals' motivations on those expectations. A priori expectations were considered an important phenomenon to understand, as they can influence building occupants' perceptions of indoor climate conditions once inside a building, which can, in turn, influence perceptions of comfort, satisfaction with the building environment, and even workplace productivity and well being.

The current study found that a priori expectations of IEQ were more positive among those who received information about and were asked to envision working in a sustainable building than among those asked to envision working in a conventional building. However, this total/main effect seems best explained by the mediating role of hope.

Feelings of hope were found to significantly mediate the influence of building type on expectations of IEQ. Those who were provided information about and asked to envision in a sustainable building reported more hope than those asked to envision working in a conventional building. Those feelings of hope were, in turn, associated with more positive IEQ expectations. Although the test of H1*a* identified a significant influence of building type on expectations, when feelings of hope were added to the model, that influence became non-significant. This finding suggests that the positive association between the sustainable building condition and expectations identified in the test of H1*a* was largely explained by the feeling of hope elicited among participants asked to envision working in that building. Additionally, greater variance in IEQ expectations was explained by the mediation model that included hope as compared to that explained by the total effect model, which isolated the effect of building type (and the control variables). Accordingly, we suggest future studies examine the potential influence of positive emotions such as hope on expectations and perceptions of IEQ along with additional attempts to identify which types of occupants are likely to feel more hopeful.

We anticipated, but did not find, a moderating effect of personal norms on the influence of building type on hope and on IEQ expectations. One explanation for this lack of influence is that personal norms among this sample were rather high, significantly above the midpoint (4) of the scale, $M = 5.52$; $SD = 1.10$; $t = 23.66$; $p < .001$. Sample means for biospheric values and climate change beliefs were also above the midpoint of those scales (see Table 2). Accordingly, study participants might have been generally predisposed to being supportive of sustainable buildings (and to feeling hopeful about working in them) because they likely recognize the threat (e.g., have high levels of climate change beliefs) and hold beliefs, values, and related moral motivations that lead them to seek or appreciate potential solutions to mitigate the threat. Additionally, responses from participants in this study could reflect a recent trend in the U.S. toward majority support for efforts related to renewable energy and tax incentives for energy-efficient buildings [63] as well as more global public support for reducing energy use in buildings [31]. If a majority of a population supports such efforts, individual differences among members/research participants from that population might be less important than the main effect of an opportunity to achieve a widely valued goal (e.g., reduced energy use). As noted above, a general preference bias for green buildings has been identified. The findings reported herein could reflect such a general, positive bias that led to participants feeling more hopeful when envisioning working in such a building.

Given that insufficient comfort in buildings should be associated with occupants' desire to take action to achieve personal comfort, we predicted that greater expectations of comfort (reflected by more positive IEQ expectations) would be associated with less perceived need to make adjustments in order to stay comfortable (H4). In support of this proposition, significant negative correlations were identified between IEQ expectations and anticipated need to use a personal fan or portable heater as well as anticipated need to make personal adjustments. However, there was no significant correlation between a priori expectations and perceived need to interact with building systems (windows, blinds, or thermostat). The lack of such a correlation could be due to the fact that adjusting a thermostat, windows, or blinds can impact other occupants in an office setting and so might not be a preferred option for adjusting the environment when feeling uncomfortable. For instance, Schweiker and Wagner [44] observed that the adaptive behaviors of participants (e.g. adjusting blinds or fans) were negatively impacted by the number of people in the space. Another potential explanation for the lack of correlation is building automation systems being perceived as complicated to operate [64] or generally not accessible to occupants of office buildings with fixed windows and inaccessible thermostats [65]. Future studies could include measures of such occupant perceptions (perceived preferences of co-workers and perceived ease of operation and accessibility of systems) in order to test these explanations. Additionally, future studies could investigate whether the association of more positive IEQ expectations with less anticipated need to use personal appliances could be due to an expectation of better performance of central systems in sustainable buildings, greater perceived resilience of the building design (thus less need for personal means of heating or cooling), and/or greater perceived complexity of building systems that rely on automatic rather than occupant control.

5.1. Practical implications

The findings of this study suggest it might be useful to address and attempt to influence occupants' expectations of building environmental conditions and operations. Participants in this study were provided information about common features of sustainable buildings. Prior research indicates that provision of more information about how sustainable buildings function can increase occupant satisfaction with those buildings [34]. In this respect, these findings indicate IEQ expectations driven by information given to potential sustainable building occupants could inform building design, energy-use simulations, and potential building control and operational strategies. In the design and simulation of building system operations, recommended ranges of expected indoor conditions are typically employed based on research-driven predictions of hypothetical future occupants' perceptions (i.e., prior to occupancy). If sustainable building occupants' IEQ expectations can be influenced by the provision of relevant information as they were in this study, simulations and designs could account for potential tolerance of a wider range of indoor conditions (with the exception of conditions that are driven by radiant temperatures) among occupants, which could, in turn, inform the design of building mechanical systems for human-centered adaptation. Human behavior factors such as those examined here have not been commonly taken into account during the design of building systems [66]. Furthermore, the same potential applies to the building operation phase, which has a more significant impact on the long-term sustainability indicators of the building: if the potential for occupant adaptation based on information provision can be quantified, more adaptive strategies for energy-efficient control via the building systems can be adopted.

Based on study findings and the potential implications for building and system design and operations, we recommend that occupants of sustainable buildings be initially informed and then regularly reminded of features of sustainable buildings and the reduced environmental impacts associated with those buildings. Such reminders could include signage in entry and common areas as well as labels on relevant systems (such as light switches, thermostats, controls for blinds). It might be also useful for building operators or communication specialists to attempt to elicit hope when communicating with occupants about sustainable building features. Message features that are proposed to elicit hope include (1) the description of an opportunity for a bad situation to improve (e.g., mitigation of negative effects of climate change) and (2) instructions regarding what actions message recipients should take in order to take advantage of the opportunity (e.g., refrain from using more energy in a building that is designed to use less energy) [50].

5.2. Limitations

This study was conducted during the Covid-19 pandemic, but data were collected during a temporary decline in infections in the United States and the beginning of vaccine availability in the spring of 2021. Participants' concerns about potential exposure to Coronavirus in a building such as the one participants read about were measured controlled for and were not found to influence the outcome variable of expected IEQ. The limited variance on personal norms in this study might have also limited the ability to identify moderating influences of that variable on study outcomes. We suggest additional studies be conducted with a variety of samples to examine whether the apparent preference for sustainable buildings identified here is somewhat consistent or is moderated by relevant individual differences. Most importantly, because of the pandemic and the closure of research labs globally, we were not able to measure the extent to which a priori expectations influenced on-site perceptions of IEQ, i.e, real-time perceptions of IEQ among occupants currently working in a sustainable vs. a conventional building. We suggest future studies that examine such a relationship. Finally, we suggest future studies examine the extent to which more information about the features of sustainable buildings influence real-time, on-site perceptions of IEQ.

5.3. Conclusion

Findings from this study indicate that potential building occupants who are informed about sustainable building features and are asked to envision working in a sustainable building can have more positive a priori expectations of IEQ than those who envision working in a conventional building. Those expectations should be associated with anticipated, and, possibly, actual need to take adaptive actions in order to stay comfortable in a building – such perceived needs and subsequent actions have implications for energy use in buildings. To the extent that IEQ expectations and subsequent perceptions are positive, occupants might perceive less need to use personal appliances or make personal adjustments in order to stay comfortable. Findings also indicate that a priori IEQ expectations can be influenced by the emotion of hope. More research is recommended to more fully examine how individual factors, such as occupants' values or personal norms, as well as emotions (such as hope or anxiety) might influence expected comfort before occupancy and actual comfort post-occupancy (in both the short and long-term) in sustainable buildings. Findings also suggest that building designers, owners, and/or operators communicate to occupants the features of sustainable buildings regularly and attempt to elicit feelings of hope in at least some of those messages.

Appendix

Table 4: Participant Demographics in Sustainable vs. Conventional building Conditions and Results of Tests of Equivalence of Research Conditions.

	Sustainable building	Conventional building	Full sample	Tests of Independence		
	n	n	n	X^2	df	*p*
Gender Identity				4.85^{*}	1	.028
Female	85	57	142			
Male	72	81	153			
Highest degree				.26	2	.88
No high school up to high school degree	42	38	80			
Some college up to college degree	95	80	175			
Graduate (master's, doctorate, and professional)	20	20	40			
Prior work in sustainable buildings				1.31	3	.728
Never	100	86	186			
Previously	12	12	24			
Currently	7	10	17			
Don't know	38	30	68			
Currently minimum 1 day/ week in office				1.26	1	.533
Yes	38	34	72			
No	27	23	50			
Current employment status				11.53[a]		.11
Management & related	12	12	24			
Other	15	12	27			
Services	12	12	24			
Sales & office	8	7	15			
Farming, fishing, forestry	2	1	3			
Construction & related	5	11	16			
Production & related	4	5	9			
Government	8	0	8			
Ever worked in office				0.40	2	.819
Yes	104	96	200			
No	52	41	93			

Note: * $p < .05$. [a]*Fisher's exact test used to examine potential differences in current employment status between research conditions.*

Table 5: Other Participant Characteristics in Sustainable vs. Conventional Building Conditions and Results of Tests of Equivalence of Research Conditions.

	Sustainable building		Conventional building		
	M	*SD*	*M*	*SD*	*t*
Political Orientation	3.92	1.68	3.96	1.67	-.24
Biospheric values	4.60	1.13	4.77	.94	-1.33
Environmental concern	4.61	.57	4.66	.64	-.80
Climate change beliefs	5.63	1.42	5.70	1.45	-.41
Personal norms[a]	5.45	1.12	5.59	1.07	-1.09
Coronavirus concern[b]	1.04	1.04	1.26	1.09	-3.75***
Coronavirus Concern influence[c]	.67	.87	.91	1.07	-2.13*

Note: * $p < .05$, *** $p < .001$

[a]*Existing personal norms to protect the environment and use less energy.*
[b]*Participants' concern about being exposed to Coronavirus while working in the building described*
[c]*Extent to which participants thought that Coronavirus exposure concern influenced the way they answered the questions in the study.*

Table 6: Explanation of Statistical Symbols Used in This Manuscript.

r	Correlation coefficient indicating extent and direction of relationships among variables
M	Mean: average score
SD	Standard deviation: amount of dispersion of a set of scores relative to the mean
χ^2	Chi-square statistic resulting from analysis of expected vs. observed scores
t	Statistical test of group mean differences, based on the Student *t* distribution
F	F-test of equality of variance among two or more groups or populations
R^2	Coefficient of determination: amount of variance explained in a dependent variable by one or more independent variables in a model
B	Beta/regression coefficient: estimated increase in an outcome variable for every 1-unit change in a predictor variable
SE	Standard error: estimate of the standard deviation of a sampling distribution
p	Statistical probability of a given outcome or the magnitude of a given test statistic

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