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# Nature and patient waiting: Mediating effects of anxiety and perceived wait time on the association between nature and service perception

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ABSTRACT

Visitors to emergency department waiting areas often experience high anxiety, which results in discomfort during their waits. Our findings offer empirical evidence for the positive impact of including natural elements in these waiting areas. We created four high-fidelity virtual environments that incorporated natural elements in three ways, i.e., the presence of plants, the use of nature images and natural materials, and a combination of those two, in addition to a controlled environment without natural elements. We tested how subjects responded to each environmental setting. Our findings demonstrated that the inclusion of natural elements significantly lowered patients' anxiety in hospital environments, confirming previous research, and the presence of natural elements improved perceived wait time, as well as service quality through anxiety and perceived wait time. The combination yielded higher scores in anxiety, perceived wait time, and service quality than the other conditions. Serial mediation analysis results revealed that underlying anxiety and patients' perceived wait time mediated the effect of natural elements on perceived service quality. Among the five dimensions of service quality, the mediating effects of anxiety and perceived wait time appeared stronger in reliability and responsiveness.

## 1. Introduction

Natural elements in the built environment, including potted indoor plants or simulated nature images, are positively associated with physical, psychological, and emotional benefits. In healthcare environments, the presence of plants in hospital rooms has shown stress-reducing effects (Andrade & Devlin, 2015; Dijkstra et al., 2008) and influences positive physiological responses such as blood pressure, heart rate, and emotions (Park & Mattson, 2008). Literature suggests that nature images induce similar effects; viewing simulated nature images in a hospital room affects pain reduction (Vincent et al., 2010), influences stress and anxiety, and contributes to environmental satisfaction (Pati et al., 2016). Anxiety reduction is one of the most potent effects of contact with nature (Beyer et al., 2014; Bratman et al., 2015; Frumkin et al., 2017; Song et al., 2015).

Emergency department (ED) waiting areas have been criticized for being uncomfortable, frightening, oppressive, and overcrowded (Derlet & Richards, 2000; Stuart et al., 2003). In ED waiting areas, patients experience anxiety, distress, fear, and pain, and these emotions are often accompanied by an increased degree of pain as well as a loss of autonomy, independence, and the feeling of being cared for (Gordon et al., 2010; Olsson & Hansagi, 2001). Anxiety is particularly prominent in patients entering a hospital (Caumo et al., 2001; Pritchard, 2009); therefore, reducing anxiety in a patient experience is an important consideration in healthcare design.

In addition to anxiety, wait time has also been identified as one of the most significant patient concerns during ED visits (Holden & Smart, 1999). Researchers have found a negative association between increased wait times and patient satisfaction (Anderson et al., 2007; Dansky & Miles, 1997; Derlet & Richards, 2000; Huang, 1994). Derived abundant evidence indicating the restorative effect of nature and its apparent potential for anxiety management (Bratman et al., 2015; Lawton et al., 2017), nature could positively affect patient wait experiences. However, studies on the impact of nature on wait time perceptions or wait experiences are scarce.

In hospitals, service quality influences patient satisfaction outcomes and financial performance (Raju & Lonial, 2002). Improved service quality likely leads to higher customer satisfaction (Sureshchandar et al., 2002); patient satisfaction is directly related to the patients' loyalty to the hospital (Meesala & Paul, 2018). Thus, service quality is a sound measure of patient satisfaction and healthcare facilities management.

The goal of this study is twofold; to examine the effects of different

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types of natural elements in the ED waiting areas on reducing anxiety levels to strengthen empirical evidence and derive practical implications, and more importantly, to explore the potential impact of natural elements on the perception of wait times and service quality focusing on how these responses relate to each other. To investigate the impact levels of different natural elements, we created four high-fidelity virtual ED waiting areas and tested how subjects responded to different approaches to incorporating natural elements into the waiting environments.

## 2. Literature review and hypothesis development

### 2.1. Benefits of nature in healthcare environments

Empirical studies have demonstrated various benefits of exposure to nature. Nature exposure promotes mental and general physical health (Triguero-Mas et al., 2015), helps autonomic function recovery (Brown et al., 2013), advances physical activity (Hartig et al., 2014), and reduces stress by lowering blood pressure and heart rate (Ulrich et al., 1991; Yin et al., 2020). Exposure to nature enhances cognitive performance (Berman et al., 2008; Bratman et al., 2019; Crossan & Salmoni, 2021) with a well-known restorative effect (Kaplan, 1995).

The stimulation of positive emotions is one of the most potent effects of nature contact (Barton & Pretty, 2010; Berman et al., 2012; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009; Ulrich, 1979). Yin et al. (2018) confirmed that natural elements in both real and virtual indoor environments decreased negative emotions and increased positive emotions with improvement in short-term memory. In healthcare environments, natural elements can help relieve stress (Beukeboom et al., 2012; Dijkstra et al., 2008), stimulate positive moods (Berman et al., 2012; Park & Mattson, 2008), and offer positive distractions and social support (Andrade & Devlin, 2015). Berman et al. (2012) compared changes in positive moods in individuals diagnosed with major depressive disorders. They found that participants who walked in a natural setting experienced significantly more positive moods than those who walked in an urban setting. Park and Mattson (2008) confirmed that patients with plants and flowers in their hospital rooms showed more positive physiological responses, evidenced by lower anxiety, pain, fatigue, and more positive feelings. They had higher satisfaction with their rooms compared to those without plants and flowers.

Several recent studies presented the positive effects of nature contact in hospital waiting areas. Beukeboom et al. (2012) found that patients exposed to real plants or posters of plants in hospital waiting rooms showed lower stress levels than those without any natural element exposure. Bai (2015) demonstrated that access to daylight and nature views from windows was associated with less negative and more positive behaviors. Watts et al. (2016) introduced large natural landscape images and nature sounds into a waiting room in a health center, confirming their impact on reducing patients' anxiety and improving levels of tranquility.

### 2.2. Anxiety and wait time perception in ED waiting

Most ED patients perceive their pain or conditions as threatening and often experience overwhelming anxiety (Olsson & Hansagi, 2001). The literature emphasizes anxiety as one of the patients' major feelings when arriving at a hospital (Caumo et al., 2001; Pritchard, 2009). Anxiety has been identified as a critical determining factor in healing rates (Cole-King & Harding, 2001) and influencing patient satisfaction in the ED experience (Ekwall et al., 2009). In medical experiences, preoperative anxiety has been associated with postoperative mood and pain (Munafò & Stevenson, 2001). Anxiety is also significantly related to low positive and high negative emotions (Watson et al., 1988).

Patients' uncertainty and confusion about the treatment process and wait times in the ED waiting area have been identified to be related to patient anxiety (Yoon & Sonneveld, 2010). Wait times have been the most significant patient concern in ED visits (Dansky & Miles, 1997; Gordon et al., 2010; Holden & Smart, 1999; Nairn et al., 2004), with substantial studies addressing a negative association between increased wait times and patient satisfaction in their hospital visits (Anderson et al., 2007; Derlet & Richards, 2000; Huang, 1994). Moreover, perceived wait times are more closely associated with patient satisfaction than actual wait times (Becker & Douglass, 2008; Boudreaux & O'Hea, 2004; Pruyn & Smidts, 1998). Pruyn and Smidts (1998) suggested that actual wait times influence satisfaction cognitively through perceived wait times. Becker and Douglass (2008) found that perceived wait times have a stronger impact on overall quality and satisfaction than actual wait times. Boudreaux and O'Hea (2004) emphasized that targeting perceived wait times is a more effective strategy than solely focusing on reducing actual wait times.

### 2.3. Nature and anxiety

Substantial studies confirmed the anxiety-reducing effects of contact with nature (Bratman et al., 2019; Hartig et al., 1991; Hartig et al., 2014; Van den Berg et al., 2007). Findings from previous literature show that nature contact improves patients' anxiety and propose that nature contact is an effective intervention for anxiety management (Bratman et al., 2015; Lawton et al., 2017). We expected natural elements would positively influence anxiety levels in the context of ED waiting areas. We formulated the following hypothesis:

**H1**. Natural elements will reduce anxiety.

### 2.4. Nature and wait time perception

While the association of natural elements with patients' wait time perception in the waiting area has been rarely explored, researchers have argued for a relationship between natural elements and waiting experiences, as well as between the attractiveness of the waiting environment and wait time perception. Nanda et al. (2012) focused on behavioral responses to nature images in ED waiting areas and found that nature images positively influence waiting experiences by reducing people-watching behavior, increasing socializing, and reducing desk queries and out-of-seat behaviors. Beukeboom et al. (2012) found a significant mediating role of the perceived attractiveness of the waiting environment in the effect of natural elements of the waiting area on stress levels. Pruyn and Smidts (1998) studied the effects of wait time and waiting environment on satisfaction and found that the attractiveness of the environment influences satisfaction, with positive affective responses mediating this effect. A recent study supported this suggestion, concluding that an emotionally affective waiting room design is one of the most influential factors impacting hospital visit experiences (Juliá Nehme et al., 2021). Building on the findings of previous studies, we could elaborate on the physical environment of the waiting areas by introducing natural elements. Through this approach, we anticipated the potential of improved patients' perception of wait time. We predicted the following hypothesis:

**H2**. Natural elements will improve the perception of wait time.

### 2.5. Nature and perceived service quality

A physical environment strongly influences consumers' perceptions of service quality. Bitner's (1992) 'servicescape' framework presented the significant importance of physical settings in service businesses, such as hotels, retail stores, and hospitals, identifying the physical environment as directly influencing consumers' perceptions of service quality, satisfaction, and approach/avoidance behavior. Service quality dimensions have been addressed as significant predictors of patient satisfaction in an ED wait experience (Mowen et al., 1993).

The SERVQUAL model (Parasuraman et al., 1988) has been widely used to measure consumers' perceptions of service quality by using five dimensions: (1) tangibles (physical facilities, equipment, and appearance of personnel); (2) reliability (ability to perform the promised service dependably and accurately); (3) responsiveness (willingness to help customers and provide prompt service); (4) assurance (knowledge and courtesy of employees and their ability to inspire trust and confidence); and (5) empathy (caring and individualized attention the firm provides to its customers). Babakus and Mangold (1992) tested the SERVQUAL scale in a healthcare setting and presented an adapted version, demonstrating the reliability and validity of SERVQUAL in measuring patients' perceptions of service quality. Lam (1997) also confirmed the reliability and validity of SEVQUAL in a healthcare context and indicated satisfactory expectations of the model, especially in measuring the physical elements of service quality.

Studies on the impact of natural elements on perceived service quality have appeared only recently, and more empirical evidence is still needed. Tifferet and Vilnai-Yavetz (2017) found plants' positive impact on pleasure, perceived service quality, and service satisfaction in three service environments, i.e., library, hair salon, and dental clinic. Apaolaza et al. (2020) investigated the significant effects of indoor plants on consumer satisfaction in restaurants; the results showed that service quality mediated the relationship between indoor plants and consumer satisfaction. Based on previous findings, we explored the relationship between natural elements and the perceptions of service quality in hospital environments, hypothesizing the following effect:

**H3**. Natural elements will improve perceived service quality.

### 2.6. Impacts of different natural elements

In the environmental psychology literature, the most researched natural elements have been plants, followed by nature images (Gillis & Gatersleben, 2015). The findings on the effects of nature images on health and well-being benefit present associations with increased positive mood (Brooks et al., 2017), psychological relaxation (Song et al., 2019), and positive influence on creative performance (Lichtenfeld et al., 2012), and lowered blood pressure (Vincent et al., 2010). Design practitioners frequently have used natural materials to bring nature into a built environment, but empirical evidence for using natural materials is still lacking (Gillis & Gatersleben, 2015). McCoy and Evans's study (2002) is one of the rare findings that investigated the impact of natural materials and suggested the potential for enhancing perceived creativity.

Brooks et al. (2017) found that actual contact with nature is more effective in improving psychological and emotional states, e.g., positive and negative affect, anxiety, and depression, while both real nature and images have affective benefits. In studies comparing the impacts of simulated and actual nature on moods, actual contact with nature has been found to improve moods more effectively than simulated natural settings, such as a photograph, slideshow, or video (Browning et al., 2020). However, the comparison with natural materials, as well as the different impacts between nature, nature images, and natural materials on perceived wait time or service quality, have rarely been discussed.

Therefore, this study explored the different effects of the most frequently discussed natural elements, i.e., plants, images of nature, and natural materials), by setting four different stimuli: 1) indoor and outdoor plants, 2) images of nature and natural materials, 3) a combination of 1) and 2), and 4) no natural elements. We hypothesized the following:

**H4a**. Indoor and outdoor plants will have a stronger impact on anxiety, perceived wait time, and perceived service quality than images of nature and natural materials.

**H4b**. The combination of indoor and outdoor plants, images of nature, and natural materials will have the strongest impact on anxiety, perceived wait time, and perceived service quality.

### 2.7. Mediating role of anxiety and perceived wait time on perceived service quality

We anticipated the presence of natural elements to improve patients' anxiety (H1) and perceived wait time (H2). We also predicted that these effects would mediate the relationship between natural elements and patients' perception of service quality. Vinagre and Neves (2008) suggested that emotional reactions can direct patient service quality perception, which is a cognitive reaction. They evaluated the significant factors affecting patient satisfaction and found the respondents to be more responsive to service dimensions that referred to emotional reactions in reporting overall service quality. Tifferet and Vilnai-Yavetz (2017) found that emotions such as reduced arousal and increased pleasure, elicited by plants, have a mediating role in the effects on consumers' perception of service quality in a dental clinic. Also, waiting times have been found to affect service quality with a higher impact on the reliability dimension than other SERVQUAL dimensions in medical service delivery (De Man et al., 2005).

However, few studies have examined the link between anxiety, perceived wait time, and perceived service quality in a healthcare environment with natural elements. Therefore, this study aimed to examine whether the patient experience variables would relate to each other, such that environmental intervention affected emotional reaction (i.e., anxiety), and emotional reaction affected cognitive reaction (i.e., perceived service quality). We conceptualized a serial multiple-mediator model presented in Fig. 1. We expected a positive effect of natural elements on lower anxiety would causally influence the improved perceived wait time, which would translate into higher perceived service quality, based on the assumption that mediators causally influence one another. We proposed the following hypothesis:

**H5**. Natural elements will affect anxiety levels, which will influence the perceived wait time. Anxiety and the perceived wait time will mediate the relationship between natural elements and perceived service quality.

## 3. Materials and measures

### 3.1. Stimuli development

This study employed computer-generated 3D virtual space models referred to as virtual environments (VEs). Today's Virtual Reality (VR) technology, empowered by the advancement of 3D modeling and visualization tools, offers high-fidelity environmental simulations that allow the viewers to feel more immersed in the simulated environment and to naturalistically respond to the presented scenario. As a result, the spectrum of environmental behavior research has broadened (Heydarian et al., 2015; Kalantari & Neo, 2020; Kuliga et al., 2015). With the ability to simulate any hypothetical scenarios, VEs have been widely applied to observe the relationship between the designed environment and human behavior in various settings, such as healthcare (Dunston et al., 2011), workplace (Heydarian et al., 2015; Yin et al., 2020), and retail environments (Siegrist et al., 2019).

For this study, we created four high-fidelity virtual ED waiting areas using the architectural modeling software Revit with the real-time rendering program Enscape (Fig. 2). The VEs were designed and developed by three professional interior designers, two with more than 15 years of experience and one with five years of related industry experience. We tested how subjects responded to two environmental conditions: with vs. without natural elements. First, we designed a controlled environmental stimulus with no natural elements and named it Env-N. The controlled setting consisted of typical spatial features of a waiting area such as a reception counter, seating areas, media walls, and a corridor connecting the entrance, exits, and consulting rooms. For the stimulus with natural element conditions, we created three sets of environmental settings with natural elements: 1) indoor and outdoor

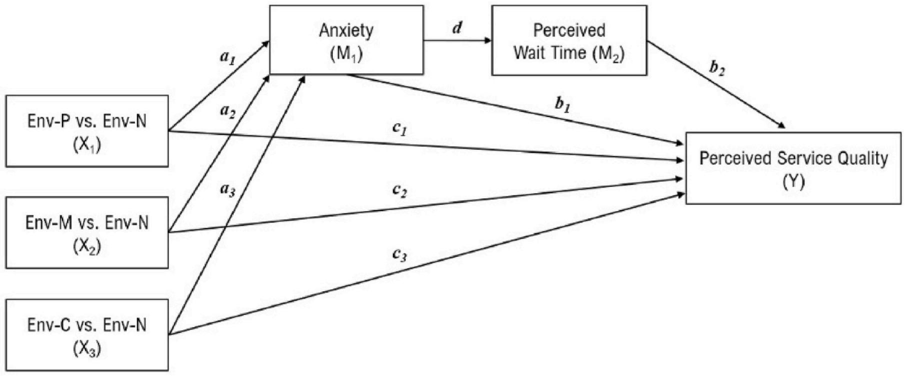


**Fig. 1.** Hypothesis 5 – Mediation model for the effect of environmental conditions, set as a multicategorical variable, on perceived service quality through anxiety and perceived wait time (indoor and outdoor plants (Env-P), use of abstracted images of nature and natural materials (Env-M), a combination of natural elements applied in Env-P and Env-M (Env-C), and no natural elements (Env-N, control).

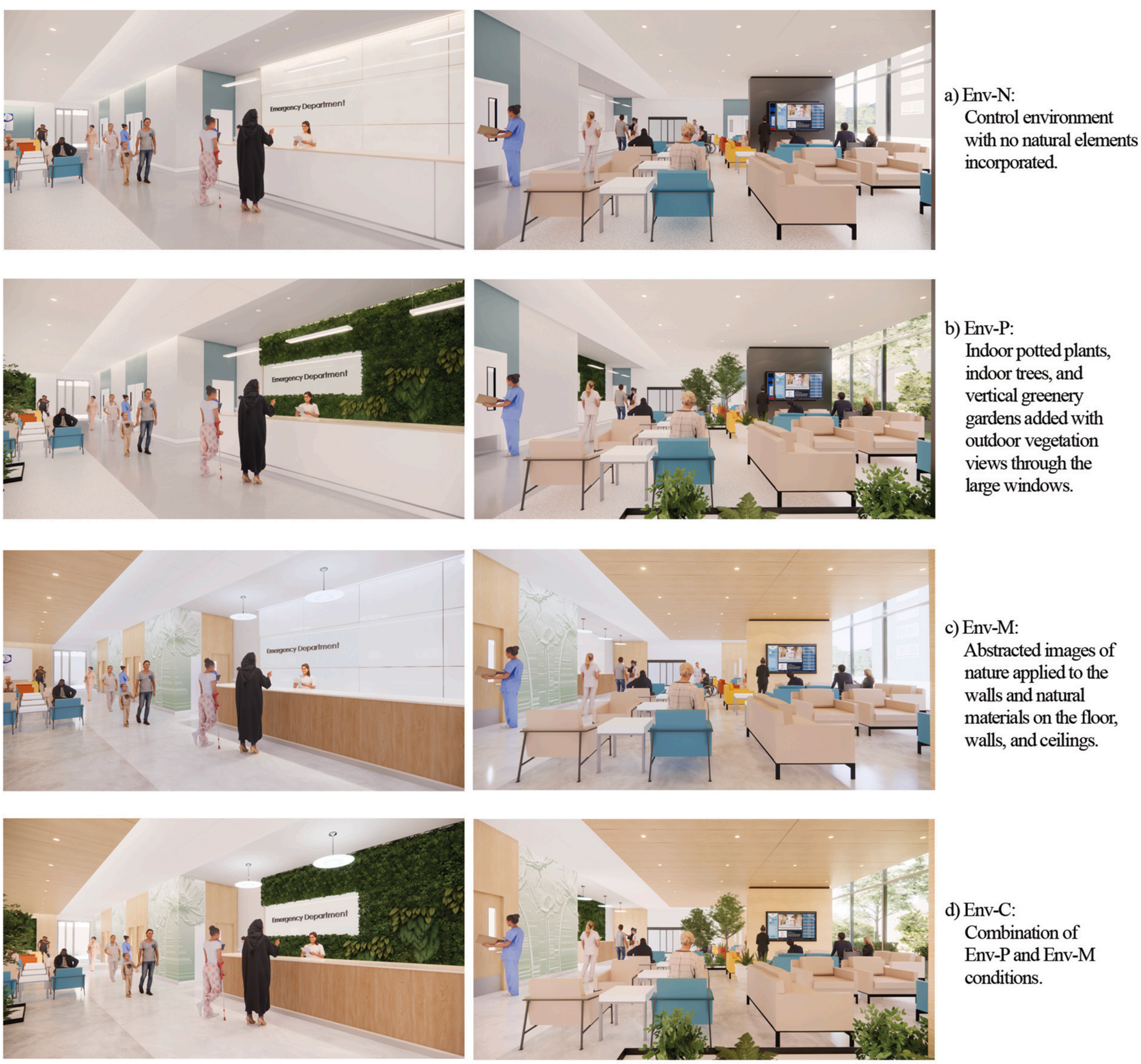


**Fig. 2.** Four conditions of environmental stimuli.

plants (Env-P), 2) abstract images of nature and natural materials (Env-M), and 3) a combination of 1) and 2) conditions (Env-C). As described earlier, we chose these natural elements based on their frequency in previous studies. Also, to compare the responses to the different natural elements, natural elements were selected from two categories. Based on the categorization of natural environmental features suggested by Kellert and Calabrese (2015), plants are considered 'direct natural environmental features,' and 'images of nature' and 'natural materials' are categorized as 'indirect natural environmental features.' Images of nature and natural materials have been applied as an environmental stimulus to control the complexity of the study. For Env-P condition, indoor plants were added with potted plants and indoor trees placed around seating areas, vertical greenery gardens on the reception wall and the back wall of the seating areas. The outdoor vegetation was made visible through large exterior windows. For Env-M, the abstracted images of nature have been applied to the consultation room walls and natural materials on the floor, walls, and ceilings. Windows and furniture arrangements and furniture materials were controlled to be the same across stimuli.

Then, the 3D virtual models were rendered and converted to 360-degree panoramic videos, with one view from the reception area and one from the waiting area of each condition. To provide an immersive spatial experience, an ambient sound of ED waiting areas was added to the video. The high-fidelity 3D stimuli videos were uploaded on YouTube in ultra-high definition to be embedded in the Qualtrics survey platform. Respondents could easily interact with the environments by scrolling and rotating the 360-degree views of the VEs.

### 3.2. Instrument

We developed questionnaires to administer before and after the task of viewing the VEs. The pre-task questionnaire asked for demographic information (i.e., gender, age, and ethnicity) and their familiarity with hospitals (i.e., the last time they visited a hospital and their familiarity with a hospital environment measured on a 7-point Likert scale). Anxiety levels were measured using 18 items adopted from the State-Trait Anxiety Inventory (STAI; Spielberger, 1983). STAI consists of 40 items that assess state and trait anxiety levels on a 4-point Likert scale (1: not at all, 2: somewhat, 3: moderately so, and 4: very much so) – 20 items on state anxiety and 20 items on trait anxiety. We used the state anxiety items to assess the intensity of participants' current feelings "at this moment" of being in the simulated hospital waiting areas. After a scale reliability analysis with the coefficient score (Cronbach α) test, we used 18 out of 20 state anxiety items. The Cronbach $\alpha$ score for anxiety items was 0.90, which indicated the high reliability of the scale. To examine perceived wait times, we used two measurements. First, participants rated how comfortable they would feel if they were to wait in the given ED waiting areas for five proposed time sets; 15 min, 30 min, 1 h, 2 h, and more than 2 h, on a 7-point Likert scale (1: extremely uncomfortable, 7: extremely comfortable), and we named it as 'perceived wait time.' According to Pruyn and Smidts (1998), 15 min is considered a short wait time, 30 min an acceptable wait, and more than 30 min a long wait. The Cronbach $\alpha$ score for the five items was 0.79, which was above an acceptable level of 0.7. Second, participants were asked for the maximum wait time that they would feel comfortable waiting in the given hospital, using a manually controlled scale bar indicating 1–180 min; their answer was named 'comfortable wait time.' We termed 'wait time perceptions' when we identified both wait time measures.

To measure the level of service quality participants would perceive in the presented environment, we used the SERVQUAL model by Babakus and Mangold (1992), which was adapted to a hospital service environment from the original SERVQUAL scale (Parasuraman et al., 1988). Participants measured their perceived service quality on a 7-point Likert scale, from strongly disagree to strongly agree. Cronbach $\alpha$ score was 0.93. All the measurements and their respective descriptive statistics are shown in Table 2.

## 4. Study 1

Study 1 tested the hypotheses using a randomized, double-blind, within-subjects design to measure the effects of the treatments more accurately while controlling the individual variability of the participants. Linear mixed models were used to analyze the statistical significance of differences in anxiety, perceived wait time and comfortable wait time, and perceived service quality with JMP 16.1. Linear mixed models, also known as linear mixed effect models, include a combination of fixed and random effects as predictor variables, resulting in more statistical power and less unexplained individual variance (Baayen et al., 2008; Brauer & Curtin, 2018). To account for the individual variability identified by the random variable, i.e., participant, we included subject ID as a random variable in the data analyses in addition to the fixed effects of the environmental conditions. The effect sizes in partial eta squared were calculated from repeated measures in SPSS. 28. The thresholds of the effect sizes were based on suggestions of Cohen (1988): small ($0.01 \le \eta_p^2 < 0.06$), medium ($0.06 \le \eta_p^2 < 0.14$), large ($0.14 \le \eta_p^2$).

We conducted mediation analyses to test the effect of natural elements on perceived service quality through anxiety and perceived wait time using Model 6 of SPSS Process Macro 4.1. In the mediation model, the environmental condition was set as a multicategorical independent variable with the control environment as a reference group, anxiety and perceived wait time as mediators, and perceived service quality as the dependent variable. 5000 bootstrapping was used for indirect effect analyses with 95% confidence intervals.

### 4.1. Participants

We recruited participants living in the United States through online survey service platforms, Amazon Mechanical Turk (MTurk) and Qualtrics. Participants provided informed consent to voluntarily participate in the study with a compensation of $5.50. A total of 116 responses out of 129 were used for analysis after data screening for missing and unengaged data and outliers. The sample comprised 50% men and 50% women, ages ranging from 18 to over 55, and included five ethnic groups. Table 1 provides an overview of participant demographics. The majority of participants (88%) had visited a hospital within one year, and 75% answered that they were more than somewhat familiar with a hospital environment.

A power analysis (G*Power; Faul et al., 2007) showed that the required sample size to achieve 80% power for detecting an effect size of $f = 0.1$ (Cohen, 1988), at a significance criterion of $\alpha = 0.05$, was $N = 110$ for analysis of variance with repeated measures of within factors. Thus, the obtained sample size of $N = 116$ was adequate to test the study hypotheses.

### 4.2. Procedure

The online survey platform Qualtrics was used for collecting data. After answering the pre-task questionnaires, participants watched a

**Table 1**
Sample characteristics – study 1.

| Variable | | $n$ ($N = 116$) | % |
|---|---|---|---|
| Sex | Male | 58 | 50.0 |
| | Female | 58 | 50.0 |
| Ethnicity | White | 56 | 48.3 |
| | Hispanic | 28 | 24.1 |
| | Black | 15 | 12.9 |
| | Asian | 14 | 12.1 |
| | Other | 3 | 2.6 |
| Age | 18–24 | 17 | 14.7 |
| | 25–34 | 42 | 36.2 |
| | 35–44 | 36 | 31.0 |
| | 45–54 | 11 | 9.5 |
| | Over 55 | 10 | 8.6 |
| Last visit | <1 month | 49 | 42.2 |
| | <6 months | 36 | 31.0 |
| | <1 year | 17 | 14.7 |
| | More than 1 year | 14 | 12.1 |
| Familiarity | < Somewhat unfamiliar | 5 | 4.3 |
| | Neither | 24 | 20.7 |
| | Somewhat familiar | 44 | 37.9 |
| | Familiar | 34 | 29.3 |
| | Very familiar | 9 | 7.8 |

**Table 2**
Item reliability, means, and SDs of responses to the four environmental settings - Study 1.

| Variables | Range | Cronbach's α (no. of items) | Env-P | | Env-M | | Env-C | | Env-N | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | M | SD | M | SD | M | SD | M | SD |
| *Anxiety* | 1–4 | .90 (18) | 2.28 | .61 | 2.32 | .63 | 2.29 | .62 | 2.48 | .66 |
| *Per. wait time* [a] | 1–7 | .79 (5) | 4.67 | 1.23 | 4.58 | 1.22 | 4.73 | 1.21 | 4.48 | 1.35 |
| *Comf. wait time* [b] | 0–180 min | - | 86.97 | 48.08 | 83.60 | 49.83 | 92.39 | 52.24 | 80.22 | 48.52 |
| *Per. service quality* [c] | 1–7 | .93 (15) | 5.62 | .81 | 5.56 | .85 | 5.62 | .87 | 5.33 | .99 |

Note. [a] Perceived wait time, [b] Comfortable wait time, [c] Perceived service quality.

short 10-s video clip of a minor car accident from the first-person view to be primed to better connect themselves with the scenario of visiting an ED. After the video, participants were asked to view and navigate one of the four virtual waiting areas assigned to them. To control the order effects, we assigned participants to one of the four environments randomly and evenly via the randomized setting in Qualtrics, i.e., a quarter of participants viewed one of the four waiting areas first. Each environment stimulus consisted of two interactive 360-degree views of the waiting area, one captured from around the reception and the other from the seating area. Participants were asked to navigate the two views on a computer screen or tablet, not on a mobile phone, and to immerse themselves in the environment of the sound-on high-resolution videos for at least 2 min per view. Immediately after viewing the waiting area, the post-task questionnaire was administered to ask participants about their experiences, i.e., anxiety levels, wait time perceptions, and perceived service quality. Before moving to the next environment, participants had at least a 1-min break to avoid carryover effects. The experiment took approximately 45 min on average.

### 4.3. Results

#### 4.3.1. Anxiety, perception of wait time, and perceived service quality

Hypothesis 1 predicted the positive impact of natural elements on lower anxiety. The fixed effect test results from the linear mixed model analysis for anxiety levels indicated that the differences between the four environmental conditions were highly significant, as shown in Table 3 ($F$ (3, 345) = 7.2, $p$ = 0.0001). Participants' anxiety levels were lower in the three environmental conditions with natural elements than in the control condition, i.e., without natural elements. The means revealed that the lowest anxiety levels were shown in Env-P (plants added to the control) and Env-C (combination) and the highest in Env-N (control). In Env-M (nature images and natural materials added to the control), anxiety levels were slightly higher than in Env-C and Env-P but lower than in Env-N (Table 2).

Hypothesis 2 expected patients would feel more comfortable waiting in environments with natural elements than without in the given wait time sets. The mixed model analysis results showed significant differences between the environments (Table 3). Env-C had the highest scores in both wait time-related variables - perceived wait time and the maximum comfortable wait time, which was followed by Env-P and Env-M; the lowest scores were shown in Env-N.

Hypothesis 3 projected higher perceived service quality in environments with natural elements. The mixed model analysis supported significant group differences in perceived service quality scores between the four conditions (F (3, 345) = 7.42, p = < .0001). The higher scores were observed in Env-P and Env-C, slightly lower scores in Env-M than in Env-P and Env-C, and the lowest was shown in Env-N.

**Table 3**
Fixed effect test results from the linear mixed model analysis for responses to the four environmental settings - Study 1.

| Variables | Numerator *df* | Denominator *df* | *F* | *p* | *Effect size* $\eta_p^2$ |
|---|---|---|---|---|---|
| *Anxiety* | 3 | 345 | 7.20 | <.001*** | .06 |
| *Per. wait time* | 3 | 345 | 2.96 | .032* | .03 |
| *Comf. wait time* | 3 | 345 | 4.51 | .004** | .04 |
| *Per. service quality* | 3 | 345 | 7.42 | <.001*** | .06 |

*Note.* $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

#### 4.3.2. Patient responses to different natural elements

According to Hypothesis 4 a, it was expected that the conditions with plants (i.e., Env-P and Env-C) would have a greater impact on patient wait experiences compared to the condition with nature images and materials (i.e., Env-M). To test this hypothesis, we conducted mixed model analyses and compared the mean differences between each natural element condition and the control. Table 4 summarizes the fixed effect test results, which show that Env-P and Env-C had statistically stronger differences with Env-N than Env-M in four measures. Significant differences were observed in anxiety and perceived service quality measures between all three conditions with natural elements and the control, with Env-P and Env-C showing similar levels of effects and Env-M displaying slightly lower effects. We further compared Env-P and Env-C vs. Env-M to explore the statistical differences in the effects of each natural element condition (Table 4). Although a significant difference was observed between Env-C and Env-M in comfortable wait time, the effects were relatively small, and the other effects were not significant. Therefore, while both Env-P and Env-C showed stronger effects than Env-M, their differences were not statistically significant.

Hypothesis 4 b proposed that the combination of plants, images of nature, and natural materials (i.e., Env-C) would have the strongest impact on patient wait experiences. As shown in Table 4, Env-C showed the most significant differences with Env-N in both wait time perceptions. In anxiety and perceived service quality, Env-C and Env-P showed similar significant differences with Env-N. Overall, Env-C showed the highest level of impact on patient experiences. However, Env-P was equally effective as Env-C in reducing anxiety and improving service quality, and the differences between the effects of each natural element condition were not statistically significant.

#### 4.3.3. Mediation effects

Hypothesis 5 expected the environments to affect patients' perceived service quality through anxiety and perceived wait time. We conducted a serial multiple mediation analysis, as depicted in Fig. 1, in which anxiety and perceived wait time were located causally between environmental conditions and perceived service quality. In the model, the environmental condition was set as a multicategorical variable, and the control environment was set as the reference group in the indicator coding. We also conducted a preliminary correlation analysis to examine mutual relationships between variables. In the results, anxiety negatively correlated with the two wait time measures and perceived service quality, and the wait time measures positively correlated with perceived service quality (Table 5). Between the two wait time measures, the perceived wait time was selected to test for Hypothesis 5 because it showed a higher correlation with perceived service quality than the comfortable wait time variable.

In the serial mediation analysis, there was a significant relationship between environmental conditions (independent variables ($X_{123}$)) and perceived service quality (outcome variable (Y)) in the presence of two

**Table 4**
Fixed effect test results from the linear mixed model analysis for comparison of responses to environments with vs. without natural elements - Study 1.

| Variables | Numerator *df* | Denominator *df* | *F* | *p* | Effect size $\eta_p^2$ |
|---|---|---|---|---|---|
| *Anxiety* | | | | | |
| Env-P vs. Env-N | 1 | 115 | 15.72 | <.001*** | .12 |
| Env-M vs. Env-N | 1 | 115 | 9.29 | .003** | .08 |
| Env-C vs. Env-N | 1 | 115 | 13.48 | <.001*** | .11 |
| Env-P vs. Env-M | 1 | 115 | .87 | .351 | .01 |
| Env-C vs. Env-M | 1 | 115 | .27 | .603 | .00 |
| Env-P vs. Env-C | 1 | 115 | .16 | .692 | .00 |
| *Per. wait time* | | | | | |
| Env-P vs. Env-N | 1 | 115 | 3.57 | .061 | .03 |
| Env-M vs. Env-N | 1 | 115 | 1.08 | .300 | .01 |
| Env-C vs. Env-N | 1 | 115 | 7.92 | .006** | .06 |
| Env-P vs. Env-M | 1 | 115 | 1.26 | .265 | .01 |
| Env-C vs. Env-M | 1 | 115 | 2.77 | .099 | .02 |
| Env-P vs. Env-C | 1 | 115 | .57 | .452 | .01 |
| *Comf. wait time* | | | | | |
| Env-P vs. Env-N | 1 | 115 | 5.65 | .019* | .05 |
| Env-M vs. Env-N | 1 | 115 | 1.02 | .316 | .01 |
| Env-C vs. Env-N | 1 | 115 | 11.87 | <.001*** | .09 |
| Env-P vs. Env-M | 1 | 115 | 1.17 | .281 | .01 |
| Env-C vs. Env-M | 1 | 115 | 4.65 | .033* | .04 |
| Env-P vs. Env-C | 1 | 115 | 2.17 | .143 | .02 |
| *Per. service quality* | | | | | |
| Env-P vs. Env-N | 1 | 115 | 15.78 | <.001*** | .12 |
| Env-M vs. Env-N | 1 | 115 | 7.59 | .007** | .06 |
| Env-C vs. Env-N | 1 | 115 | 15.44 | <.001*** | .12 |
| Env-P vs. Env-M | 1 | 115 | .92 | .340 | .01 |
| Env-C vs. Env-M | 1 | 115 | .55 | .459 | .01 |
| Env-P vs. Env-C | 1 | 115 | .02 | .901 | .00 |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

**Table 5**
Correlations of variables – Study 1.

| Variable | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. Anxiety | - | | | |
| 2. Per. wait time | −.21*** | - | | |
| 3. Comf. wait time | −.10* | .69*** | - | |
| 4. Per. service quality | −.37*** | .40*** | .16*** | - |

*Note.* *$p < 0.05$, ***$p < 0.001$.

mediators, anxiety (mediator 1 ($M_1$)) and perceived wait time (mediator 2 ($M_2$)). The results are shown in Fig. 3 and Table 6. The indirect effects analyses statistically supported that anxiety and perceived wait time had mediating roles in the relationship between environmental conditions and perceived service quality. However, Env-M did not show significant mediating effects with bootstrapping CI, including zero in the analysis result, $B$ ($X_1$) = 0.019, 95% CI [0.003, 0.041], $B$ ($X_2$) = 0.015, 95% CI [0.000, 0.035], $B$ ($X_3$) = 0.017, 95% CI [0.002, 0.039]. Among three categories of indirect effect paths, paths from Env-P and Env-C to perceived service quality through anxiety (i.e., X - > $M_1$ - > Y) and through anxiety and perceived wait time (i.e., X - > $M_1$ - > $M_2$ - > Y) were significant with bootstrapping CI not including zero. However, paths through the perceived wait time (i.e., X - > $M_2$ - > Y) were not significant with bootstrapping CI including zero.

The direct effects of environments on anxiety were significant, while the direct effects on the perceived wait time and perceived service quality were insignificant in the mediation model. Anxiety had significant direct effects on both perceived wait time and perceived service quality, and perceived wait time also significantly affected perceived service quality. Therefore, the analysis showed a full mediation effect of the environment on perceived service quality through anxiety and perceived wait time with insignificant direct effects of the environment on perceived service quality. In the overall mediating analysis results, Env-P and Env-C showed stronger significant effects on the variables than Env-M (e.g., Anxiety: $t$ ($X_1$) = 2.53, $p$ = 0.012, $t$ ($X_2$) = 2.01, $p$ = 0.045, $t$ ($X_3$) = 2.47, $p$ = 0.014).

We also examined the mediating effects of anxiety and perceived wait time in the relationship between environment and perceived service quality in terms of five dimensions of service quality: tangibility, reliability, responsiveness, assurance, and empathy. The direct effects of the environment on perceived service quality displayed the strongest effect on reliability in the results (Table 7). The indirect effects of the environment on perceived service quality through anxiety and perceived wait time revealed significant indirect effects of Env-P and Env-C in all five service quality dimensions; Env-M showed significance except for reliability and assurance (Table 8). The indirect effects appeared most strongly significant in the reliability and responsiveness dimensions, and the effects were lowest in tangibility.

## 5. Study 2

Study 2 examined the impact of different environmental conditions on anxiety, wait time perception, and perceived service quality, as well as the mediating effects of anxiety and perceived wait time on the relationship between the environments and perceived service quality, using a between-subjects design. While a within-subjects design used in Study 1 was expected to provide a more precise investigation of the effects of the treatment conditions by controlling individuals' variability, an additional study was conducted using a between-subjects design to further validate whether consistent results could be obtained when each participant was exposed to only one environmental condition, thus mitigating the possibility of response modifications due to repeated exposure to stimuli.

Analysis of variance (ANOVA) was used to assess statistically significant differences in participants' anxiety, wait time perception, and perceived service quality. A serial multiple mediation analysis was conducted using Model 6 of SPSS Process Macro 4.1.

### 5.1. Participants and procedure

Participants living in the United States were recruited through the online survey service platform, Prolific, and Qualtrics was used for data collection. Participants provided informed consent to voluntarily participate in the study with compensation. The sample comprised 185 participants, 46% men and 54% women, with ages ranging from 18 to over 55. The majority of participants (67%) had visited a hospital within one year, and 74% answered that they were more than somewhat familiar with a hospital environment.

The same study procedure as in Study 1 was followed in Study 2, with the exception that each participant viewed only one stimulus. After

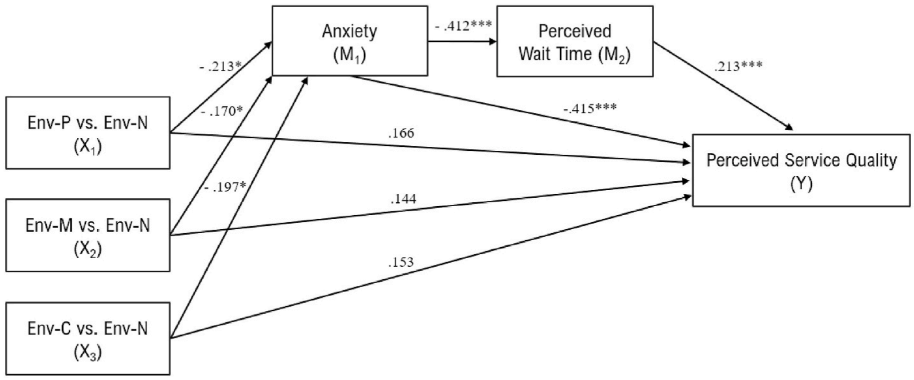


**Fig. 3.** Mediation analysis results for Hypothesis 5 (unstandardized coefficients) – Study 1.

completing the pre-task questionnaires and watching the car accident video, participants were asked to view and navigate a single virtual waiting area. Following the waiting area experience, the post-task questionnaire was administered, in which participants answered the questionnaires about their experiences, i.e., anxiety levels, wait time perception, and perceived service quality. On average, the experiment took approximately 10 min.

### 5.2. Results

#### 5.2.1. Anxiety, perception of wait time, and perceived service quality

Participants' anxiety levels were lower in the three environmental conditions with natural elements than in the control, as shown in Table 9. In Env-C and Env-M, participants reported slightly lower anxiety levels than in Env-P, and the highest anxiety was observed in Env-N, the control without natural elements. The statistical differences between the four environments were significant, $F$ (3, 181) = 4.76, $p$ = 0.003 (Table 10). Thus, Hypothesis 1 was met.

Participants felt more comfortable waiting in environments with natural elements than without in the given wait time sets, showing significant differences between the environments, $F$ (3, 181) = 4.69, $p$ = 0.004. Env-C showed the highest scores in both wait time-related variables - perceived wait time and the maximum comfortable wait time, and Env-M showed similar scores. The lowest scores were shown in Env-N.

For perceived service quality, the environmental conditions with natural elements showed higher mean scores than the control, but there were no significant differences between the conditions, $F$ (3, 181) = 0.60, $p$ = 0.613. Among the environments with natural elements, Env-C showed slightly higher scores than Env-P and Env-M; the lowest was shown in Env-N.

#### 5.2.2. Mediation effects

In the serial mediation analysis, there was a significant relationship between environmental conditions (independent variables ($X_{123}$)) and perceived service quality (outcome variable (Y)) in the presence of two mediators, anxiety (mediator 1 ($M_1$)) and perceived wait time (mediator 2 ($M_2$)). The indirect effects analysis results showed that anxiety and perceived wait time mediated the relationship between environmental conditions and perceived service quality, as expected in Hypothesis 5. The results are shown in Fig. 4 and Table 11.

The direct effects of environments on anxiety and perceived wait time were significant, while the direct effects on perceived service quality were not significant. Anxiety had significant direct effects on perceived wait time, and perceived wait time significantly affected perceived service quality. Thus, the analysis showed a full mediation effect of the environment on perceived service quality through anxiety and perceived wait time with insignificant direct effects of the environment on perceived service quality.

All three natural element conditions, Env-C, Env-M, and Env-P, showed significant mediating effects with bootstrapping CI, not including zero in the analysis result, $B$ ($X_1$) = 0.011, 95% CI [0.0001, 0.035], $B$ ($X_2$) = 0.016, 95% CI [0.001, 0.045], $B$ ($X_3$) = 0.014, 95% CI [0.001, 0.042]. Among three categories of indirect effect paths, paths from the environments to perceived service quality through anxiety (i.e., X - > $M_1$ - > Y) were not significant, while through perceived wait time (i.e., X - > $M_2$ - > Y) were significant. Paths through anxiety and perceived wait time (i.e., X - > $M_1$ - > $M_2$ - > Y) were significant with bootstrapping CI not including zero.

## 6. Discussions

Our findings contribute empirical evidence of the positive impact of natural elements in ED waiting areas, where visitors experience high anxiety resulting in discomfort during their waits. Despite substantial evidence supporting the benefits of nature contact for human health and well-being, no studies have been conducted on the impact of natural elements in enhancing patients' perceptions of service quality and wait time in ED waits, to our best knowledge. The current study confirmed that natural elements have a positive influence on patients' reduced anxiety levels, and it was found that natural elements significantly improved the perception of wait times. Participants responded with higher scores indicating that they felt more comfortable waiting in environments with natural elements.

Furthermore, the presence of natural elements in the waiting areas was linked to elevated service quality attributed to reduced anxiety and improved wait time perception. However, these effects showed marginal significance, while the effects of natural elements on anxiety and wait time perception have been clearly confirmed in the results. Hence, further research is needed to validate the effects on service quality perception.

Although the effects on service quality mediated by these factors showed relatively modest effect sizes, the findings unveiled the potential mediators within the associations between natural elements and service quality. Further research will be valuable in identifying potential factors that contribute to the relationships between natural elements and patients' wait experiences.

In addition to hypothesis testing, exploratory analyses were conducted to investigate the potential moderating effects of participant characteristics such as age, gender, and ethnicity. The results of these analyses did not reveal statistically significant effects.

### 6.1. Theoretical implications

This study contributes to the understanding of nature's positive impacts on patient wait experiences by suggesting that anxiety and wait time perception mediate the effects of natural elements on perceived service quality. Natural elements were associated with anxiety, which

**Table 6**
The mediation analysis results for the effect of the environments on perceived service quality through anxiety and perceived wait time - Study 1.

| Paths | *B* | SE | *t* | *p* | 95% LLCI | 95% ULCI |
|---|---|---|---|---|---|---|
| *Relative Total Effect* | | | | | | |
| Env-P → Anxiety → Per.wait time → Per.service quality | .294 | .116 | 2.53* | .012 | .066 | .522 |
| Env-M → Anxiety → Per. wait time → Per. service quality | .233 | .116 | 2.01* | .045 | .005 | .461 |
| Env-C → Anxiety → Per. wait time → Per. service quality | .286 | .116 | 2.47* | .014 | .058 | .514 |
| | $R^2$ = .018, *F* (3, 459) = 2.83*, *p* = 0.038 | | | | | |
| *Relative Direct Effect* | | | | | | |
| Env-P → Anxiety | −.213 | .083 | −2.56* | .011 | −.376 | −.050 |
| Env-M → Anxiety | −.170 | .083 | −2.04* | .042 | −.333 | −.006 |
| Env-C → Anxiety | −.197 | .083 | −2.37* | .018 | −.360 | −.033 |
| Env-P → Per. wait time | .094 | .163 | .58 | .562 | −.225 | .414 |
| Env-M → Per. wait time | .019 | .162 | .12 | .906 | −.300 | .338 |
| Env-C → Per. wait time | .163 | .162 | 1.00 | .316 | −.156 | .482 |
| Env-P → Per. service quality | .166 | .104 | 1.61 | .109 | −.037 | .370 |
| Env-M → Per. service quality | .144 | .103 | 1.39 | .165 | −.059 | .347 |
| Env-C → Per. service quality | .153 | .104 | 1.47 | .141 | −.051 | .356 |
| Anxiety → Per. wait time | −.412 | .091 | −4.54*** | .000 | −.590 | −.234 |
| Anxiety → Per. service quality | −.415 | .059 | −7.02*** | .000 | −.531 | −.298 |
| Per. wait time → Per. service quality | .213 | .030 | 7.17*** | .000 | .155 | .272 |
| *Relative Indirect Effect* | | | | | | |
| Env-P → Anxiety → Per. service quality | .088 | .039 | | | .020 | .174 |
| Env-M → Anxiety → Per. service quality | .070 | .038 | | | −.001 | .149 |
| Env-C → Anxiety → Per. service quality | .082 | .038 | | | .011 | .162 |
| Env-P → Per. wait time → Per. service quality | .020 | .035 | | | −.048 | .089 |
| Env-M → Per. wait time → Per. service quality | .004 | .035 | | | −.065 | .075 |
| Env-C → Per. wait time → Per. service quality | .035 | .035 | | | −.032 | .106 |
| Env-P → Anxiety → Per. wait time → Per. service quality | .019 | .010 | | | .003 | .041 |
| Env-M →Anxiety →Per. wait time → Per. service quality | .015 | .009 | | | .000 | .035 |
| Env-C → Anxiety → Per. wait time → Per. service quality | .017 | .009 | | | .002 | .039 |

*Note.* *$p < 0.05$, ***$p < 0.001$.

causally influenced perceived wait time, and perceived wait time affected service quality. The results showed that natural elements had an impact on perceived service quality through a combination of anxiety and perceived wait time. This finding highlights the role of anxiety in the relationship between natural elements and perceived service quality, as well as supporting previous research on nature's potent effects on reducing anxiety.

The findings also provide new insights into the role of emotions in mediating the effects of natural elements on cognitive responses, especially perceived service quality in this study. Emotions have been suggested as potent effects of nature (Brengman et al., 2012; Zelenski & Nisbet, 2014). Emotions, such as reduced arousal and increased pleasure, have been proposed to mediate cognitive responses, such as the perception of service quality (Tifferet and Vilnai-Yavetz (2017). However, evidence for this has been lacking. Our findings explain the mechanism by which the emotional reaction to nature, i.e., anxiety, is linked to cognitive reaction, i.e., perceived service quality, by suggesting that a mixture of emotional and cognitive response, i.e., perception of wait time, lies in the relationship.

The findings of this study also indicate the potential impact of natural elements on different sub-dimensions of service quality. The results show that natural elements have a stronger impact on the reliability dimension of service quality, and the indirect effects through anxiety and perceived wait time are also stronger in the reliability and responsiveness dimensions. These findings support previous research indicating that wait times have a high impact on the reliability dimension of service quality in medical service delivery (De Man et al., 2005). Reliability and responsiveness are reported as significant predictors of patients' satisfaction among five service quality dimensions (Meesala & Paul, 2018). Moreover, service quality has been widely studied as a predicting factor for various emotional, cognitive, and behavioral responses in service contexts, such as satisfaction (Amin & Nasharuddin, 2013), brand trust and loyalty (Zehir et al., 2011), and behavioral intentions (Salanova et al., 2005). Therefore, it is likely that natural elements may have other potential impacts on patient responses through service quality. Further research on the relationship between nature and service quality dimensions will provide more insights.

### 6.2. Practical implications

One of the key findings of our study was the varying levels of patient responses to three practical scenarios with natural elements. While the most recognized nature-incorporated design strategy in research and design practice has been the inclusion of plants in indoor environments (Gillis & Gatersleben, 2015), few discussions have addressed the impact of other natural elements applied in the built environment. We examined the impact levels of different natural elements, namely: 1) incorporating plants, 2) using nature images and natural materials, and 3) combining both approaches. The results revealed that incorporating plants and using nature images and natural materials were equally effective in improving outcomes. However, it was observed that the combination of both approaches yielded the highest scores, indicating a more significant impact on the desired outcomes.

In Study 1, the condition with plants (Env-P) showed slightly greater impacts on patient wait experiences than the condition with nature images and materials (Env-M), while the latter showed slightly stronger impacts in Study 2. However, both conditions were significantly more effective in advancing patient experiences than the control without natural elements in the results. We acknowledge that there are still areas where the impact of natural elements needs further exploration. A recent study by Ojala et al. (2023) investigated the effects of natural materials, specifically wooden interiors, on human well-being in an office setting. They found that participants reported significantly lower anxiety levels when they were resting in a wooden room compared to a control room without wood. Among several other psychological measures assessed, including restoration, energy level, mood, sustained attention, heart rate variability, and skin conductivity, the wooden room provided slightly greater benefits across these measures compared to the control room. Despite the broad studies already done regarding the effects of nature in the healthcare context, continued research on the effects of natural elements will be necessary to expand knowledge of additional factors and gain practical insights.

With nature's positive impacts on human health and well-being, nature exposure or bringing natural elements into the built

**Table 7**
Direct effects of the environments on each dimension of perceived service quality in the mediation analysis - Study 1.

| | Independent variable | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Env-P ($X_1$) | | | | Env-M ($X_2$) | | | | Env-C ($X_3$) | | | |
| Paths | *B* | SE | *t* | *p* | *B* | SE | *t* | *p* | *B* | SE | *t* | *p* |
| *Env → Per. service quality* | | | | | | | | | | | | |
| Tangibility | .150 | .123 | 1.22 | .223 | .058 | .123 | .47 | .638 | .112 | .123 | .91 | .361 |
| Reliability | .309 | .128 | 2.42* | .016 | .263 | .127 | 2.06* | .040 | .311 | .128 | 2.43* | .015 |
| Responsiveness | .052 | .126 | .41 | .679 | .040 | .126 | .32 | .749 | .054 | .126 | .43 | .667 |
| Assurance | .177 | .116 | 1.53 | .127 | .144 | .116 | 1.25 | .214 | .143 | .116 | 1.23 | .219 |
| Empathy | .128 | .129 | .99 | .321 | .248 | .128 | 1.93 | .054 | .142 | .129 | 1.11 | .269 |

**Table 8**
Indirect effects of the environments on each dimension of perceived service quality in the mediation model analysis - Study 1.

| | Independent variable | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Env-P ($X_1$) | | | | Env-M ($X_2$) | | | | Env-C ($X_3$) | | | |
| Paths | *B* | SE | 95% LLCI | 95% ULCI | *B* | SE | 95% LLCI | 95% ULCI | *B* | SE | 95% LLCI | 95% ULCI |
| *Env → Anxiety → Per. wait time → Per. service quality* | | | | | | | | | | | | |
| Tangibility | .014 | .008 | .003 | .033 | .011 | .008 | .000 | .029 | .013 | .008 | .002 | .032 |
| Reliability | .021 | .011 | .004 | .045 | .016 | .010 | −.000 | .040 | .019 | .011 | .002 | .043 |
| Responsiveness | .022 | .012 | .004 | .050 | .018 | .011 | .000 | .044 | .021 | .011 | .003 | .047 |
| Assurance | .018 | .009 | .003 | .039 | .014 | .009 | .000 | .034 | .017 | .009 | .002 | .038 |
| Empathy | .019 | .010 | .004 | .042 | .015 | .010 | .000 | .037 | .018 | .010 | .002 | .040 |

**Table 9**
Means, and SDs of responses to the four environmental settings - Study 2.

| Variables | Range | Env-P ($n = 43$) | | Env-M ($n = 49$) | | Env-C ($n = 46$) | | Env-N ($n = 47$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | M | SD |
| *Anxiety* | 1–4 | 2.43 | .56 | 2.28 | .73 | 2.33 | .74 | 2.77 | .72 |
| *Per. wait time* [a] | 1–7 | 4.24 | 1.26 | 4.24 | 1.15 | 4.31 | .96 | 3.55 | 1.14 |
| *Comf. wait time* [b] | 0–180 min | 68.44 | 42.36 | 72.61 | 50.17 | 75.85 | 45.63 | 52.32 | 31.85 |
| *Per. service quality* [c] | 1–7 | 5.63 | .80 | 5.66 | .74 | 5.79 | .59 | 5.60 | .71 |

**Table 10**
Test results of responses to the four environmental settings - Study 2.

| Variables | Numerator *df* | Denominator *df* | *F* | *p* | *Effect size* $\eta_p^2$ |
|---|---|---|---|---|---|
| *Anxiety* | 3 | 181 | 4.76 | .003** | .07 |
| *Per. wait time* | 3 | 181 | 4.69 | .004** | .07 |
| *Comf. wait time* | 3 | 181 | 2.75 | .044* | .04 |
| *Per. service quality* | 3 | 181 | .60 | .613 | .01 |

*Note.* *$p < 0.05$, **$p < 0.01$.

environment has gained increased attention in healthcare design. Many strategies and principles have been proposed for the incorporation of nature into the built environment, encompassing natural shapes and forms, materials, daylighting, and so forth (Kellert & Calabrese, 2015; Kellert et al., 2011; Ryan et al., 2014). However, implementing these strategies in existing built environments often faces limitations. Our findings suggest that introducing plants can serve as an efficient design strategy. In cases where live plants cannot be accommodated, such as due to limited daylight or maintenance challenges, the use of nature images and natural materials could be a viable alternative. Notably, our study suggests that a combination of these two applications would be more effective in enhancing patient wait experiences.

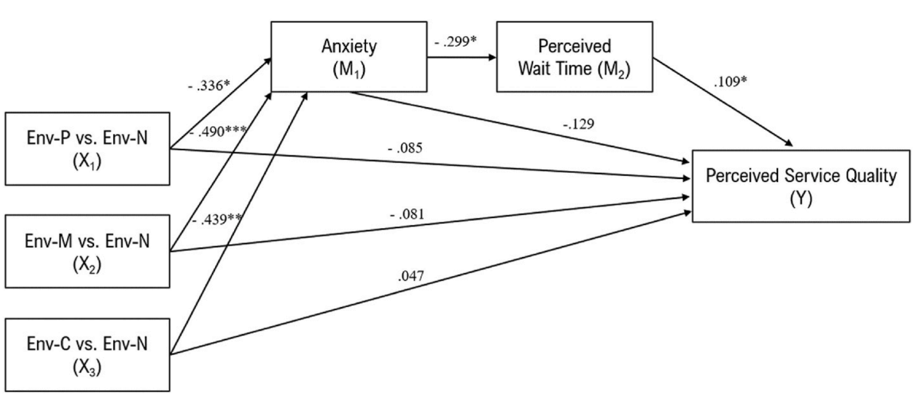


**Fig. 4.** Mediation analysis results for Hypothesis 5 (unstandardized coefficients) – Study 2.

**Table 11**
The mediation analysis results for the effect of the environments on perceived service quality through anxiety and perceived wait time – Study 2.

| Paths | *B* | SE | *t* | *p* | 95% LLCI | 95% ULCI |
|---|---|---|---|---|---|---|
| *Relative Total Effect* | | | | | | |
| Env-P → Anxiety → Per.wait time → Per.service quality | .034 | .151 | .23 | .822 | −.263 | .331 |
| Env-M → Anxiety → Per. wait time → Per. service quality | .057 | .146 | .39 | .695 | −.230 | .345 |
| Env-C → Anxiety → Per. wait time → Per. service quality | .187 | .148 | 1.26 | .208 | −.105 | .479 |
| | $R^2$ = .010, $F$ (3, 181) = .60, $p$ = 0.613 | | | | | |
| *Relative Direct Effect* | | | | | | |
| Env-P → Anxiety | −.336 | .147 | −2.29* | .023 | −.625 | −.046 |
| Env-M → Anxiety | −.490 | .142 | −3.46*** | .001 | −.771 | −.210 |
| Env-C → Anxiety | −.439 | .144 | −3.04** | .003 | −.723 | −.154 |
| Env-P → Per. wait time | .588 | .239 | 2.46* | .015 | .117 | 1.06 |
| Env-M → Per. wait time | .541 | .235 | 2.30* | .023 | .077 | 1.01 |
| Env-C → Per. wait time | .633 | .237 | 2.67** | .008 | .164 | 1.10 |
| Env-P → Per. service quality | −.085 | .152 | −.557 | .578 | −.384 | .215 |
| Env-M → Per. service quality | −.081 | .149 | −.545 | .587 | −.376 | .213 |
| Env-C → Per. service quality | .047 | .151 | .309 | .758 | −.252 | .345 |
| Anxiety → Per. wait time | −.299 | .119 | −2.51* | .013 | −.535 | −.064 |
| Anxiety → Per. service quality | −.129 | .076 | −1.70 | .090 | −.279 | .021 |
| Per. wait time → Per. service quality | .109 | .047 | 2.34* | .020 | .017 | .201 |
| *Relative Indirect Effect* | | | | | | |
| Env-P → Anxiety → Per. service quality | .043 | .033 | | | −.009 | .118 |
| Env-M → Anxiety → Per. service quality | .063 | .044 | | | −.012 | .162 |
| Env-C → Anxiety → Per. service quality | .057 | .040 | | | −.011 | .146 |
| Env-P → Per. wait time → Per. service quality | .064 | .040 | | | .001 | .152 |
| Env-M → Per. wait time → Per. service quality | .059 | .039 | | | .000 | .150 |
| Env-C → Per. wait time → Per. service quality | .069 | .039 | | | .006 | .157 |
| Env-P → Anxiety → Per. wait time → Per. service quality | .011 | .009 | | | .000 | .035 |
| Env-M →Anxiety →Per. wait time → Per. service quality | .016 | .011 | | | .001 | .045 |
| Env-C → Anxiety → Per. wait time → Per. service quality | .014 | .011 | | | .001 | .042 |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

### 6.3. Limitations and future directions

We explored the effects of natural elements on patient wait experience measures and selected the most frequently discussed or used natural elements to test; plants, nature images, and natural materials. To control the complexity of the study, we applied abstract nature images and natural materials (wood veneers and stones) in one environment condition, instead of creating two separate conditions for each element. There are other types of natural materials and colors and nature images such as large landscape pictures, to consider and test if the gap with the response to actual plants could be narrowed. In addition, the use of nature images and natural materials showed small effect sizes, and continuous studies with larger sample sizes will be helpful to provide more robust results. In addition, extension studies are needed to understand how different users across diverse contexts perceive natural elements in the built environment to benefit fully from their use in the real world.

Our study results have limitations in providing clear evidence of the direct associations between natural elements and service quality. While statistically significant direct effects on service quality were observed in Study 1, this significance was not evident in Study 2. We recognize the possibility that the outcomes of Study 1 could have been inflated by participants adjusting their responses to the experimental conditions, potentially with demand effects. As such, further research is necessary to validate and confirm these findings.

Finally, a limitation of our study is that virtual environments cannot fully capture the complexity and richness of real-world settings, including the influence of other sensory modalities such as touch and smell on environmental perceptions. Although we used audio in our stimuli to mediate the limitation, this may not fully address the differences between virtual and physical environments. As such, caution should be exercised when interpreting the findings in the context of real-world settings.

## 7. Conclusion

Overall, our findings provide compelling evidence supporting the positive effects of natural elements on anxiety and perception of waiting time in waiting situations. They also indicate the potential of natural elements in enhancing service quality through these effects. Furthermore, our study contributes to a practical approach to incorporating natural elements by demonstrating the effectiveness of the presence of plants and the use of natural materials and images to yield positive outcomes.

Healthcare providers could benefit from incorporating natural elements to improve patient wait experiences, and the application contexts could be expanded to diverse business sectors, where consumer service levels and experience perceptions are highly valued.

## Funding

This research received no external funding.

## Data availability statement

The data presented in this study are available on request from the authors.

## Ethics statement

The study was reviewed and approved by the Institutional Review Board as an exempt study. Informed consent was obtained from all subjects involved in the study.

## Credit author statement

**Lee, Jisun:** Designed the study, recruited participants, submitted IRB, collected, and analyzed the data, wrote the original manuscript draft, project administration, and reviewed and revised the manuscript.

**Yoon, So-Yeon:** Developed the original research topic, designed the study, analyzed the data, supervised IRB, and wrote the manuscript – reviewed and revised the manuscript.

All authors reviewed and approved the final manuscript.

## Declaration of competing interest

We have no conflicts of interest to disclose.

## Appendix

The links to the high-fidelity virtual waiting area images in Fig. 2 are provided below. Eight 360-degree images of four environmental settings were created and used in this study.

| Stimuli | Link |
|---|---|
| Env-N: Control environment with no natural elements incorporated. | URL: https://youtu.be/zTOWRfaflbY<br>https://youtu.be/GB1GcMvtSks |
| Env-P: Indoor potted plants, indoor trees, vertical greenery gardens, and outdoor window views of vegetation. | URL: https://youtu.be/zLvybrIx4MM<br>https://youtu.be/lvVoZGWUzRE |
| Env-M: Abstracted images of nature applied to the walls and natural materials on the floor, walls, and ceilings. | URL: https://youtu.be/VErRwowHafg<br>https://youtu.be/eI4dtilWaWk |
| Env-C: Combination of Env-P and Env-M conditions. | URL: https://youtu.be/O6wR4fOl6G8<br>https://youtu.be/hLflpkdvxkM |

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