THE IMPORTANCE OF BOTH: COMPETING FACTORS THAT IMPACT ATTENTION LEVEL RESTORATION AND MENTAL HEALTH

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1 ABSTRACT

Attention Restoration Theory (ART) puts forward that being in nature has a restorative impact on direct attention level (Kaplan, 2001). Some researchers have tried to measure the perceptual implications of the four characteristics suggested by ART of a restorative environment (Korpela et al., 2010), and others have attempted to measure the cognitive consequences of immersion in a natural environment (Ohly et al., 2016). What has been examined far less is the interrelationship of perception and cognition and how they indicate the restorative impact. This research aimed to measure both perceptual and cognitive impacts of an immersive visual interaction with natural green elements. One hundred and eighty-two participants were randomly assigned to physically walk through, via VR goggles, one of two versions of a building's lobby modeled as a 3D virtual reality (VR) environment. One version was with, and the other was without natural green elements consisting of three types of indoor plants. To measure the two environments' perceptual impact, participants filled out a Perceived Restorative Scale (PRS) questionnaire (Hartig et al., 1997) after experiencing the environment. To assess possible improvement in attention level through cognitive processes, participants completed, before and after experiencing the environment, a Sustained Attention to Response Task (SART) (Jung et al., 2017). The results of this research seem to indicate that measuring one influencing factor may not be sufficient to evaluate the impact of an environment on attention level and may lead to misleading conclusions.

1.1 Keywords:

Attention Restoration, restorative environments, virtual reality (VR), direct attention, natural green elements/ vegetation, residential high-rise lobby

2 INTRODUCTION

Presence in nature (Kaplan & Kaplan 1989; Pilotti et al., 2015, Jenkin et al., 2018; Pascoe et al., 2017) or viewing a natural scene (Berto, 2005; Berman, Jonides, & Kaplan, 2008) for a few minutes to hours (Bratman, Hamilton, & Daily, 2012) has proven to have a positive physical and psychological impact. Numerous studies have focused particularly on possible improvements in individuals' attention level (Hartig, Evans, Jamner, Davis, & Garling, 2003; Lee, Park, Tsunetsugu, Kagawa, & Miyazaki, 2009). Different theories have tried to explain the process that helps the improvement in people's attention level to occur. One of those theories is the Attention Restoration Theory (ART), introduced by Rachel and Stephen Kaplan in 1989.

The Kaplans, in their book "The experience of nature: a psychological perspective," explained how interaction with nature could influence attention restoration (Kaplan & Kaplan, 1989). Their theory suggests four characteristics of environments with restorative capabilities. According to ART, natural environments are typically fascinating for individuals without being exhausting (Fascination). Those environments can also accommodate a broader range of activities and are more compatible with people's needs (Compatibility). Natural environments empower individuals to distance themselves from their daily routines and regular thoughts (Being Away). Finally, natural environments are extensive enough and enriched with different activities and content that allow people's minds to get involved with them for an extended period without noticing the environment's boundaries (Extent) (Kaplan, 1995; Kaplan & Kaplan, 1989).

ART has been extensively used in evaluating an environment's impact on people's attention level (Kaplan, 2001; Perkins et al., 2011; Raanaas et al. 2011, Wells & Phalen, 2018), a few points need to be discussed that have been addressed less in those studies. First, ART uses individuals' self-reported perception of an environment's four restorative characteristics to evaluate the environment's impact on attention levels. This theory proposes that the higher the perception of the restorative characteristic of an environment, the higher the level of restoration in peoples' attention level. ART puts forward that the restorative impact that an environment has on individuals is directly correlated with their perception of the four restorative qualities of the space. Individuals' understanding/perception of those qualities can vary from one person to another and can be impacted by their life experience and personal background (CDM Group, 2014); therefore, perceptions are subjective.

However, an individual's encounter with different environments triggers around the same time cognitive processes and functions in the brain (Maclean et al., 2010). Neuroimaging research has demonstrated that different cognitive functions activate separate networks in the brain, such as the networks involved in maintaining attention towards specific tasks (Sturm & Willmes, 2001) and the networks associated with processing external distractors (Maclean et al., 2009). Cognitive functions are exhausting efforts that consume underlying mental resources (Maclean et al., 2010). Areas in the brain, including brain networks, which are associated with controlling attention become less active after executing demanding cognitive tasks (Lim et al., 2010). One of the main indicators of the decrease in brain activities in the areas related to attention control is restricted blood flow in those areas promptly before lapses in attention (Weissman, Roberts, Visscher, & Woldorff, 2006). The consequences of this physiological response can be measured through different cognitive tests. These tests objectively measure the impact of interaction with nature on individuals' attention levels.

Therefore, cognitive function impacts an individual's attention level and studies that measure the restorative quality of an environment need to take individuals' perceptual understanding (subjective measures) and cognitive performance (objective measures) into account simultaneously.

Finally, most of the studies focused on the individual's physical presence or visual access to nature. There is mounting evidence to show that vegetation used in designing parks and urban green spaces also has restorative benefits (Hartig et al., 2014). However, recent studies revealed that those who live in high-density urban areas spend most of their time at home, at work, and commuting between those two locations. Similar studies also demonstrated that per capita encounter with urban green spaces and parks for those individuals is less than thirty minutes daily (U.S. Bureau of Labor Statistics, 2017). Therefore, people living in high-rise buildings in dense urban areas may have restricted physical access or views of nature. Nevertheless, those people may have access to other forms of vegetation, such as indoor greenery, in the design of the interior spaces. Thus, it is essential to see if those natural green elements, which in this research are interchangeably referred to as vegetation, can compensate, to some degree, for a lack of access to nature.

This paper expands on the former studies by exploring the impacts that micro-interaction with natural green elements have on people's attention level when utilized in interior design, in this case, a high-rise residential building lobby. Micro-interactions in this research are defined as spontaneous and informal encounters with natural green elements throughout the day that last less than a minute. This research employed methods and tests used in neuroscience to measure changes in individuals' cognitive performance as an indicator of attention restoration (Ohly et al., 2016). Researchers aim to answer the question: Does micro-interaction with natural green elements utilized in the high-rise residential building lobby's design enhance the participants' attention level?

2.1 Attention restoration and high-density urban areas

Large cities are filled with different types of information, both necessary and unnecessary. Those who live or work in urban areas encounter that information, from a small traffic sign to a huge LED billboard, daily. These encounters with a massive volume of data consumes mental resources involved in controlling attention (Herzog, Black, Fountaine, & Knotts, 1997). Mental resources depletion occurs when individuals try to direct their voluntary attention towards a task and at the same time ignore surrounding distractions that may interfere with executing that task (Kaplan, 1995). ART suggests that interaction with nature engages non-voluntary attention and allows depleted mental resources that enhance voluntary attention to replenish (Berman et al., 2008; Kaplan, 1995).

Growing population and increased demand for housing forced cities to expand and add higher-density housing to accommodate peoples' needs. In this way, traditional views of nature in urban areas such as trees on the streets and small community and local parks (van den Berg, Jorgensen, & Wilson, 2014) have become less accessible. However, other forms of vegetation, such as the natural green elements used in designing buildings' interior spaces, may provide similar restorative benefits to the city dwellers. Visual access to a limited amount of vegetation has similar attention restoring advantages as nature (Kaplan, 1993; Ulrich, 1986; Herzog, 1989). Therefore, it is likely that the utilization of natural green elements in designing indoor spaces can play a role in restoring peoples' attention. Hence, this paper examines the extent to which less than a minute walking through a lobby that uses vegetation in its design, as opposed to a lobby with no vegetation utilized in its design, can improve attention.

2.2 Attention restoration and cognition

Sustained attention is defined as the capability to maintain control of attention throughout a task (Maclean et al., 2010), an underlying element of attention involved in memory and learning (Cowan, 1995; Sarter et al., 2001). Controlling attention consumes mental resources; therefore, it is difficult to sustain attention for a long time (Maclean et al., 2010). Even further, trying to sustain attention for an extended duration may cause mental health and productivity impairments (Sonnentag, Binnewies, & Mojza, 2010).

Two separate processes are involved in sustaining attention. Each process occurs in a separate network in the brain. Focusing on performing a specific task is processed cortically through the dorsal attention network (Sturm & Willmes, 2001) while surrounding distractors are processed sub-cortically via ventral attention network (Warm et al., 2008; Corbetta & Shulman, 2002). Studies have revealed that just before failures in attention occur, blood flow restricts the brain's area associated with attention control (Hitchcock et al., 1999; Weissman et al., 2006). The same area of the brain becomes significantly less active after operating an attentional resource depleting task, denoting that the depletion is imminent (Lim et al., 2010).

Drawing on ART, this paper suggests that walking in a lobby with vegetation utilized in its design could provide individuals with a restorative experience to help them replenish their mental resources exhausted from maintaining attention control. Similar to previous study outcomes (Kaplan, 1993; Kaplan, 2001), researchers expected to observe visual micro-interactions with vegetation in the residential building lobby, enhancing attention. The possible enhancement can be measured via the Sustained Attention to Response Task (SART). Performing SART activates both brain networks associated with maintaining sustained attention. Homogenous variability in response time performing the SART task demonstrates participants' ability to sustain their attention while avoiding distractions and momentary arousals (Manly et al., 2003; Barkley, 1997; Bellgrove, Hester, & Garavan, 2004).

Two different response time variabilities can occur in performing SART. One mirrors the quick alternation in the response time over the course of the task, referred to as the "Fast Frequency Variability

(FFV).” The other shows the gradual changes in the response time variability during the task’s operation and is called the “Slow Frequency Variability (SFV).” Different studies suggest that shifts in FFV indicate changes in cortical attention control. Those studies also argue that alternations in SFV demonstrate changes in sub-cortical arousal (Johnson et al., 2007; Johnson, Kelly, et al., 2008). Using these two measures allows researchers to evaluate possible changes in individuals’’ sustained attention more accurately as they reflect how both processes involved in sustaining attention get affected over the experiment set up by the researchers.

Using this method helps to assess both processes of attention restoration. Voluntary attention is processed cortically, and FFV indicates changes in cortical attention control. In the same way, non-voluntary attention is processed sub-cortically, and SFV illustrates sub-cortical arousal. Drawing on ART, researchers speculated that the lobby with vegetation would improve cortical attention control. They also expected to observe the sub-cortical arousal simulation. These results would be reflected in less FFV and SFV and fewer errors performing the SART.

3 RESEARCH OBJECTIVES

An objective of this research was to compare the accuracy of self-reported evaluations of the perception of the restorative impact of green environments against other less subjective, and more recently developed, cognitive measures of attention restoration. In other words, some studies have recorded and examined what subjects have said about an environment’s restorative impact while other studies have measured changes in the performance of cognitive tasks as a measure of restorative impact. Several previous research efforts have relied solely on the measurement of perception, or impacts on cognition, to measure the restorative quality of an environment. Few studies have used both cognitive and perceptual measurement approaches. This study compares the outcomes of a measurement of perception, using the Perceived Restorative Scale (PRS) questionnaire, with an established cognitive measurement instrument, the Sustained Attention to Response Task (SART). The goal was to shed light on how the findings of these different approaches to measuring the impact of an environment on an individual’s health and well-being conform and or differ.

An additional research objective was to explore to what extent a micro exposure to green environments, in this case exposure of less than sixty seconds, can have a measurable positive impact on an individual’s well-being. The intent was to increase our understanding regarding the value of the greening of environments that individuals experience for only a short time each day. As we understand better the potential impact of micro exposures, we may be able to identify cost effective measures that have a maximum benefit. Finally, this research also tested the potential of using immersive VR to create an experience of an environment that can produce perceptual or cognitive impacts.

4 METHODS

This quasi-experimental exploratory research measures how visual interaction with vegetation in the residential building lobby affects participants' perception of space and cognitive performance. Researchers used quantitative data obtained from a cognitive test and a perceptual questionnaire. Experiments often draw a causal relationship between dependent variables and independent variables (Thyer, 2012). In this research, the presence of vegetation is the independent variable. This study's two dependent variables are the participants' perception of the lobby's restorative quality and their sustained attention level. Researchers used a virtual environment to keep the experiment condition consistent for all participants. However, there were still some intervening variables that researchers had limited control over. Factors such as the higher workload, lack of sleep, or family problems could impact participants' cognitive performance. Participants' background and former experience with vegetation and other design characteristics of the lobby, such as color, height, and materials, could also affect their perception of the lobby's restorative quality. Therefore, researchers could not establish a causal relationship between the dependent and independent variables and used correlational analysis to interpret the data.

4.1 Study Context

This experiment's study context was two versions of a residential building complex's lobby modeled in virtual reality. As rendered in Figure 1, one version contained some vegetation, and the other one had no vegetation utilized in its design. The two versions were modeled in Autodesk Revit 2020, and vegetation was then added to the model using Lumion for Revit. The Unity Game Engine was the platform used in this experiment to allow participants to immerse themselves in one of the two virtual environments. Participants controlled their movement through the lobby by physically walking while wearing a VR headset to accomplish the task.

Virtual reality is an emerging tool that has been used in recent years in landscape architecture research (Saedi et al., 2020). Researchers have used screen based (Berto, 2005; Ohly et al., 2016) and semi-immersive (Chung et al., 2018; Moreno et al., 2018) VR environments, that would allow participants to experience the VR environment through head movements in contrast to physically walking, to measure the impact of physical and visual interaction with nature. Moreover, those studies are mostly focused on the participants' perception of the restorative quality of an environment and not their cognitive performance after experiencing an environment. The number of studies that have utilized fully immersive VR environments, that allow participants to explore the VR environment while physically walking during the experiment, for that purpose is limited compared to the other two versions (Lee et al*.,* 2015; Saedi et al*.,* 2020).

The use of virtual reality allowed the researchers to more easily modify the study site and overcome any access problems that may be associated with the use of a physical space (Saedi & Rice, 2019). In addition, research has shown that a virtual reality environment can generate a restorative impact similar to a real physical environment. The primary difference being that the restorative impact resulting from a virtual reality experience may be less than the impact of a physical space. For these reasons it was felt that using VR was both more manageable format and possibility a more rigorous test.

Figure 1. Snapshots of the two versions of the residential building lobby as the study sites. Toward the building entrance (Top) - Toward the building elevators (Bottom)

4.2 Participants

One hundred and eighty-two residents of a high-rise residential building voluntarily agreed to participate in the entire experiment as reflected in Figure 2. including the pre-test and the post-test. Each participant experienced only one of the two versions of the study context. The participants were 63% male and 37% female with a mean age of thirty-five. One hundred and seventy-one out of one hundred and eighty-two participants carried out the pre and post SART test correctly. Seven of the participants did not respond to more than half of the PRS questions; thus, their data was not used for the final analysis. Therefore, the data obtained from one hundred and sixty-four participants was ultimately analyzed.

4.3 Measures

Researchers used two measures in this study. The first measure was the Sustained Attention to Response Task (SART) used to gauge the participants' cognitive performance. The second measure was the Perceived Restorative Scale (PRS), which was employed to determine how the participants perceived the two lobbies.

The Sustained Attention to Response Task measures participants' sustained attention level. The study used SART to record any significant changes in participants' sustained attention level (Johnson et al., 2007). Using E-prime Software, participants were given a series of numbers on an iPad Air 2. They were asked to respond to any number, except the number '7' by touching an arrow on the bottom of the screen when the response cue in the form of "⊗" appeared on the screen. Researchers used the response cue to control the response speed between participants and to minimize the trade-off between pace and accuracy (Lee et al., 2015). The same number order consisting of two-hundred and twenty numbers were issued to all participants. One hundred and ten numbers before virtually walking through the assigned lobby, to establish the baseline of their attention level, and one hundred and ten after experiencing the lobby to detect any changes.

The Perceived Restorative Scale is a questionnaire designed to analyze individuals' impressions of the four aspects considered by Attention Restoration Theory for environments with restorative capabilities, namely: Extent, Being Away, Fascination, and Compatibility. The Perceived Restorative Scale (Hartig et al., 1997) was regarded as the basis for assessing the participants' perception of the lobby's ability to restore their attention. Researchers omitted a few questions from the original twenty-six PRS questionnaire (Hartig et al., 1997) as they applied to outdoor spaces, while this study took place in an indoor environment. The result was that a questionnaire consisting of eleven questions with Cronbach's α of 0.82. Researchers evaluated participants' responses on a 6-point Likert Scale with number one indicating "Not at all" and number six representing "Very much so".

4.4 Experiment Procedures

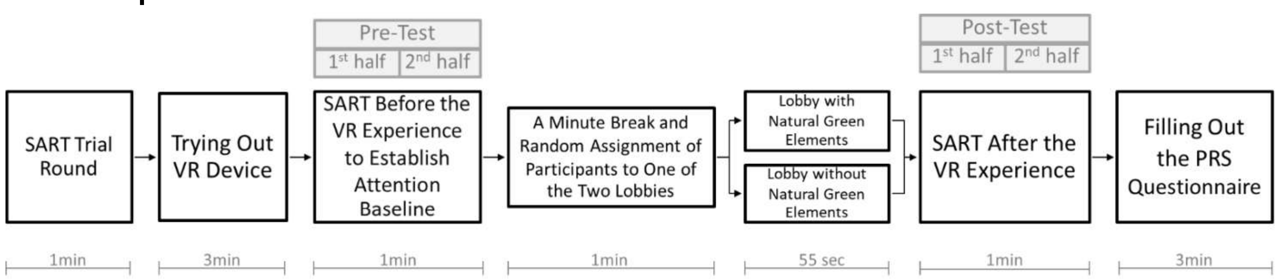

Figure 2. The process that participants had to go through to successfully participate in the experiment

Daily routines and responsibilities consume attentional resources and increase the chance people get mentally fatigued (Austria, 2014). Therefore, the 55 seconds long VR experience took place at the end of weekdays to help detect significant changes in the participants' cognitive functioning as an indicator of attention restoration (Ohly et al., 2016). Each participant after arriving in the residential complex was invited to move to a separate space to take the pre-immersion SART tests. The room had no natural ventilation or doors to the outside areas, just artificial lights, and the air-conditioning that was kept the same for all participants. Those consistencies helped researchers take out some of the intervening variables, such as various room temperatures and daylighting, out of the equation so they could not change the participants' cognitive performance. Figure 2 summarizes the experiment's procedure and dedicated timeframe for each step of the process that all participants who went through the study completed.

When the pre-test was completed, participants under researchers' supervision, first practiced using the VR Headset and VR controllers. Following the practice, researchers randomly assigned each participant to walk through one of the two 3D virtual reality versions of the building lobby, as illustrated in Section 4.1. To complete this task participants were taken to the building's 12x8 meter conference room as illustrated in Figure 3. All the furniture inside the room was removed. Only 12 chairs were kept in two sides of the room for the participants to take a rest in case they felt VR sickness and its symptoms such as nausea (LaViola, 2000). The 10x5 meter cleared space was marked down on the ground to define the area available to participants during the VR experience. Four SteamVR (SV) base stations were used to detect the participants' movements. The participants put on the VR Headsets and physically walked through the experiment's VR context. As the participants physically moved in the room their virtual location also changed relative to their starting point as recorded by the GPS embedded in the VR headset.

Modeling the lobby in the VR settings, rather than changing the real lobby, made it easier for researchers to try various prototypes to create the desired version more rapidly and at a lower cost (Saedi & Boone, 2018). The HTC VIVE Pro-Eye has been used for this study. Participants began the immersive experience of the VR world by clicking one of the keys on the VR controllers. They had to push the same button again when they got to the elevator to finish and register their encounter. The participants were required to walk across the lobby from the building entrance to the elevators at their normal walking speed, not rushing or pausing during the experience, without interacting with the vegetation or the lobby itself.

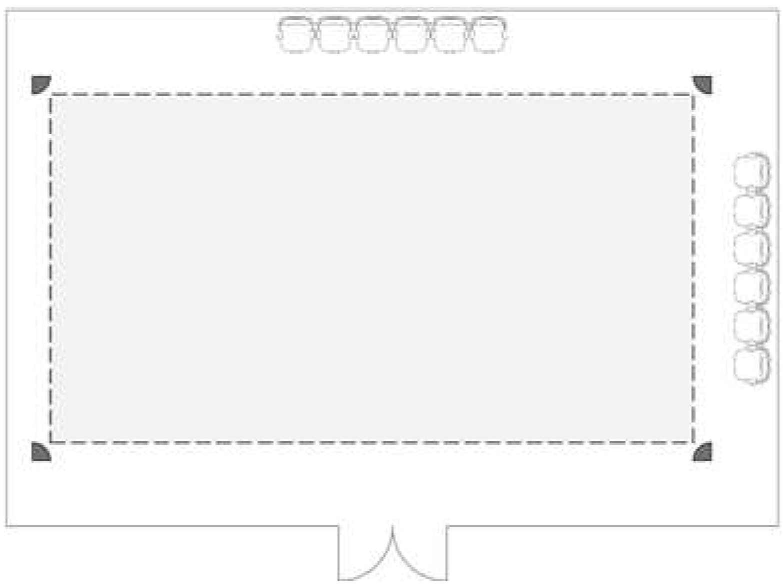

Figure 3. The layout of the building's conference room, the cleared space, and the four SteamVRs (SV) base stations

5 RESULTS

The standard deviation of each participant's response time and the average response time for all participants of the two groups was calculated. Using the fast Fourier transform, fast frequency variability was the variability for one SART cycle. The components of the SART test included one hundred and ten numbers in groups of ten. The slow frequency variability Included all variabilities in SART cycles (Johnson et al., 2007)

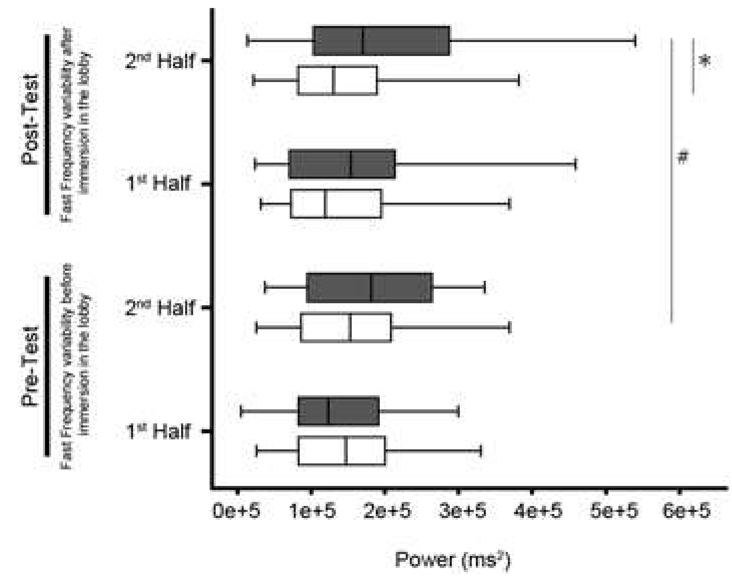

Figure 4. Boxplot of the median and variance of fast frequency response variability (reported as power). Participants experienced the lobby without natural/green elements (gray boxes) or with natural/green elements (white boxes). Data shown for the 1st and 2nd half of the pre-test, and the 1st and 2nd half of the post-test. The asterisk indicates a significant difference between participants exploring the lobby with and without natural/green elements (p= 0.014). The hash sign indicates a significant increase in variability for participants experiencing the lobby with no natural/green elements in the 2nd half of the SART task from pre-test to post-test (p= 0.041).

The SART response times were converted into time-series data, trended, and divided into seven segments according to the method used by Johnson and her colleagues in 2007 to calculate the fast frequency variability for each participant. Every segment consisted of seventy-five data points with fifty points overlapping. These data points were then hamming-windowed and zero-padded for a cumulative length of four hundred and fifty points to assess possible improvements in the individuals' sustained attention level. Researchers analyzed the standard deviation to response time and the fast frequency variability for the two halves of the pre-test and the two halves of the post-test. The slow frequency variability results were not divided into two halves and were analyzed for the entire pre-test and the entire post-test sections. The results obtained from the Sustained Attention to Response Task were different. The fast frequency and slow frequency variability data had non-normal distribution. Hence, the Mann-Whitney U-test was used to measure differences between fast and slow frequency variability for the two groups. Also, researchers employed Friedman`s analysis of variance to measure differences in performance among the same group's participants. The mean response time and the standard deviation to response time were analyzed by analysis of variance and the pairwise adjusted Bonferroni comparison, as the data obtained from the experiment had a normal distribution.

The mean response time comparison among the two groups suggested that there was not a significant difference. This result confirmed that members of one group were not inherently quicker in reacting to numbers when they appeared on the screen [F (1,164) = 0.10, p = 0.759]; therefore, it made it possible to compare the results obtained from the participants in the two groups (Johnson et al., 2007).

The results of the experiment revealed that overall, all participants responded faster in the post-test as compared to the pre-test [F = (1, 164) = 5.33, p = 0.021, r = 0.19]. They also responded faster in the second half of the pre-test and second half of the post-test in comparison with the first half of the pre-test and the first half of the post-test, respectively [F = (1,164) = 14.88, p<0.001, r = 0.35] (Lee et al., 2015, p. 182-189). This response speed difference can be associated with the experience the participants had from the pre-test (Lee et al., 2015).

The results of this experiment demonstrated that the fast frequency variability declined over the course of the experiment. Researchers observed this decline solely among those who walked through the lobby with no vegetation [Lobby with no vegetation, $x^2(3)$= 29.05, p< 0.001; Lobby with vegetation, $x^2(3)$= 2.11, p= 0.533]. The results also, as illustrated in Figure 4., revealed have more significant fast frequency variability between the two halves of the post-test in comparison with the two halves of the pre-test [z= -1.75, p= 0.034, r= -0.14]. Moreover, there was neither a significant difference between the members of the two groups' fast frequency variability for the two halves of the pre-test [1st half, U= 2450, p= 0.376, r= -0.03, 2nd half, U= 2322, p= 0.165, r= -0.08] nor the first half of the post-test. On the contrary, there was a significant fast frequency variability difference in the second half of the post-test between the members of the two groups, as it is marked by the asterisk in Figure 4. Results indicated that after the VR experience in the lobby without vegetation, participants` attention control was significantly less than that of participants in the other group [U= 1989, p= 0.013, r= 0.18].

Results from the sustained attention to response task verified no significant difference between the members of the two groups' attention level prior to walking through one of the two lobbies [U= 2231, p= 0.148, r= -0.12]. After physically walking through the VR lobby the participants who encountered the vegetations during the experience demonstrated significantly lower slow frequency variability compared to those who experienced the lobby with no vegetation [U= 1971, p= 0.008, r= -0.21]. Also, no significant changes were observed in the slow frequency variability among the participants of each group [Lobby with vegetations, z= -1.37, p= 0.090, r= -0.09, Lobby without vegetation, z= -0.74, p= 0.232, r= -0.05].

An analysis of the standard deviation revealed a more consistent response time pattern from, individuals who experience the lobby with natural green elements, see Table 1. The results indicated that a higher level of sustained attention was maintained by the individuals in that group F (1, 164) = 12.56, p < .001. Data also recorded no significant difference in the baseline for individuals in two groups F (1, 164) = 0.00, p= 0.939, r= 0.00.

There was a significant difference in the performance of individuals after experiencing different lobby versions F (1, 164)= 5.44, p= 0.031, r= 0.18. As reflected in Figure 5. Individuals who experienced the lobby with vegetation demonstrated less variability in response time F (1, 164) = 5.00, p= 0.023, r= 0.18. A significant response time variability increase was seen with participants in the group that experienced the lobby with no vegetation F (1, 164) = 7.59, p= 0.007, r= 0.27. The response time variabilities measured for both halves of the pre-test and both half of the post-test demonstrated that both groups' response time variability was lower on the first half of the pre-test as compared to the second half of the pre-test. Similar interpretation was valid for the first half of the post-test compared to the second half of the post-test F (1,164) = 4.57, p= 0.041.

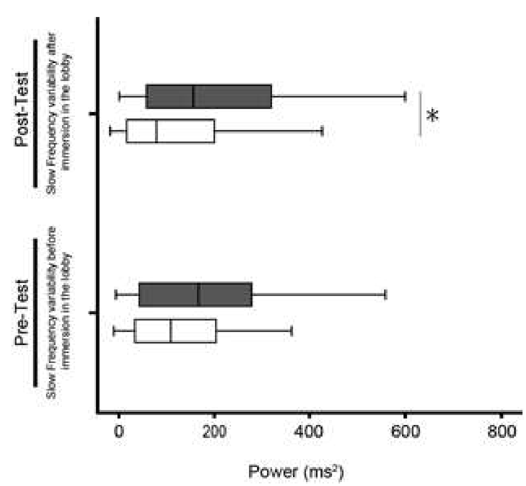

Figure 5. Boxplot of the median and variance of slow frequency changes in response variability. Results for performance at pre-test and post-test obtained from participants who experienced the lobby without natural/green elements (black boxes) and the lobby with natural/green elements (white boxes). The asterisk indicates a significant difference between participants who walked through the lobby with natural/green elements compared to those who experienced the lobby with no natural/green elements at post-test (p= 0.008). No meaningful difference was observed at pre-test (p= 0.143).

Table 1. The Mean (M) ± Standard Error (SE) for Response Time and Standard Deviation of Response Time provided in Seconds. Median (M.E.) and Interquartile Range (IQR) are Presented for the fast frequency and slow frequency variability on the sustained attention to response task SART test in power.

	Pre-Test								Post-Test					
	1st Half				2nd Half				1st Half				2nd Half	
	M.E.	IQR	M	S.E.	M.E.	IQR	M	S.E.	M.E.	IQR	M	S.E.	M.E.	IQR
Standard Deviation of response time														
Lobby with Natural Elements			95.20	4.33			102.36	4.90			89.54	3.67		
Lobby without Natural Elements			92.48	3.76			106.88	4.55			103.11	5.01		
Fast frequecny variability														
Lobby with Natural Elements	127,886	121,693			122,839	130,020			114,859	127,934			137,836	119,009
Lobby without Natural Elements	131,684	124,522			146,138	162,641			136,987	142,638			182,348	188,746
Slow frequency variability														
Lobby with Natural Elements	137.13	168.14							117.80	152.78				
Lobby without Natural Elements	151.11	262.2							193.26	242.65				
Mean response time														
Lobby with Natural Elements			561.71	17.23			521.16	18.33			523.37	18.51		
Lobby without Natural Elements			539.53	16.34			519.92	18.63			518.72	20.10		

The data collected from the PRS had a standard distribution and did not include any outliers (≥2.85SD). The t-test was used to compare the PRS scale findings between the two groups. The PRS Data demonstrated no significant difference in the perception of the two groups' participants of the two different lobbies' restorative quality introduced by Kaplan and Kaplan in 1989. According to ART, researchers expected to observe that participants who walked through the lobby with vegetation find that lobby significantly more restorative compared to the participants in the other group. The lobby with natural green elements (M=3.46, S.E.=0,10) and the lobby with no natural green elements (M= 3.13, S.E.= 0.12) were not perceived significantly different among participants in terms of their restorative quality (t (164)= -3.48, p= 0.061).

6 CONCLUSIONS

It has been revealed through the data that micro visual interaction with natural green elements in a residential building has the potential to have a significant positive impact on the sustained-attention level of those who walk through that lobby.

Many studies have used perceptual impacts to evaluate the effect of interacting with natural green elements on people's attention levels. Other studies have utilized cognitive tasks to measure that effect. Both methods are widely used in research related to attention restoration. Despite the abundant usage of the two methods, what seems to be neglected is that encounters with an environment impact peoples' perception and cognition simultaneously. So, measuring one impact without measuring the other may not provide a comprehensive perspective on the consequences and eliminates the benefits gained from triangulation of results.

The outcomes of this research demonstrated that physically walking through a VR representation of the lobby with vegetation had no significant impact on the participants' perception of the lobby's restorative characteristics, as measured by the (PSR) questionnaire. On the other hand, participants' cognitive performance significantly improved after experiencing the lobby with vegetation. These unparalleled results reinforce the idea that different criteria, perception of the restorative quality of the space and the cognitive performance after experiencing the space, that researchers utilize to measure an environment's impact on peoples' attention restoration do not necessarily support each other. Therefore, these two measures should be considered competing factors and how restorative quality of an environment is measured may need to be reevaluated.

These results also underscore the necessity of a more holistic approach that brings together all the factors that influence an environment's restorative effect on individuals' attention level and reinforces the Importance of using multiple measurement methods that then allow for triangulation.

7 DISCUSSION

The outcomes of this experiment can be divided into two contradictory findings. The first finding demonstrated that walking through a lobby that utilized vegetation in its design significantly impacted a participant's cognitive performance, as measured by the Sustained Attention to Response Task. Those who experience the lobby with vegetation had significantly lower fast frequency and slow frequency response time variability than those who experienced the lobby with no vegetation. These results were in line with the previous studies that suggest that spending time in nature has a positive effect on an individual's attention level (Berto, 2005; Kaplan & Kaplan, 1989).

The second finding revealed that walking through the lobby with vegetation evoked no meaningful increase in participants positive perception of the space regarding the four aspects considered by Attention Restoration Theory for environments with restorative capabilities. These outcomes contradicted the outcomes of the former studies that suggest visual interaction with nature has positive impacts on peoples' perception as measured by these four restorative characteristics of the space (Abbott et al., 2016, Warm et al., 2008, Kaplan & Kaplan, 1989).

Previous studies on attention restoration demonstrated that visual access to nature for a minimum of a few minutes to hours and days could significantly enhance an individual's attention level (Berto, 2005, Bratman et al., 2015). This study expands on previous studies by suggesting that the positive effects that occur through visual interaction with complex natural environments can also occur through interaction with a limited amount of vegetation for less than a minute.

The researchers utilized a virtual reality environment to help minimize the impact that mediating variables such as noise, room temperature, lighting, and more could have on the results (Saedi & Rice, 2021). VR environments have been demonstrated to produce physiological and psychological responses similar to those produced by actual environments. Moreover, it is expected that under the same conditions the impact of interaction with vegetations in physical environments are more pronounced than interaction with vegetation in VR environments (Bailenson, 2018; Banfi et al., 2018). One concern was that VR environments, though they can produce similar responses, tend to have less of an impact on participant and therefore may not reveal significant differences. However, the VR research environment was able to produce significant differences in cognitive function. It can be argued that, if this research was to take place in a physical environment the recorded differences could be even more prominent.

Although this research did not focus on the characteristic of the virtual experience, the outcomes of this research expanded the tools used to explore the impact on attention restoration from still images (Laumann et al., 2003), videos (Wang et al., 2016; Pilotti et al., 2015), and 360-degree images (Chung et al., 2018; Moreno et al., 2018) to the interactive virtual reality domain.

There are a few aspects that this research did not probe deeply that are worth exploring in the future. First, this research focused on exploring the possible impact on an individuals' attention level when visually interacting with vegetation in an indoor setting. What this research did not explore was how long a significant effect remains with the participants.

Second, vegetation has different characteristics, such as color and height. Each of these characteristics might impact an individual's attention. In this study, researchers did not focus on a specific type of vegetation or its characteristics but used the rendering software options. Now that the significant impact of interaction with vegetations on attention level has been detected subsequent studies can explore the role of vegetation and its design characteristics in the restoration process. These proposed studies may more directly contribute to design and planning suggestions.

Finally, this research measured the perceptual and cognitive impact of interaction with vegetation in an indoor setting on participants' attention level. There might be other psychological processes that need to be considered in evaluating the ultimate impact.

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