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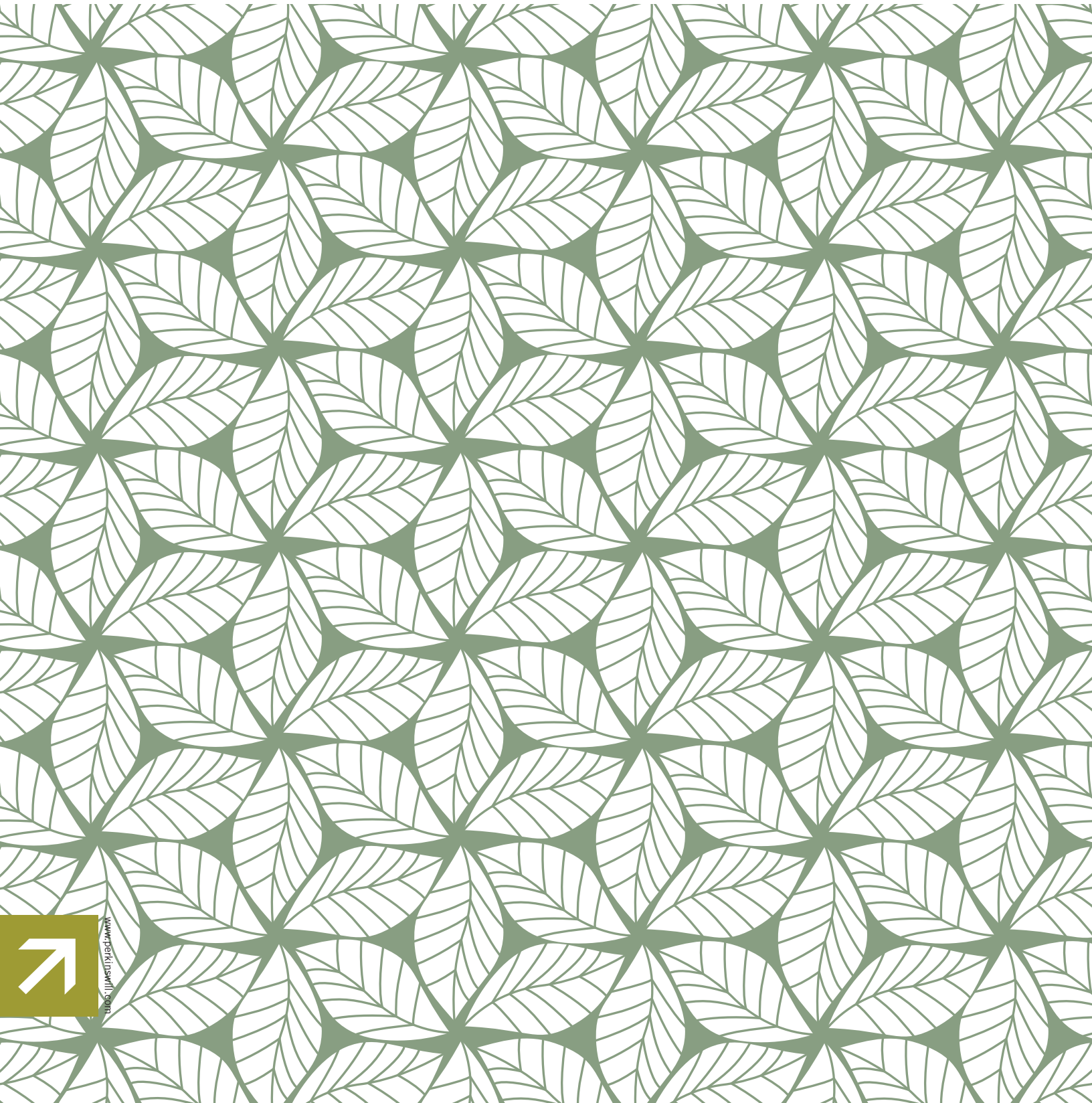

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03.
OUTSIDE IN:
Influences of Indoor Plants on Psychological Well-Being and Memory Task Performance in a Workplace Setting

Micah Lipscomb, LEED AP BD+C, *micah.lipscomb@perkinswill.com*
Kimberly Rollings, PhD, *krolling@nd.edu*

ABSTRACT
Although the benefits of nature exposure to human health are well documented, less is known about the psychological benefits of exposure to nature indoors. This study observed whether the addition of greenery to a workplace setting improved psychological well-being and performance of employees. A crossover study among 63 adults examined perceived psychological well-being and objective memory task performance with and without indoor greenery present in an open workplace setting. Statistical analyses indicated that there was only a marginally significant increase in memory task performance with the presence of plants. However, participants showed slightly better psychological well-being without the presence of plants when compared to performance with plants, on both floors. Study results suggest that the presence of windows, natural light, and high ratings of perceived psychological health may have confounded the effects of plant presence.

KEYWORDS: nature; indoor plants; psychological health; task performance

1.0 INTRODUCTION:
The benefits of outdoor nature exposure to human health are well-documented[1]; however, less is known about the psychological benefits of exposure to nature indoors[2]. Our hypothesis is that the addition of plants and greenery to a workplace setting will improve psychological well-being and performance on a memory task

2.0 LITERATURE REVIEW
Research on the health benefits of indoor plants has typically focused on psychological restoration. Steve and Rachel Kaplan's Attention Restoration Theory (ART) and Roger Ulrich's Stress Reduction Theory (SRT) explain the mechanisms by which nature exposure promotes psychological restoration. ART posits that nature exposure, via direct experiences or views, attracts our indirect, effortless attention and allows our directed attention to be restored; this restoration improves our ability to concentrate[3]. SRT suggests that people experiencing stress and anxiety may benefit most from nature exposure[4]. Most research on the psychological health benefits of nature has focused on direct exposure to or views of outdoor nature and imagery; however, little research has examined the benefits of indoor plants on psychological well-being.

According to Bringslimark and colleagues, just twenty-one articles about the psychological benefits of indoor plants from passive exposure (as opposed to horticulture therapy) were published in peer-reviewed journals between 1976 and 2007, in the English language[5]. Although additional articles examining benefits of indoor nature exposure have been published since 2007[1,2,5,6,7,8,9,10,11,12,13,14,15,16,17,18], results are inconsistent due to varying methods, measures, durations of nature exposure, and experimental settings[2]. The most consistent results support positive associations between indoor nature presence and improved pain management in health care settings[14,15,18,19] as well as improved psychological well-being when nature is present in controlled windowless research settings[10,11,21,22,23,24].

Results of studies focused on benefits of indoor plants specifically within office settings are also inconsistent. These studies monitored outcomes such as emotional states, productivity and task performance, room assessments, health and discomfort symptoms, sick leave, psychophysiological stress responses, and job satisfaction[7,8,9,10,19,21,25]. Five studies found statistically significant improvements in room assessments, self-reported health, and job satisfaction associated with the presence of plants[7,8,10,11,26]. However, other studies did not find significant improvements in emotional state[26], room assessments[26], or job satisfaction[27] associated with indoor plant presence. Evenson and colleagues' experiments found no change in directed attention capacity or self-reported restoration associated with increased plant exposure[9], while Raanaas and colleagues found positive associations between attention capacity and plant exposure in a similar study[17].

Research findings also suggest that associations between indoor plant exposure and outcomes vary by the intensity (number and size of plants)[11,25]. Jumeno and Matsumoto's study, for example, included different numbers and sizes of plants. However, there were higher productivity results with only one small plant in the room than with three small and three medium sized plants[11]. Larson and colleague's study on productivity tasks with plant exposure showed a similar inverse linear relationship to the number of plants in the office and productivity[25]. Interestingly the participant's in this study perceived they performed better on tasks even though the results did not support their perceptions. Both studies indicated that an increase in the number and size of plants present was associated with an increase in mood.

The role of indoor plant exposure duration was explored in additional studies[12,18]. Smith and colleagues measured participant responses over a six month time period and found that a reduction in stress and subjective health concerns and an increase in morale were associated with plant exposure in an office setting[18]. Korpela and colleagues tracked changes in questionnaire responses before and after a one-year study period to evaluate the influence of several types of nature exposure (window views, indoor plants, and outdoor physical activity)[12]. Results did not show a statistically significant association between nature exposure and employee well-being with indoor plant exposure.

The majority of studies in office settings were cross-sectional and conducted in laboratories or simulated offices. While simulated settings reduce the presence of confounding variables and isolate effects of indoor plant exposure, the artificial setting and short duration of exposure limits generalizability of study results to actual office settings. A positive health benefit of indoor plants in a windowless lab setting might not be replicable in an office setting where complex physical (sound, lighting, temperature, and air quality) and psychosocial (stress level, amount of control and support) confounds are present[7]. Better understanding the effects of indoor plant exposure on employees in actual office settings is needed. Therefore, this study took advantage of an office setting with two identical floors to examine effects of indoor plant exposure on employee psychological well-being and memory task performance.

3.0 METHODS

3.1 Research Design

A crossover study design was used to evaluate employees' perceived psychological well-being and objective memory task performance on two identical floors of an office building. The two study periods were distinguished by the presence or absence of plants in the office (Table 1). The order of experimental conditions was counterbalanced. Each participant was exposed to each condition for a total of 13-15 days before data were collected. Employees participated in data collection over two, three-day periods to accommodate work schedules.

Table 1: Experimental condition.

Office level	Plants (duration)	No plants (duration)
Floor 4	Session 1 (13-15 days)	Session 2 (13-15 days)
Floor 6	Session 2 (13-15 days)	Session 1 (13-15 days)

3.2 Study Site

The early 2017 study was conducted in the office of a multi-disciplinary design firm in Atlanta, Georgia. The office's two floors have an almost identical floor layout with similar natural and artificial light levels. Floor to ceiling glazing is present on the east, west, and north faces of the floors, with no natural light on the south face. Study participants were seated in the open office plan with rows of seating closest to the north wall (Figures 1a and 1b).

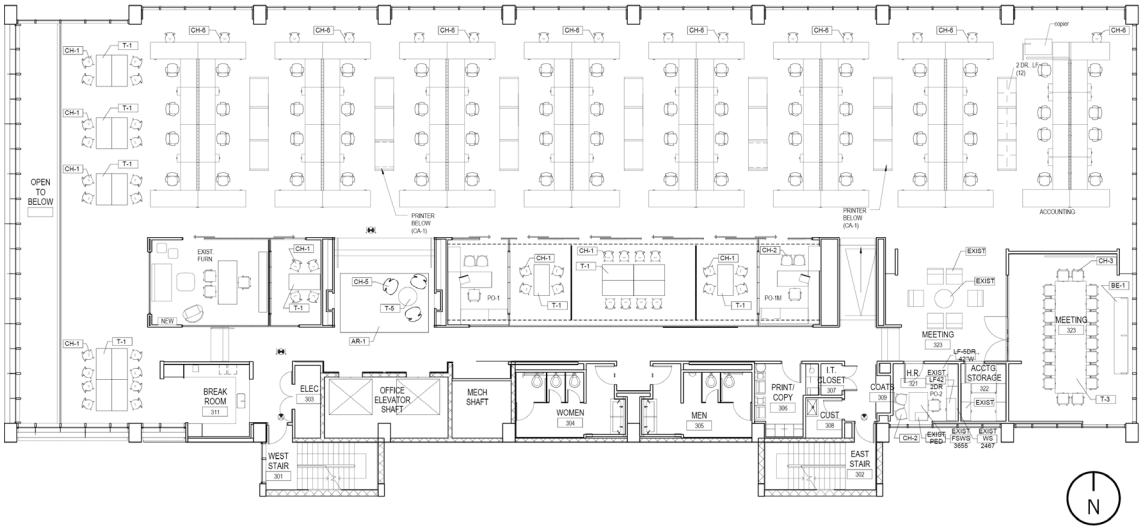

Figure 1a: Level 4 office floor plan.

Figure 1b: Level 6 office floor plan.

3.3 Participants

Eighty employees (40 per floor) seated in the open-plan areas of the two floors were eligible to participate in the study. Employees with private offices were excluded from study recruitment due to differing physical space characteristics (e.g., varying noise and privacy levels and different window views). Study participation was voluntary. A $25 gift card was offered as compensation to participants who completed both rounds of data collection. A total of 63 adults completed both rounds of data collection. The study was approved by the University of Notre Dame Institutional Review Board and Perkins + Will research and human resources departments.

3.4 Constructs and Measures

Predictors (independent variables)

Plant presence: Exactly 129 plants were installed on each floor during the "plant" study session (Figures 2, 3a, and 3b). All study participants had a 6" pot with a *Philodendron hederaceum* (Philodendron) placed within arm's length of their workstation. Additionally, 18 *Chamaedorea seizfrizii* (Bamboo Palm) and 18 *Dracaena fragrans* (Lemon Lime Warnecki) were located on the north side of the office along the window, and a total of 24 *Sanseveria trifasciata* (Sanseveria) were located on the south side of the workstation rows. An assortment of other plants was located in the breakroom and office elevator lobby. All plants were potted plants in white plastic containers and ranged in height from 2-8" for desk plants and 2-3' for floor plants. With the exception of one flowering orchid, all plants were green foliage plants.

Lighting conditions (light levels and cloudy days): Light levels were measured from the building's lighting system three times daily for six days. A *Leaton L830 Lux Meter* was used as the measuring device at participant seat locations throughout the floors. Each floor level was photographed to document the office lighting and views from participants' desks (Figures 3a and 3b). Additionally, the presence of clouds was documented during the study. Overcast skies throughout most of the day occurred on two study days and partly cloudy skies (more sun than clouds) occurred on six study days. Participant data collection did not occur on cloudy days.

Figure 2: Level 4 plant layout.

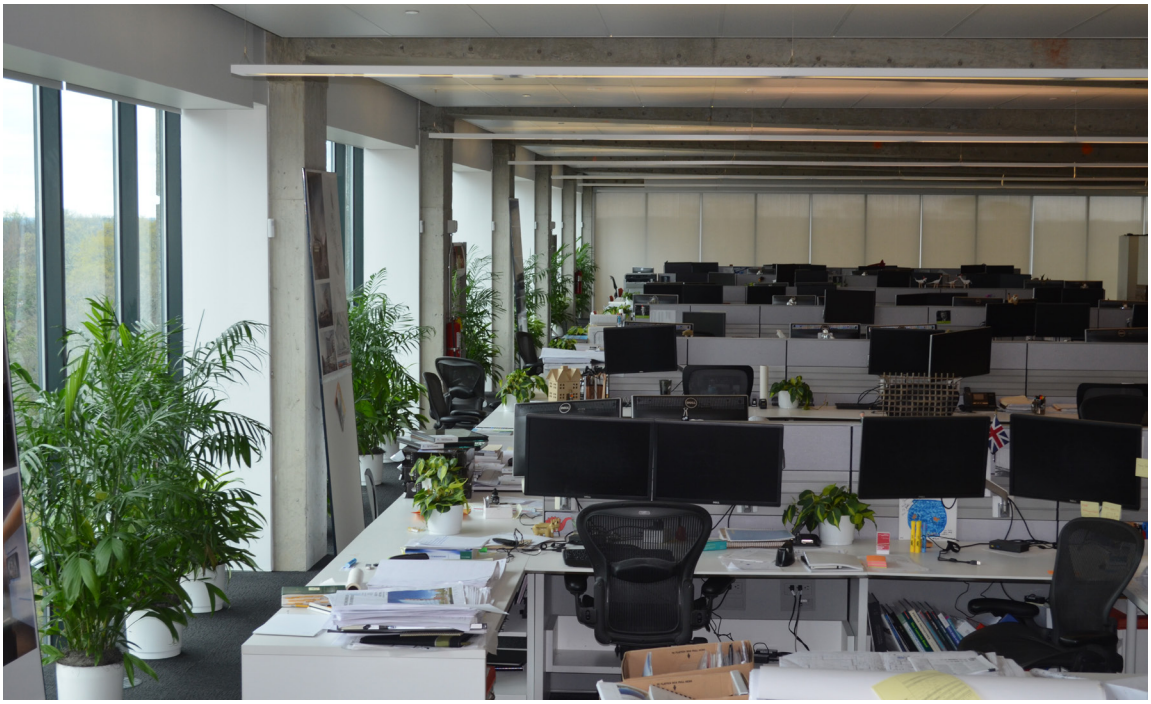

Figure 3a: View of plants along the north face of Level 4.

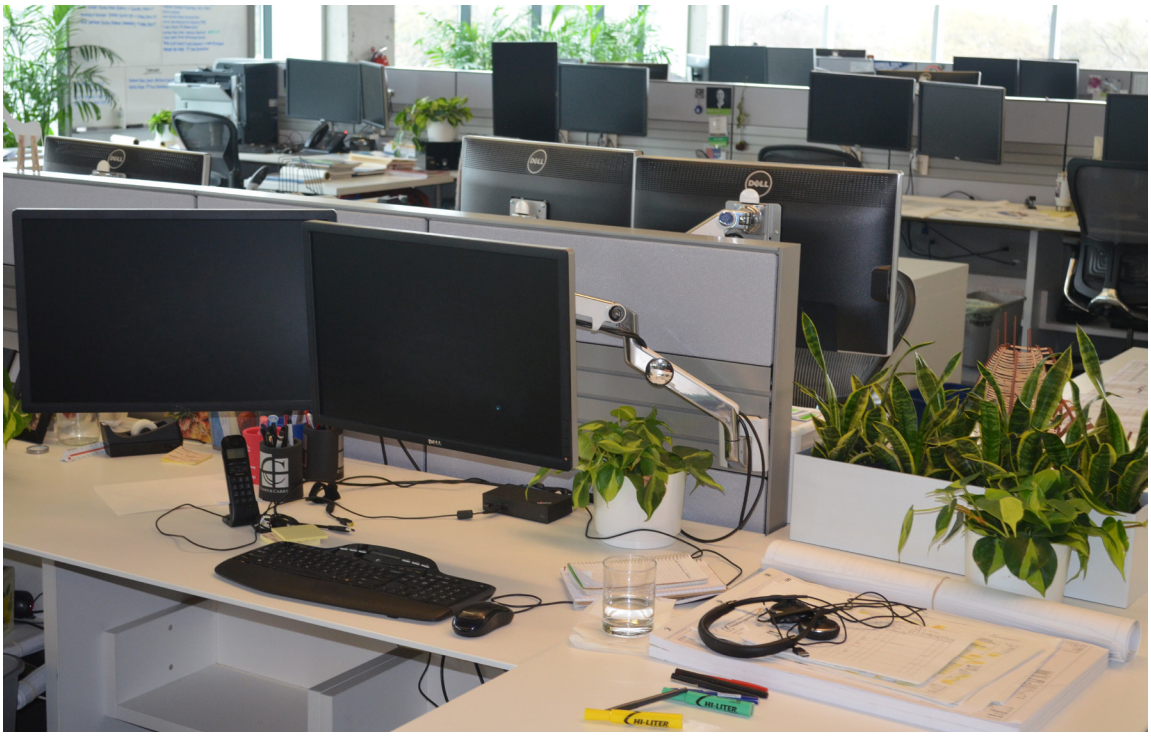

Figure 3b: View of the south side of an employee desk row and plants on Level 6.

Demographic information: Gender, age, income, education, ethnicity, amount of time spent in the office daily (hours) and weekly (days), and exposure to interior and exterior greenery at home were collected via questions added to the end of the psychological well-being questionnaire (PERI). Seat locations were noted by row, with the row closest to the north windows given a one (most natural light) and those farthest away given a four (least natural light). Occupation type was also noted (landscape architecture, architecture/design, or administrative position).

Outcomes (dependent variables)

Psychological well-being: The Standardized Demoralization Index of the Psychiatric Epidemiology Research Instrument (PERI) for nonclinical populations measures psychological distress[28]. Study participants indicated on a five-point scale (never to very often) whether they experienced a specific symptom (e.g., "felt lonely") in the previous three months. Total psychological well-being scores were calculated by summing all items.

Digit span backwards (DSB): The DSB memory task measure used in this study was based on procedures outlined in the Wechsler Adult Intelligence Scale Manual[29]. Participants listened to a sequence of numbers, starting with 3 digits, and were asked to repeat each sequence in the reverse order (e.g., 357 was repeated as 753). A participant's score is the longest number of digits repeated correctly before two consecutive trials fail. This test was used to measure short-term memory and attention of participants.

3.5 Procedures

Data collection

After completing consent forms, employees completed the PERI, demographic questions, and DSB during each of the two data collection sessions. The PERI and demographic questions were completed via computer after participants received an email with a link to a Qualtrics questionnaire. The order of completing the PERI with demographic questions and the DSB was counterbalanced. One of two trained employees at the study site administered the DSB.

Data analysis

Using the Statistical Package for the Social Sciences (SPSS, Version 23), all predictors, demographic covariates, and outcomes were subjected to a linear mixed model procedure, similar to a repeated measures analysis of variance.

4.0 RESULTS

4.1 Study participants

A description of study participants is displayed in Table 2. Participants' occupations included positions in landscape architecture, architecture and design (architecture, branded environment design, graphic design, healthcare planning, and urban design), and administration (accounting, administrative assistant, information technology, and operations). In Session 1, a total of 33 participants completed the PERI first, while 31 participants completed the DSB first (not recorded for 4 participants). In Session 2, a total of 38 participants completed the PERI first, while 28 participants completed the DSB first (not recorded for 2 participants).

Table 2: Participant Description

Variable	Levels	#	%	Variable	n	Mean (SD)	Range
Gender	Male	39	57.35	Age (years)	67	37.25 (9.14)	*21-57*
	Female	28	41.18				
	No answer	1	1.47				
Education level	Some/in college	1	1.47				
	Undergrad degree	21	30.88	Avg light level *foot candles*	67	26.41 (12.52)	10-59
	Some/in grad school	2	2.94	Daily office hour avg	67	8.64 (0,98)	5.5-10
	Graduate degree	43	63.24	Avg office days/week	67	4.87 (0.57)	3-7
	No answer	1	1.47				
Ethnicity	White	50	72.53	Self-reported physical health	67	3.72 (0.78)	2-5
	Non-white	16	23.53	Self-reported psych. Health	67	3.90(0.76)	2-5
	No answer	2	2.94				
Income	<$30k/year	1	1.47	Home exterior greenery *(1 low - 5 high)*	67	2.25 (1.12)	1-5
	$30,001-60k	11	16.18				
	$60,001-80k	9	13.24				
	$80,001-120k	17	25.00				
	>$120k	24	35.29				
	No answer	6	8.82				
Floor level	4	40	58.82				
	6	28	41.18				
Seat Row	1	16	23.53	Home interior greenery *(1 low - 5 high)*	67	4.00 (1.06)	1-5
	2	14	20.59				
	3	15	22.06				
	4	23	33.82				
Occupation	Landscape architect	12	17.65				
	Architect/designer	42	61.76				
	Administrative	10	14.71				
	Not reported	4	5.88				

4.2 Analysis Results

Figures 4a-b display average PERI and DSB scores. Overall scores were poorer with than without plants present on both floors. However, when accounting for study order, gender, psychological health, seat location, and average daily office hours (all other covariates were eliminated due to lack of variation and non-significant results), results indicated that there was a marginally significant effect of plants on memory task performance such that participants performed better on the memory task when plants were present (DSB, p=.055; Table 3). No significant effect of plant presence on psychological well-being was found (PERI, p>.05; Table 3). The strongest predictor of perceived psychological well-being was perceived psychological health (p<.01; Table 3).

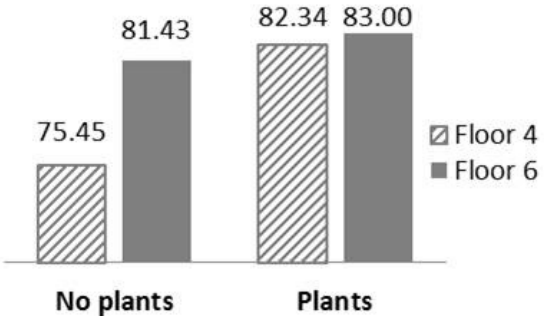

Figure 4a: Psychological Well-Being (PERI sum; higher scores indicate more distress).

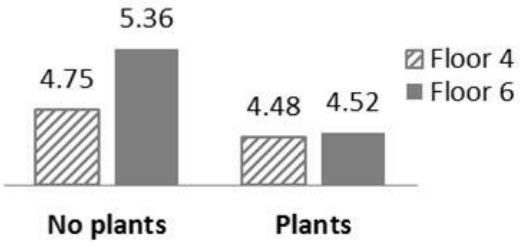

Figure 4b: Memory Task Performance (DSB; higher scores indicate better performance).

Table 3: Effects of Indoor Plants on Psychological Well-Being and Memory Task Performance.

		Psychological Well-Being (PERI)			Memory Task Performance (DSB)		
Variable (levels)		**Estimate**	**(SE)**	**t-test results**	**Estimate**	**(SE)**	**t-test results**
Intercept		91.60	*(10.93)*	t(110) = 8.38, p < .001	5.23	(1.33)	t(79) = 3.93, p < .001
Plants (no, yes)		-0.47	*(1.18)*	t(57) = -0.40, p = .691	0.41	(0.21)	t(62) = 1.96, p = .055
Order (no 1st, yes 1st)		-1.87	*(2.59)*	t(53) = -0.72, p = .473	0.37	(0.28)	t(56) = 1.30, p = .198
Gender (male, female)		3.15	*(2.77)*	t(54) = 1.14, p = .259	0.27	(0.30)	t(56) = 0.90, p = .370
Psych. Health (0-5)	2	-30.76	*(6.59)*	t(104) = -4.67, p < .001	-0.77	(0.82)	t(82) = -0.94, p = .352
	3	-20.90	*(2.92)*	t(114) = -7.15, p < .001	-0.22	(0.39)	t(99) = -0.56, p = .575
	4	-9.96	*(2.35)*	t(112) = -4.23, p < .001	0.16	(0.32)	t(108) = 0.49, p = .622
Seat row (1-4)	2	2.40	*(3.60)*	t(58) = 0.67, p = .508	-0.40	(0.39)	t(61) = -1.03, p = .307
	3	-0.75	*(3.65)*	t(54) = -0.21, p = .838	-0.03	(0.39)	t(57) = -0.07, p = .948
	4	-0.76	*(3.46)*	t(53) = -0.22, p = .826	-0.08	(0.37)	t(55) = -0.20, p = .839
Avg. daily office hours		0.16	*(1.24)*	t(113) = 0.13, p = .896	0.04	(0.15)	t(82) = 0.27, p = .792

Italicized p-value = marginally significant result (.10 > p > .05)
Bold p-value = significant result (p < .05)

5.0 DISCUSSION

5.1 Strengths and Limitations

This study contributes to the literature by examining the effects of indoor plants on design firm employees' psychological well-being and memory task performance. The marginally significant memory task performance and lack of statistically significant psychological well-being results in this study suggest inconclusive rather than negative results. The results allow us to state that no significant effects were found for the specific group of participants in this study, at the specific study location and time. Further studies are required to identify the reasons why significant results were not found. Possible reasons include: 1) there was no effect of plants on psychological well-being and task performance in this study; 2) that other confounding variables were present and not addressed by the research design, such as those discussed in the following paragraph; or 3) that the effect of the plants was small and a better research design is needed. A larger and more varied participant sample; longer duration of plant exposure; isolating the effect of the plants from the presence of windows, views of nature, and natural light;, and randomly assigning participants to the study order will improve the research design. Furthermore, the relatively high ratings of perceived psychological health among all participants indicate that the employees in this study might not benefit from the addition of plants as much as employees who report lower levels of psychological health[4]. A more varied participant sample with employees who report both high and low levels of psychological health is needed.

Previous literature and anecdotal comments from participants offer additional plausible explanations for the study results. Prior work suggests that plants in an office setting may not be noticed by employees who are focused on required daily tasks; instead, plants may have a greater effect in spaces that are intended for restoration (e.g., hospitals)[2]. Anecdotally, one study participant observed that there was initial excitement about the plants among participants, but after a few days, the plants seemed to fade into the background, somewhat like furniture. This comment is consistent with previous studies that find participants may habituate to the presence of plants; their beneficial effects may only be strong during an initial period after their introduction[30]. Several studies have also shown more significant influences of plants in windowless settings[10,19,22,23,24,26]. Furthermore, people who initially report lower levels of psychological well-being may also benefit more from the presence of plants. In other words, the effects of indoor plants on psychological well-being might vary by environmental quality and/or psychological health, such that those who work in poorer quality environments and/or those with poorer quality psychological health may experience greater benefits from indoor plants more than participants in better quality environments and/or with better quality health.

5.2 Future Work

Future studies examining the effects of indoor plans can strengthen and expand upon the research design in four ways. First, larger and more varied participant samples are needed to detect smaller anticipated beneficial effects of indoor plants, especially when compared to effects of direct exposure to outdoor nature. Second, additional variables can be studied. It is unclear how close plants must be to participants and how "green" someone's view must be to influence psychological well-being, task performance, and other outcomes. Documenting and testing plant proximity and the amount of green visible to participants are needed. Third, quantifying the percentage of the view and room occupied by indoor plants are other relevant measures to document and test. This type of quantitative information can facilitate cross-study comparisons as well as identify specific characteristics of plant presence to inform design guidelines. Fourth, a longitudinal study that documents plant effects multiple times, including shortly after installation, a few weeks later, and months later allows for testing short- and longer-term effects of indoor plants. Finally, innovative interventions might be tested to maintain the "novelty" of indoor plant installations so that participants do not become habituated to their presence.

Practitioners who conduct research in professional office settings must also address practical considerations. Thorough and repeated training, including practice sessions and scripts, are needed for practitioners conducting data collection sessions to ensure that each measure is administered in the exactly same way to maintain study validity and reliability. This adds additional time for researchers in busy office settings. Busy office settings also require multiple proctors to administer data collection measures to accommodate busy employee participant schedules. Collecting data in a concise time period is critical to maintain equal plant exposure time among all participants. Adequate funding is needed to support a research design that not only maintains rigor and contributes to the literature, but also is practical for researchers and participants.

6.0 CONCLUSION

Although study results did not support our hypotheses, additional research is warranted to explore further the influence of plants in indoor settings on psychological well-being and task performance. Most people spend the majority of their time indoors. If plants have even a small positive influence on the well-being and performance of individuals in workplaces, it is important to better understand this influence.

Acknowledgments

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