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Tree Cover Ratio Effects on Users' Perceptions, Impressions and Suitability Judgment for Different Activities in Privately Owned Public Spaces

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ABSTRACT

People are drawn to natural settings because they instinctively associate them with providing, nurturing environments. Many studies have linked higher urban greenery ratios to social, psychological, economic, and human health improvements. While urban greenery benefits a large number of people, the monetary burden of its installation and maintenance falls typically to local governments or private entities, requiring urban designers to be able to justify the higher costs of implementation and maintenance. To date, there is still no precise data linking tree cover ratio and the specific effects it has on peoples' perceptions and impressions of urban plazas or in the environment's suitability for different activities. This study expands on the findings of previous studies to explore the effects of tree cover ratio and environment scale across twenty-three different evaluation scales. It used immersive virtual environments to control for confounding variables and head-mounted displays to present the stimuli, allowing participants to experience the environment in its totality as in a natural setting. Higher tree cover ratios improved participants' willingness to stay and pay for goods, improved perception, impressions, and how suitable the environment was for different activities. The specific effects on five measurement scales for activities, nine measurement scales for impression and seven different measurement scales for perception are shown as well as the effects of the interaction of tree cover ratio and environment scale. The effects of sex and architectural background are also tested and discussed. Results offer designers with evidence for the definition of tree amount in relation to environment scale, based on the desired effect.

KEYWORDS

Tree cover ratio;
Privately owned public space;
Plaza-design;
Scale;
Urban environment;

Proporção de Árvores em Espaços de Uso Público: efeitos na percepção, impressão e julgamento da adequação para diferentes atividades pelo usuário

RESUMO

As pessoas são atraídas por ambientes naturais pois, instintivamente, os associam a ambientes férteis que provém condições de sobrevivência. Uma vasta gama de estudos vinculam proporções maiores de vegetação urbana a melhorias em condições sociais, psicológicas, econômicas e de saúde. Embora a vegetação urbana beneficie um grande número de pessoas, o custo de instalação e manutenção desta infra-estrutura normamente recai sobre governos e entidades privadas, sendo exigido de arquitetos, urbanistas e paisagistas a capacidade de justificar os custos mais elevados de implantação e manutenção de seus projetos ao utilizarem uma maior quantidade de vegetação. Até o momento, não há dados precisos vinculando a proporção de cobertura de árvores aos efeitos específicos na percepção e impressão de praças urbanas ou a percepção da adequação destes espaços para o desenvolvimento de diferentes atividades. Este estudo expande as conclusões de estudos anteriores para explorar os efeitos que a cobertura por árvores e a escala do ambiente têm em vinte e três diferentes escalas de avaliação. Usa ambientes virtuais imersivos para controlar para o efeito de variáveis indesejáveis e *head-mounted dysplays*, permitindo que os participantes percebam e avaliem o ambiente em sua totalidade, como no ambiente real. Áreas maiores de cobertura por árvores melhoraram a disposição dos participantes para permanecer por mais tempo e pagar mais por produtos de consumo, melhorou a percepção, impressão e adequação do ambiente para a execução de cinco diferentes atividades. Os efeitos específicos, assim como possíveis efeitos da interação entre a cobertura por árvores e escala do ambiente são apresentados em cinco escalas de avaliação de atividades, nove escalas de impressões e sete escalas de avaliação da percepção do ambiente. Os efeitos de sexo e conhecimento de arquitetura também são testados e discutidos. Os resultados oferecem evidência baseada em dados para que designers possam propor a quantificação de árvores em função do efeito desejado.

PALAVRAS-CHAVE

Proporção de cobertura por árvores;
Espaços de uso público;
Desenho de praças;
Escala;
Espaço Urbano

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1. INTRODUCTION

Special attention to the selection of trees may be given in the design of ecological systems, wildlife/green corridors, or parks, in contrast to the urban context where the attention is given to characteristics such as tree shape/height, aesthetics, or maintenance. Research in urban greening has focused on users' preferences for landscapes (HOFMANN *et al.*, 2012), scenery (JIANG *et al.*, 2015; LOHR; PEARSON-MIMS, 2006; NG *et al.*, 2015), tree characteristics (GERSTENBERG; HOFMANN, 2016; NELSON, THOMAS, *et al.*, 2001; SOMMER, 1997; ZHAO; XU; LI, 2017) or presence of a tree as an isolated element (HSIEH; LEE, 2010).

The evidence for the relationship between increases in the quantity/quality of urban greenery and its effects on users' perceptions and impressions of the urban environment is lacking, especially if distinguishing between different public settings such as streets, public squares, or parks. Furthermore, because preference varies depending on the intended activity (NASAR; YURDAKUL, 1990; NELSON, N. M. *et al.*, 2008; WARD THOMPSON, 2013) and overall context (SUMMIT; SOMMER, 1999), a qualification of "*preference*" is needed.

This qualification may be achieved by asking participants about the environment's *suitability for a specific activity* instead of *preference*. Asking participants about suitability for different activities has the added benefit of going one step further into users' behavior and provide results that are better suited for evidence-based design.

The present study investigates the effects of tree cover ratio (TCR) on users' perceptions and impressions of privately owned public spaces (POPS) and the environments' suitability for five specific activities and their willingness to stay and willingness to pay in said environment. It also considers the environment's scale and its interactions with the tree cover ratio. The aggregated results presented may establish a baseline of the effects tree cover ratio has on POPS' users and provide designers with a practical reference for evidence-based design.

2. BACKGROUND

Trees resonate with our primal subconscious, with our idea of a fertile and nurturing environment, and, as such, they provide aesthetic beauty to our built environment as well as relief from it (ORIANS; HEERWAGEN, 1992). In urban design, trees are used to give a sense of comfort, create a specific micro-climate, provide shade, scenery, for its colors, flowers, fruits, or smells. The designer may have to consider the tree amounts, sizes, species, combinations, and maintenance, amongst other variables.

The mere presence of trees can positively affect the perception of an urban plaza, city image, shopping atmosphere, cleanliness, worth of stay, and willingness to visit or revisit urban squares (RAŠKOVIĆ; DECKER, 2015). In addition, they can positively affect perceptions, patronage behavior, and product pricing in business districts (WOLF, 2005) and reduce crime rates for assault, battery, robbery, and narcotics (SCHUSLER *et al.*, 2018).

People's perceptions of urban trees are positive regardless of their socio-economic context (GWEDLA; SHACKLETON, 2019).

The number of trees present in an urban environment can also affect users' propensity to develop specific activities in it, such as rest, stay, meet or wait (HSIEH; LEE, 2010; JIANG *et al.*, 2015; TANAKA; KIKATA, 2008).

In streetscapes, trees mitigate oppressiveness (ASGARZADEH *et al.*, 2012). Tree cover density is positively correlated with the preference of streets in residential areas (JIANG *et al.*, 2015), with higher house prices and shorter market period (DONOVAN; BUTRY, 2010; MEI; HITE; SOHNGEN, 2017), higher land prices (ISHIKAWA; FUKUSHIGE, 2012) and with a reduced risk of adverse mental outcomes such as depression (TAYLOR *et al.*, 2015).

Aesthetically, several studies relate the crown, also known as the tree canopy, regarding the amount and shape of the leaves and whether the trees shed their leaves in the fall (deciduous trees) or keep the leaves year-round (evergreen). For example, it was found that deciduous trees are preferred over Conifers (GERSTENBERG; HOFMANN, 2016), that broad canopies are preferred over narrow ones (LOHR; PEARSON-MIMS, 2006; SOMMER, 1997; SOMMER; SUMMIT, 1996; SUMMIT; SOMMER, 1999), that dense canopies are preferred over sparse ones (GERSTENBERG; HOFMANN, 2016; LOHR; PEARSON-MIMS, 2006; NELSON, THOMAS, *et al.*, 2001), and high crown size to trunk ratio is preferred (GERSTENBERG; HOFMANN, 2016; SOMMER; SUMMIT, 1995; SUMMIT; SOMMER, 1999).

Context conditions preference for tree form: in suburban and city environments, trees that match the surrounding buildings in height and shape are preferred, while in undeveloped settings, people prefer taller trees (SUMMIT; SOMMER, 1999).

When used in streets for urban greening, people prefer trees planted on both sides over trees in the middle of the street, which is still better than no trees at all (NG *et al.*, 2015).

Increasing the number of trees improves general preference, with the most improvement occurring between 0 and 10% of tree density as measured in site plan or between 0 and 20% as measured from panorama pictures. The effects' magnitude diminishes as density increases up to 60% (JIANG *et al.*, 2015).

Based on Jiang *et al.* (2015) research, there is no financial incentive to increase tree coverage past 20% of floor area ratio since there will be little improvement in preference but at a standard implementation and maintenance costs.

Especially when designing privately owned spaces, designers may be asked to justify the need for higher tree cover ratios, and, aside from the vague concept of preference, there is still little understanding of its effects on people's experience of the environment.

A higher tree cover ratio may also mean that people will be willing to stay longer or spend more on goods and services, translating into a financial incentive for higher tree cover ratios. Additionally, it is not clear that users' judgment of tree cover ratio in plazas will follow the same preference curve proposed by Jiang *et al.* (2015) for streets in residential areas.

This study focuses on privately owned public spaces and investigates whether increasing tree cover ratio affects users' perceptions, impressions of the environment, and the perceived suitability for five different activities. It also examines the effects of the environments' scale and possible interactions between variables.

3. METHODS

This study expands the results of a previous study (AVALONE NETO *et al.*, 2017) that first investigated the presence or absence of an effect from TCR and of interactions with tree height and seating ratio on twenty-three measurement scales: five related to the environments perceived suitability for different activities, nine related to impressions of the environment, seven related to the perception of it, one related to peoples' willingness to pay for goods (a cup of coffee or tea), and one related to peoples' willingness to stay in the environment.

That study adopted TCR at two levels: covering 20% and covering 40% of the floor area ratio (FAR), and found an effect on 9 out of 23 measurement scales. The present study expands the range of TCR from 5% to 50%, investigates the effects at higher and lower ratios, and possible interactions with the environment scale. It utilizes the same methodology adopted in Avalone Neto *et al*. (2017) for practical and comparative purposes.

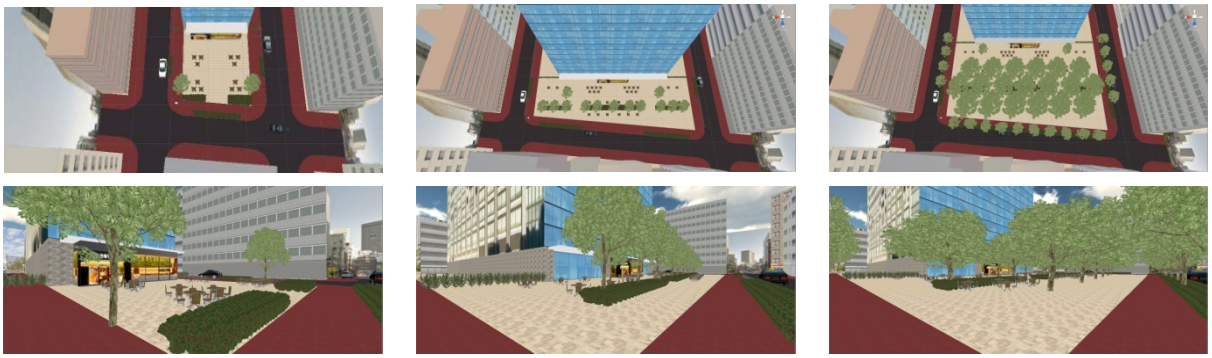
This experiment adopted two variables with three levels each: TCR at 5%, 10%, and 50%, and environment size varying from small (600m²), medium (2000m²), and large (3500m²), resulting in 9 different environment combinations (Table 1). All other variables, such as surrounding buildings' height and type, amount of bushes, seats, or cars, were controlled. Figure 1 shows an example of samples.

Table 1 Stimuli matrix.

	Small (600m²)	Medium (2000m²)	Large (3500m²)
TCR at 5%	S01	S04	S07
TCR at 10%	S02	S05	S08
TCR at 50%	S03	S06	S09

Table 2 Adopted measurement Scales.

		Measurement	Scale
1	Activities	Suitability for stay activity	Unsuitable – suitable
2		Suitability for eat/drink activity	Unsuitable – suitable
3		Suitability for rest activity	Unsuitable – suitable
4		Suitability for read activity	Unsuitable – suitable
5		Suitability for wait activity	Unsuitable – suitable
6	Impressions	Appeal	Not appealing – appealing
7		Interest	Not interesting – interesting
8		Enclosure	Do not feel enclosed – feel enclosed
9		Atmosphere	Gloomy – cheerful
10		Relaxation	Not relaxing – relaxing
11		Openness	Not open – open
12		Oppression	Do not feel oppressed – feel oppressed
13		Liveliness	Not lively – lively
14		Diversity	Uniform – diverse
15	Perceptions	Size	Small – large
16		Greenery amount	To little greenery – a lot of greenery
17		Greenery placement	Badly placed – well placed
18		Seating amount	Too few seats – a lot of seats
19		Seating placement	Badly placed – well placed
20		Seating design	Badly designed – well designed
21		View	Bad View – good View
22		Willingness to Pay	From 0 to 1000 yen or more
23		Willingness to Stay	From 0 to 2 hours or more



A S01 – stimulus 01. B S05 – stimulus 05 C S09 – stimulus 09

Figure 1 Stimuli adopted for the experiment, seen from above (top images) and from the ground level (bottom). Here are shown the stimulus 01 (small environment with TCR at 5%) marked as 'A'; stimulus 05 (medium environment with TCT at 10%) marked as 'B', and stimulus 09 (large environment with TCR at 50%) marked as 'C'.

Each stimulus was digitally modeled using SketchUp and compiled into the Unity software for materials, lighting, and camera positioning. Participants experienced the samples as an immersive virtual environment (IVE) through a head-mounted display (HMD - Oculus rift) and were able to move around it using a Logicool F710 gamepad.

The evaluation of computer-generated environments yields results similar to those of real settings (JANSEN-OSMANN; BERENDT, 2002; LANGE, 2001; STAMPS, A. E., 1990; WILCOX *et al.*, 2003). Avalone *et al*. (2016) tested the specific use of IVE stimuli experienced through HMD to evaluate public space environments and found no significant difference between real and virtual environments for the measurement scales adopted.

Stimuli consisted of a plaza, with 10% of FAR covered by bushes and 3% covered with seating. The plaza always had 3

of its sides open to streets that were 7m wide, while the fourth side had a 120m tall building (34 floors) with a coffee shop at the ground level. All sidewalks were designed at 4m wide, and the total area of the plaza includes a sidewalk area (Figure 1).

Participants were presented with the questionnaire in paper format after they examined each environment. However, they were still able to see the environment through the monitor and move through it while answering the questionnaires, and they were free to use the HMD whenever they judged necessary, even while answering the questionnaire.

The questionnaire consisted of 21 seven-point semantic differential scales and two multiple choice questions regarding stay time and willingness to pay (Table 2). The semantic differential questionnaire had the statement "neither" on the middle and "somewhat agree," "agree," and "totally agree" as it got closer to each statement on both sides of the evaluation scale.

A total of 20 participants (13 Males, 7 Females) took part in the study, each evaluating all nine samples in random order, totaling 180 observations. They were all Japanese university students from different fields of study and averaged 21.3 years of age (SD=1.89).

The sample size was chosen based on a power analysis. Previous exploratory research showed a standard deviation of measurement scales varying between 1 and 1,5. For this study, a significance level of 0,05, a standard deviation of 1,6, and power of 0,8 allowed the detection of a 0,6 difference in score with only 18 participants, meaning that, with 18 participants, there was an 80% chance to detect value differences of 0,6 or more if they are present in responses score. Thus, although not ideal, 20 participants still ensure a 90% chance to detect differences of 0,6 or more at the expected standard deviation of 1,5.

A two-factor analysis of variance (ANOVA) with interaction was conducted using TCR and Scale as predictors of each evaluation scale's responses. In addition, Tukey's HSD multiple comparison tests were also undertaken to test if the variables' means were significantly different and could thus be treated as different levels of that variable.

4. RESULTS

An analysis of variance was conducted using the variables as predictors to the score of each evaluation scale to evaluate the effects of TCR and environment scale, presenting the following results:

4.1 Activities

TCR affected *Read* activity, increasing it from 5% or 10% to 50% increased perceived suitability for *Read* activity. It also had a small effect on *Stay* and *Rest* activities, but only between the ratios of 5% and 50%, while no statistical difference could be perceived between 5% and 10% or 10% and 50% of TCR. No effect of TCR could be observed on *Eat/drink* or *Wait* activity (Table 3 and Figure 2).

The *Scale* also affected *Stay*, *Rest,* and *Read* activities where small environments were worse than medium or large environments, but no statistical difference was observed between medium and large-scale environments, and no interaction was observed (Table 3 and Figure 3).

For *Wait* activity, small environments were perceived as more suitable than medium or large ones, while no statistical difference could be observed between medium and large environments. Furthermore, no effect of environment scale was observed in *Eat/drink* activity, and no interaction between TCR and environment *Scale* was observed for any activity (Table 3 and Figure 2).

Table 3 TCR and Scale Effect on Activities

	Stay	Eat/drink	Rest	Read	Wait
TCR	10.76**		3.45*	12.70**	
Scale	6.64*		8.20*	9.70**	6.77*
TCR x Scale					
R^2	0.17		0.12	0.22	0.08

Note: values expressed are F (2,171); ** = p<.0001; * = p<0.005.

4.2 Impressions

A direct effect of TCR could be seen in *Appeal* and increasing TCR improved environment *Appeal* at all levels. Increasing TCR from 5% to 10% did not affect *Interest*, *Enclosure*, *Relaxation*, or *Oppression*, but a positive effect could be seen between 5% and 50% and between 10% and 50%.

A negative effect of TCR could be perceived in the impressions of *Openness,* and when TCR was increased from 5% or 10% to 50%, the environment was perceived as less *Open*.

Diversity was affected by TCR, but only when increasing it up to 50%, and no statistical difference could be observed between 5% and 10% or 10% and 50%. TCR did not affect *Atmosphere* or *Liveliness* (Table 4 and Figure 4).

The environment *Scale* directly affected *Openness* perception, and the larger the environment, the more open it was perceived. *Interest*, *Liveliness,* and *Diversity* were also affected by the environments' scale, with small environments been perceived as worse than medium or large ones. No difference between medium and large environments was observed.

The impression of the environment's *Atmosphere* was also affected by *Scale,* and large environments were perceived as better than small ones. However, no difference between medium and large or small and large environments was observed (Table 4 and Figure 5).

Medium and large environments were perceived as less *Enclosed* than small environments, and small environments were perceived as more *Oppressive* than large ones, although no statistical difference could be observed between small and medium or medium and large environments.

Table 4 TCR and Scale Effects on Impressions

	Appeal	Interest	Enclosure	Atmosphere	Relaxation	Openness	Oppression	Liveliness	Diversity
TCR	14.74**	12.32**	31.53**		15.03**	17.80**	5.33*		3.62*
Scale		9.22*	9.53**	4.77*		18.27**	4.03*	11.50**	12.04**
TCR x Scale			3.59*			2.89*	2.90*		
R^2	0.17	0.20	0.36	0.09	0.15	0.33	0.15	0.12	0.16

Note: values expressed are *F* (2, 171); ** = p<.0001; * = p<0.005.

No effect of environment *Scale* could be observed for environment *Appeal* or *Relaxation*. Interactions between TCR and environment *Scale* could be observed only in impressions of *Enclosure* (R^2 = 0.36; F (4, 171) = 3.59; p = 0.0078),

Openness (R^2 = 0.33; F (4, 171) = 2.89; p = 0.0237) and *Oppression* (R^2 = 0.15; F (4, 171) = 2.90; p = 0.0235) where large environments with 50% of TCR were perceived as less open, more enclosed and more oppressive than expected. No other interaction between TCR and environment *Scale* could be observed in any perception scale.

4.3 Perception

TCR directly affected the perception of *Greenery Amount,* and increasing tree coverage increased the perceived greenery amount at all levels. *View* required a larger coverage ratio to be affected, and an effect could be observed when the ratio was incremented from 5% to 50% and from 10% to 50%, but no effect was observed when incrementing from 5% to 10%.

A small effect could be perceived in *Greenery Placement* and *Seating Amount* and increasing TCR from 5% to 50% improved perception, but no effect could be seen in increments from 5% to 10% or 10% to 50%. TCR does not affect the perception of *Size*, *Seating Placement,* or *Seating Design* (Table 5 and Figure 6).

Environment *Scale* matched actual environment *Size* at all levels, showing no scale perception bias from the selected method. In addition, no interaction between the TCR and environment *Scale* was observed (Table 5 and Figure 7).

An effect of *Scale* could be observed in *Greenery Amount*, *Seating Amount,* and *View* perception. Although small environments were perceived as having fewer seats/greenery and worst (less interesting) *View* than medium or large scale environments with the same ratio (i.e., greenery at 10% of floor area), no statistical difference could be observed between medium and large environments and no interaction was observed.

No effect of *Scale* or interactions could be observed in the perception of *greenery placement*, *seating placement,* or *seating design* (Table 5).

Table 5 TCR and Scale Effects on Perceptions

	Size	Greenery Amount	Greenery Placement	Seating Amount	Seating Placement	Seating Design	View
TCR		72.17**	6.49*	3.83*			7.45*
Scale	88.30**	12.36**		18.81**			14.37**
TCR x Scale							
R^2	0.52	0.50	0.10	0.21			0.22

Note: values expressed are *F* (2, 171); ** = p<.0001; * = p<0.005

4.4 Willingness to pay and willingness to stay

TCR had a positive effect on both *willingness to pay* (R^2 = 0.10; *F* (2, 171) = 6.30; p = 0.0023) and *willingness to stay* (R^2 = 0.22; *F* (2, 171) = 14.19; p<.0001) and people were willing to pay more and stay longer in environments with 50% of tree coverage than in environments with only 5% of TCR. No statistical difference could be observed between 5% and 10% or 10% and 50% (Figure 8 and Figure 9).

Scale also had an effect and people were *willing to pay* (R^2 = 0.10; *F* (2, 171) = 3.37; p = 0.0333) more and *willing to stay* (R^2 = 0.22; *F* (2, 171) = 8.66; p = 0.0003) longer at larger environments than small ones. Additionally, people also were willing to stay more in medium-sized environments than small ones, although this could not be observed in willingness to pay. No interaction between scale and TCR was observed.

Considering the average values provided by participants, when TCR was at 50% of FAR, participants were willing to pay up to 16.8% more and spend 34% more time than when trees covered only 5% of the floor area. People were also willing to pay 12.4% more and stay 40.9% longer in larger environments than in smaller ones and stay 52.3% more in medium-sized environments than in small ones.

4.5 Effects of sex

The averaged data by stimuli and sex was used to analyze the effects of sex. There were two data points for each stimulus, one for the average answer of males (13 participants) and another for the average answer of females (7 participants). Analysis of variance was done with sex as a predictor for each of the 23 evaluation scales, using those 18 data points.

From the 23 different evaluation scales (Table 2) sex effect was found in the *Atmosphere* (R^2 = 0.28; F (1, 17) = 6.19; p = 0.0243) and *Seating Placement* (R^2 = 0.22; F (1, 17) = 4.56; p = 0.0485) with women judging the environment as having a better *Atmosphere* and better *Placed Seats* than as judge by men. All other evaluation scales had no significant sex effect.

4.6 Effects of architectural background

The averaged answer by background and stimuli was used to test for the effects of architectural background, resulting in 18 data points: two for each stimulus, one for architecture students, and another for non-architect students. An analysis of variance using the architectural background as predictors for each of the 23 evaluation scales was conducted.

Only *Atmosphere* (R^2 = 0.22; F (1, 17) = 4.60; p = 0.0476) was affected by architectural background, with architectural students perceiving the environment as having a worse atmosphere than non-architecture students. This notion agrees with Llinares and Inarra (2014) and Akalin *et al.* (2009) that people with an architectural background are more critical of the environment than laypeople. All other scales had no significant effect on the architectural background.

5. DISCUSSION

Higher TCR or canopy size have already been linked to environmental preference (DONOVAN; BUTRY, 2010; GERSTENBERG; HOFMANN, 2016; JIANG *et al.*, 2015; LOHR; PEARSON-MIMS, 2006; RAŠKOVIĆ; DECKER, 2015; SOMMER, 1997; SOMMER; SUMMIT, 1996; SUMMIT; SOMMER, 1999), although preference does not easily translate into behavior. There is still the question of whether preferable environments will improve visitability, prolong users' stay or stimulate any specific activity. Other research has asked more design-centered questions such as whether or not it enhances visitability (ABDULKARIM; NASAR, 2013) or for which activity is the environment suitable (AVALONE NETO, *et al.*, 2017).

This study explored the effects of TCR on specific behavioral-related measurement scales, such as environment perception, impressions, specific activities, willingness to stay, and willingness to pay for goods. The findings, their implications, and their relation to previous research are discussed below.

Increased TCR had a definite effect on suitability for the *Read* activity, but no effect could be observed for *Eat/drink* or *Wait* activities (in agreement with Avalone Neto *et al*., 2017). A small effect in *Stay* and *Rest* activities was also observed in the present study, but not in Avalone Neto *et al*. (2017). Since the improvement of perceived suitability was small for these two activities, it could only be observed at more considerable differences of TCR (e.g., 5% and 50%) but not at minor (e.g., 20% and 40%) ratio differences, as tested by Avalone Neto *et al*. (2017), when the effects seem to be negligible (Figure 2). Participants prefer environments with more TCR for *Read* activity, but it does not affect their preference for *Eat/drink* or *Wait* activities. These differences in judgment could only be observed due to the distinction made between different activities instead of inquiring about preference.

The perception of the environments' *Appeal*, *Interest*, *Enclosure*, *Relaxation*, *Openness,* and *Oppression* was similarly affected by TCR as Avalone Neto *et al*. (2017), as were the absence of effects in the *Atmosphere* and *Liveliness* evaluation scales (Figure 4). While tree cover may mitigate oppression in street settings (ASGARZADEH *et al.*, 2012), they increased perceived oppression and enclosure in plaza settings. This difference most likely occurs because enclosure and oppression are highly related to boundary height and proximity to the boundary (STAMPS, ARTHUR E., 2013), which are different in street and plaza settings. In Asgarzadeh *et al.* (2012), trees mitigated oppression by diminishing the perception of an oppressive boundary, while in this study, tree cover itself was perceived as a boundary, and as its size increased, so did oppression (Figure 1).

The positive effect TCR had on *Appeal* is consistent with Rašković and Decker (2015), who found that the presence of trees improves perceived aesthetics, and with Jiang *et al.* (2015) that suggest its effects increase with higher ratios.

Impressions of *Diversity* also showed a small effect when TCR increased from 5% to 50% (Figure 4). However, the effect was not observed in Avalone Neto *et al.* (2017).

Perception of *Greenery Amount*, *Seating Placement,* and *Seating Design* was consistent with Avalone Neto *et al.* (2017). However, *Greenery Placement* and *Seating Amount* showed a small effect, while Avalone Neto *et al.* (2017) showed none, which may be explained by the TCR range evaluated. Improvement in the perception of seat placement and seat design agrees with Rašković and Decker (2015), who found that people perceive a square as having more comfortable seating possibilities when trees are present.

Differences between studies could be observed in *View* and *Size* perception: while Avalone Neto *et al.* (2017) found a small effect of TCR in the perception of environment *Size* and no effect on perceived *View*, the present study found no effect in the perception of the environment *Size* and a small effect in *View* perception (Figure 6). Since, in both cases, the effects observed are small, it could be attributed to the *tree cover ratio* range studied, but further investigations are necessary for conclusive results.

Overall, when the effect of TCR is present, it seems to follow a response curve similar to that proposed by Jiang *et al*. (2015) in which, although there is an effect, it offers only a small improvement in perception/impression/suitability in the ranges from 5% and 50% and large increments in the range between 0% and 5%. The only exceptions to this pattern were the perception of *Greenery Amount* and *Enclosure*, both with a more steep increment curve.

The effects of *Scale* partially agree with the supposition of Avalone Neto *et al.* (2017) that small environments are perceived as somewhat different than other environments. Small environments were perceived to be less suitable for *Stay*, *Rest* and *Read* activity, more suitable for *Wait* activity, less *Open*, less *Interesting*, less *Lively*, less *Diverse*, more *Enclosed*, more *Oppressive*, *Smaller*, having fewer *Seats*, less *Greenery,* and worst *View*. However, no consistent difference was observed between medium and large-scale environments, except for *Atmosphere*, where large environments were perceived as better than medium or small environments.

Environment *Scale* had no observable effect in suitability for *Eat/drink* activity, the impression of *Appeal*, *Relaxation,* or perception of *Greenery Placement*, *Seat Placement,* or *Seat Design*.

People were willing to pay more and stay longer in environments with greater than 50% TCR compared to 5%. The result in peoples' willingness to pay agrees with Joye *et al.* (2010) that the presence of trees affects respondents' valuations of products and translates into a higher mean price acceptance.

A positive effect was also observed for *Scale*, and participants were more willing to pay and stay longer in larger environments when compared with small ones. The same relation is valid for medium and small environments regarding willingness to stay but not willingness to pay.

The results presented in this study were limited by its sample size, demographic, and cultural factors, being representative of Japanese in their 20s. Different social and economic strata may yield different results, and further studies are necessary for a broader generalization. Results presented in this study aggregate, however, with those given by Avalone Neto *et al.* (2017), which had a larger sample size of 59 participants from a wider age group (M=24; SD=6.22), included office workers and adopted the same methods and materials.

Because of the small sample size, this study could not detect score differences lower than 0,6 with any statistical confidence, meaning that, even when this study found no effect of TCR or Environment Scale in a given measurement scale, there may still be a small effect that was not detected. Further studies with larger sample sizes are needed to test more subtle effects.

The study is also limited since it did not consider climate, time of year, or weather condition related variables such as temperature, wind, sun exposure, or presence of rain, which may directly affect peoples' thermal comfort and skew preference towards environments with more or less tree cover. Previous research (LIN *et al.*, 2013; NIKOLOPOULOU; LYKOUDIS, 2007; ZACHARIAS; STATHOPOULOS; WU, 2001) have pointed out that thermal comfort can affect public space attendance during different seasons, and people tend to seek shaded areas during hot seasons, which may increase ratings of highly shaded environments in hot tropical regions.

Another possible limitation was that the TCR measured the overall area of the canopy tree against the floor area ratio, but it did not consider the canopy density itself. There may be some differences in the effects of dense canopies and sparse ones, as suggested by several other researchers in different settings (GERSTENBERG; HOFMANN, 2016; LOHR; PEARSON-MIMS, 2006; NELSON, THOMAS, *et al.*, 2001). If there is an effect of the canopy density itself in the perception and impressions of the environment, a tree cover ratio measure that accounts only for the projected leaf area of the canopy, disregarding voids in the canopy, may be more suitable.

6. CONCLUSIONS

Increasing TCR to 50% improves environment suitability for *Read*, *Stay* and *Rest* activities, although, to *Stay* and *Rest*, no difference could be found between 5 and 10% or 10 and 50%.

Furthermore, no effect could be consistently observed for *Eat/drink* or *Wait* activities.

Increasing TCR will make the environments to be perceived as more *appealing*, *interesting*, *relaxing,* and *diverse* (marginally) but also more *enclosed*, less *open*, and more *oppressive*. However, it did not affect the impressions of an environments' *Atmosphere* or *liveliness*.

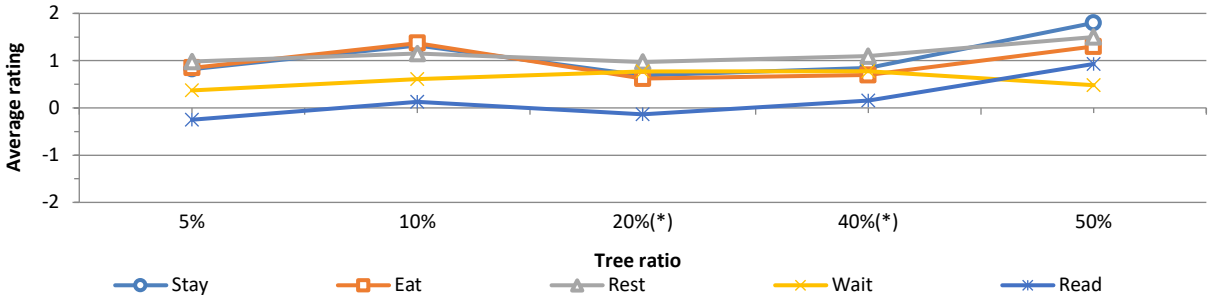


Figure 2 Activities average score by TCR.
"(*)" denotes results obtained from Avalone Neto et al. (2017)

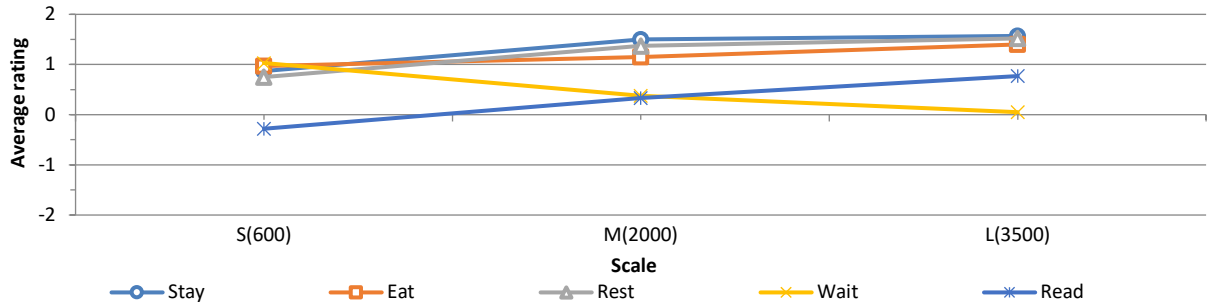


Figure 3 Activities average score by scale.

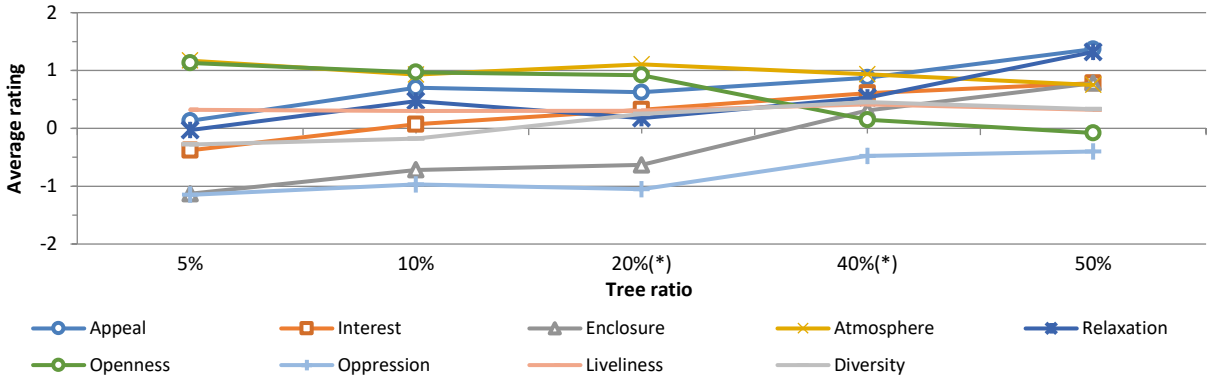


Figure 4 Average impression score by TCR.
"(*)" denotes results obtained from Avalone Neto et al. (2017)

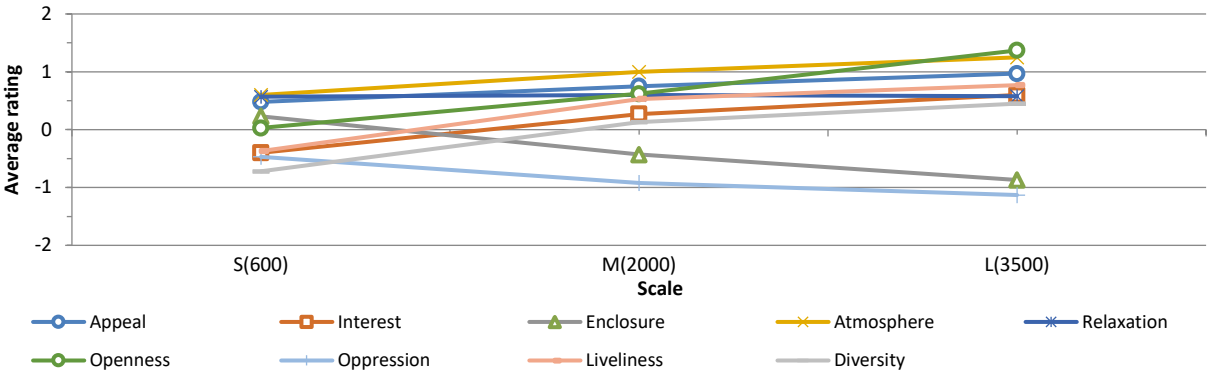


Figure 5 Average impression score by scale.

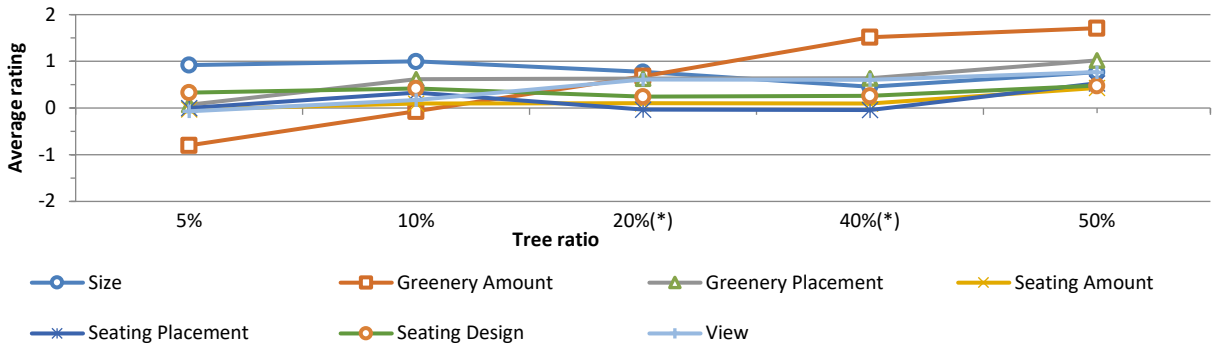


Figure 6 Average perception score by TCR
"(*)" denotes results obtained from Avalone Neto et al. (2017)

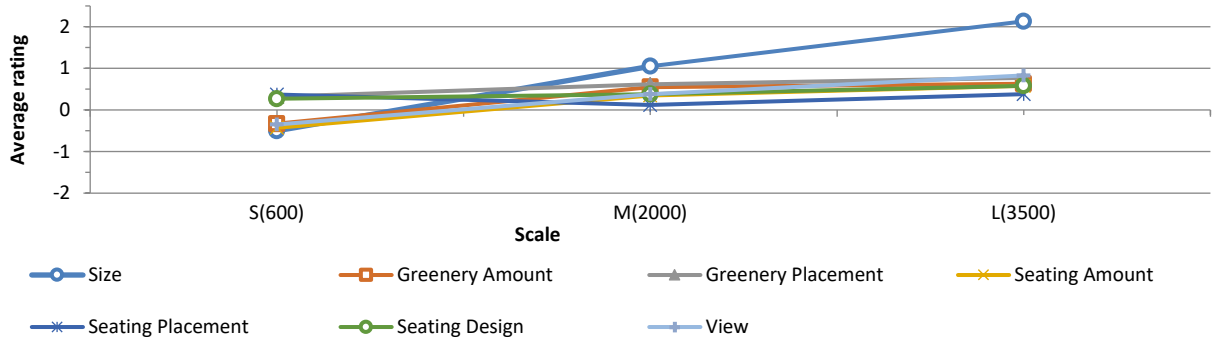


Figure 7 Average Perception score by scale

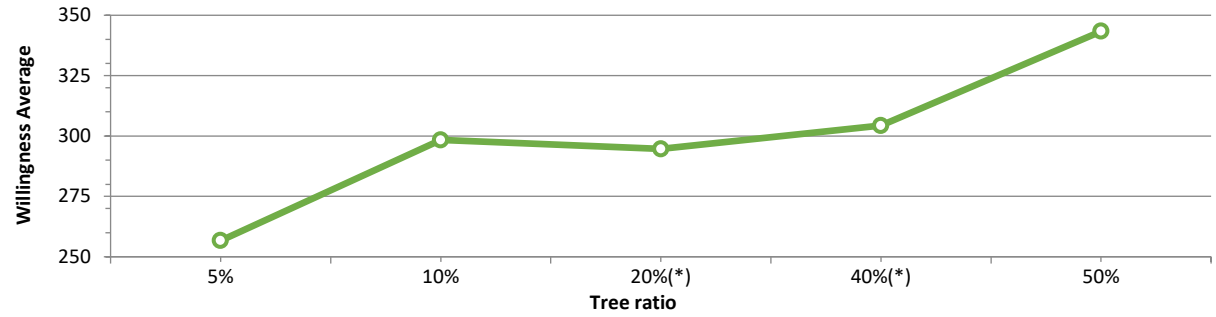


Figure 8 Average amount participants were willing to pay for a drink. Values in Japanese yen.
"(*)" denotes results obtained from Avalone Neto et al. (2017)

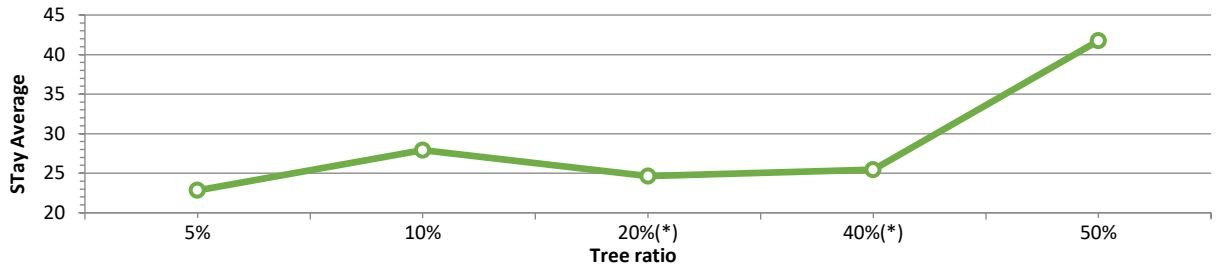


Figure 9 Average time participants were willing to stay in the plaza. Values in minutes.
"(*)" denotes results obtained from Avalone Neto et al. (2017).

Overall, increasing TCR made the environments' perception, impressions, and suitability for activities either improve or remain the same, except for *Enclosure*, *Openness*, and *Oppression*. It also positively affected the *willingness to pay* and *willingness to stay* in the environment.

Small environments (600m^2) were perceived as less suitable for *Stay*, *Rest*, and *Read* and more suitable for *Wait* activity.

Although TCR does not affect perceived suitability for activities other than *Read*, it does improve users' impressions of the environment considerably. Overall, the more tree cover, the better are the impressions of the environment, at least up to 50% of the floor area, which was the limit investigated by this study. The apparent exceptions to this rule are perceived *Openness*, *Oppression*, and *Enclosure,* which are

negatively affected by higher cover ratios (less open, more oppressive, and more enclosed).

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