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Evaluation of the effect of landscape distance seen in window views on visual satisfaction

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Abstract

Daylighting standards dictate that the view seen through a window can be evaluated using several criteria. Among one of them is the distance at which the visual content can be seen. However, not enough guidance is given on how this criterion can be applied in practice. We used two approaches to address this problem: online surveys and human subject assessment in a controlled experiment using an artificial window. Images were used in both cases to represent window views. Two independent groups of participants took part in either study and both gave subjective satisfaction ratings to three parameters, namely, connection to the outside, visual content and visual privacy. Eighteen images were evaluated in the online surveys by a total of 91 participants while eight images were rated by 50 participants that took part in the controlled experiment. We developed a calculation method, named the Observer Landscape Distance (OLD), to quantify the distance of the window view landscape from the occupant. Our initial results showed that people are more satisfied when features are far away. However, we also showed that when the landscape contained nature, the effect of distance was smaller. If far away views cannot be provided due to site constrains, nature (e.g. trees) should be integrated nearby to increase satisfaction. Current daylighting standards promote distant views regardless of its visual content (nature or urban). We found that visual content matters and occupants prefer urban features to be viewed from a distance, whereas this same recommendation does not apply for nature.

Keywords: Artificial window; Landscape; Nature; Window view; Urban

1. Introduction

Horizontal stratification is used to define different window views by separating distinct boundaries that are present within the visual scene according to three layers: "ground", "city or landscape" and "sky" [1]. Both the EN 17037 [2] and Society of Light and Lighting (SLL) Lighting Guide 10 [3] provide nearly the same guidance to designers by recommending the presence of all three layers in window views. Both daylighting standards also recommend that visual content seen in the view be distanced at minimum thresholds from the occupants' viewing position: distance ≥6 m, 20 m and 50 m, resepectively. The quality of the view would qualify as being "sufficient", "good" and "excellent" when the content is distanced further from the view according to these thresholds.

Promoting distant views is an effective method of reducing unwanted visual fatigue and asthenopia (eyestrain) when occupants are focussing on objects close within their visual field (e.g., computer display screens) [4]. This allows the eyes to focus on far objects and provides muscular relief that can minimise the risks of strain [5]. Studies indicate that asthenopia or related visual discomfort symptoms become risk factors at short viewing distances between the observer and the visual stimulus [6,7]. These ocular problems have been associated with the prolonged use of visual displays (e.g., computer screens [8,9], cellular mobile phones [10] and tablet computers [11]. When 324 individuals reported that they used a visual display at their workplace for a minimum of two hours a day, 65 % had eyestrain and 42 % reported headaches [12].

Studies have shown that window views containing distant elements are generally favoured. Markus [1] discovered in an office building that occupants preferred to see a distant city or landscape layer in the window view. Ne'Eman and Hopkinson and [13] showed that the minimum acceptable window size was smaller when the observer viewed a landscape containing distant objects. The authors suggested that distant objects containing more information could still be seen through a smaller apperture due to the visual parallax. When the landscape is seen at a far away distance, the configuration of the mullions is important so as to avoid blocking this layer of visual information with a horizontal sill bar across the window [14].

Large bodies of literature have investigated visual scenes containing urban (i.e. roads, buildings) and nature (i.e. greenery) (e.g. [15–17]). Environments containing nature are generally preferred over urban settings [15–17]. This preference could be evolutionary, whereby sources of nature (e.g. forests) would have provided humans sources of food, shelter and safety [18,19].

There are a wide range of positive benefits when observers are exposed to nature [20]. These influences have often been explored in settings where individuals are directly immersed, for example, walks through forests (e.g. *Shinrin Yoku* – the Japanese practice of forest bathing), or in urbanised cities [18,21–23], and/or asked to view images [24–27]. Similar benefits of viewing nature through windows have also been reported in workspaces or residential buildings [15,28]. In windowless spaces, indoor plants (floor, table and hanging) have shown to improve occupant work productivity and reduce stress levels [29]. In general, the literature suggests there are benefitcial influences of nature exposure when an individual is emmersed or viewing the content from a close proximity.

Scenes of nature have shown improvements in cognitive and executive attention [16,30], which can improve task focus and reduces the effects of unwanted distractions [26]. Visual scenes that contain nature have been found to influence temporal perception, whereby exposure to natural elements creates the perception of time passing slower [31,32]. Another aspect widely discussed in the literature is the positive distraction caused by nature [33], whereby visual scenes and sounds of nature significantly reduces ratings of pain [34], and influence recovery times from surgery [35] and elevated stress [36]. Ko *et al.* [37] showed

positive emotions (e.g., happy, satisfied) were higher and negative emotions (e.g., sad, drowsy) were lower for the participants in a space with window on close nature versus the windowless condition. Herzog and Chernick [38] showed that settings that had distant natural and urban landscapes were perceived as more open (i.e., perceived amount of space). However, a closer urban landscape was perceived to have a higher setting care (i.e., more well maintained) and lower amount of nature present. The opposite was found when observers compared a nearby landscape of nature against one that had a distant one.

One question raised when evaluating both the influence of nature and the distance of elements seen in the view, is how the two relate to each other. While promoting distant objects seen in the view is suggested (>50 m is classified as "excellent"), this would mean that elements of nature are viewed from a distance. Therefore, it is not clear whether the recommendation of promoting distant views should be univerisally apply to all types of visual content – regardless of whether they are features of nature or urban.

Given that the literature suggests that when individuals are immersed in natural environments this promotes a wide range of positive impacts (e.g. [18,21–23]), we believe that more refined recommendations should be made regarding the distance of specific visual content seen in the window view. This helps to bring into question whether the criteria of proximity influences the amount of connection occupants have to the outside when they are inside a building. To test this question, two different research objectives were evaluated in this article. The first was to determine whether the distance of the visual content seen in the view affects visual satisfaction. In other words, when the horizontal stratification (number of visible layers) and the amount of nature and urban elements present in different views are relatively constant, are there changes in visual satisfaction ratings when the distance of visual content changes. Our secondary objective was used to evaluate how visual content containing nature and urban elements influence the effect of landscape distance that is seen in the view.

2. Methodology

To test our two objectives, we used two methodological approaches: Online survey responses and a controlled experiment. Images were used to represent different window views and could be then compared against each other across comparable conditions (e.g. same window size, weather condition, etc.), which would not have been feasible using real windows.

To provide an overview of our experimental methodology, we present a workflow (Figure 1) that illustrates how the window view images were compared against each other. Experiment 1 (online surveys) was used to determine whether nearby and distant landscapes with similar content influenced visual satisfaction, while experiment 2 (controlled experiment) compared scenes of nearby urban and nature content with a range of different window views with distant content to determine how this the effect of landscape distance.
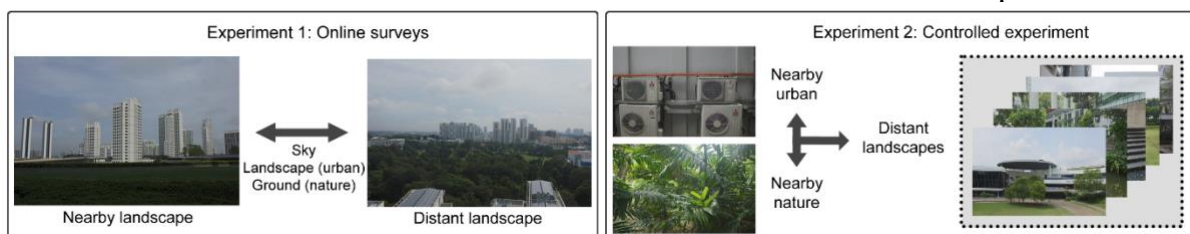

Figure 1. Workflow of our experimental methodology that presents: Experiment 1 (Online surveys) that compared window views with nearby and distant landscapes that have similar content and the same number of layers (e.g. visible sky, urban landscape, and nature in the ground (as seen in the example images)); and Experiment 2 (Controlled experiment) that compared nearby urban and nature content seen in the landscape with a range of different window views with distant landscapes.

2.1. Experiment 1: Online surveys

2.1.1. Images

Eighteen images were taken across the National University of Singapore (NUS) campus (Tables 1, 2 and 3). Images were captured on the same day from 09:00 to 11:00 am. The prevailing sky condition during that period was an intermediate (mixture of clear and cloudy) and no direct sunlight was captured in the images. A Canon 7OD camera with a Canon efs 10-55 mm f/3.5-5.6 STM lens was used. All images were taken outside either on the ground, balonies or accessible sky gardens. Almost all images were views seen from actual windows taken from outside the building. Images that were not views seen from real building windows were selected for comparative purposes.

2.1.2. Relative landscape distance

The Building Research Established Environmental Asessment Method (BREEAM) recognises that an "adequate view" is one that has a landscape layer that can be seen from the occupant's seated position [39]. The EN 17037 [2] and lighting guide 10 [3] indicate the landscape layer alone should provide a "sufficient" window view and is the area occupants are likely to direct their gaze upon the most. Therefore, we used the landscape layer in the view to determine the distance from the occupant.
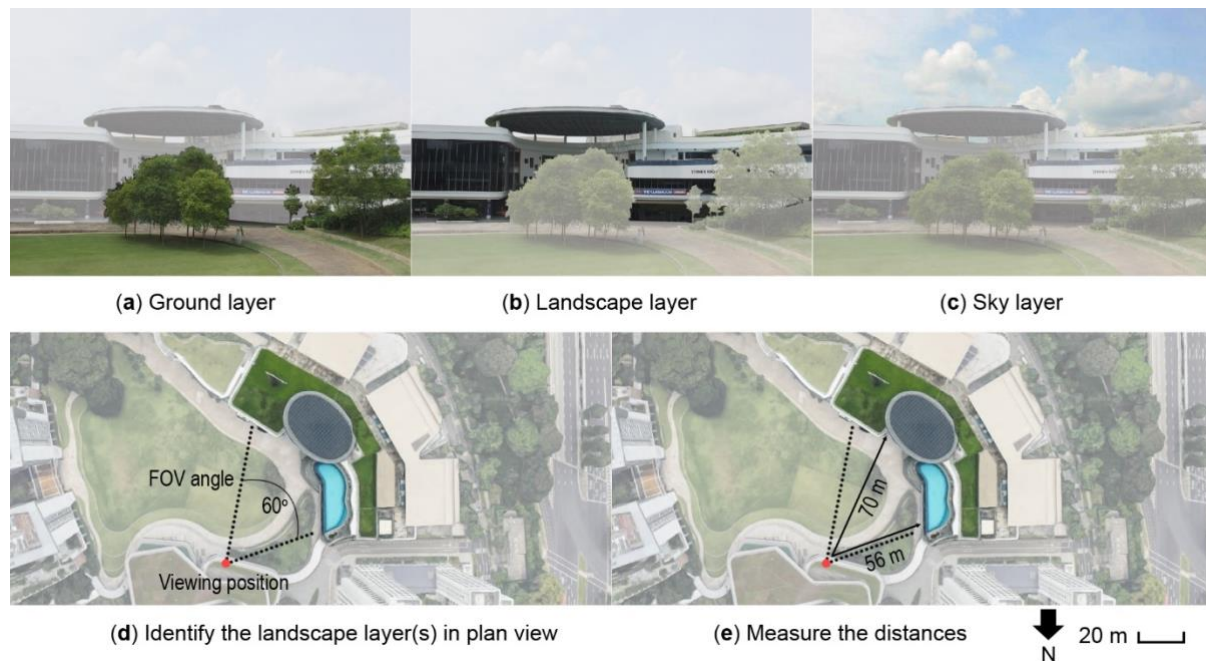

Figure 2. Horizontal stratification of a perspective image showing: (**a**) ground layer, (**b**) landscape layers, and (**c**) sky layer; and plan view images showing: (**d**) the landscape layer(s) – as seen from the perspective view at the viewing position – with the FOV angle and (**e**) the minimum and maximum distance from the viewing position and landscape layer content.

To calculate the distance, a measurement value was derived, herein known as the Observer Landscape Distance (OLD). This is the distance from the occupant's viewing position in a building to the landscape layer of the view seen in the window view, which can be used to deal with scenes that have complex visual content. The location at which the image was captured served as the occupant's viewing position and from the perspective view, the horizontal stratified layers [1] were identified (i.e., ground, landscape and sky, respectively (Figure 2 – see plots (a), (b) and (c)). The SLL Lighting Guide 10 [3] states: "*Visual information is concentrating in the junction of the layers: along the skyline and where other buildings and large objects such as trees meet the ground*". Adapting this

information, we considered all visual features that boarded both the skyline and ground as part of the landscape layer. If the scene only had two layers, we used either ground or skyline – whichever was available – as the boundary condition.

To calculate OLD, we used satellite plan views showing the visual content that appear in the images captured (Figure 2 – see plot (d). The camera focal length was set to create a constant horizontal field of view (FOV) angle of 60_o corresponding to the width of the perspective image. This is the limit of near perpheral vision in humans about the central line of their visual focus [40]. From the plan view and within the horizontal FOV, we could then identify all landscape content that appeared within the FOV at the viewing position.

However, in some plan window views can contain more than one landscape layer, or their landscape layer is not evenly spaced away from the viewing position. In Figure 2, plot (d), the landscape layer (i.e., where the building meets the ground and skyline) appears at different horizontal distances from the viewing position. At its minimum, this is 56 m and at its maximum this is 70 m, which creates a difference of 14 m. To address this aspect, we use the median value calculated from the minimum and maximum distances measured across identified visual content found in the landscape layer(s) to obtain the OLD.

2.1.3. Comparisons

To help characterise the images, we used the tables in the EN 17037 [2] and SLL lighting guide 10 [3], which gives an assessment method for evaluating window views based on the number of visible layers in addition to the present landscape. Twelve images (Tables 1 and 2) were used to determine if the distance of the visual content mattered when evaluating different images used to represent a window view. Three pairings of six different images were evaluated in both tables. The pairings had an equal number of horizontal layers and similar visual content. However, in Table 1, the OLD across the pairings varied. In each pairing, different scenarios found within the built environment were considered. For example, we compared two images containing vertical high-rise buildings (VHN(L3) and VHD(L3)). Both images contain mostly nature content on the ground layer, a visible sky layer, and vertical high-rise buildings seen within the identified landscape layer.

The description of distance (i.e. "nearby" and "distant") given to the window view images was used for comparative purposes. In Table 1, these describe images that had a smaller OLD than the scenes they were being compared to. However, we did not generalise the use of OLD to describe all the images used in this study. As a result, image VHN(L3) has a larger OLD than OCD(L2) and HBD(L3), despite being classified in the "nearby" group.

Table 1. Three comparisons used to evaluate the distance of landscape. Images are paired together in three groups for window view images contained near and distant landscapes: outdoor corridors, horizontal buildings and vertical high-rise.

Outdoor corridors		Horizontal buildings		Vertical high-rise	
Nearby landscapes					
OCN(L2)		*HNN(L3)*		*VHN(L3)*	
Ground	✓	Ground	✓	Ground	✓
Sky	✗	Sky	✓	Sky	✓
Nature	✓	Nature	✓	Nature	✓
Urban	✓	Urban	✓	Urban	✓
OLD	8	OLD	39	OLD	432
Distant landscapes					

OCD(L2)		HBD(L3)		VHD(L3)	
Ground	✓	Ground	✓	Ground	✓
Sky	✗	Sky	✓	Sky	✓
Nature	✓	Nature	✓	Nature	✓
Urban	✓	Urban	✓	Urban	✓
OLD	36	OLD	63	OLD	851

Note: OCD(L2)= Outdoor corridor with distant content and two-layers; OCN(L2)= Outdoor corridor with nearby content and two-layers; HBD= Distant horizontal building with three-layers; VHD= Distant high-rise vertical buildings with three-layers; VHN(L3)= Nearby high-rise vertical buildings with three-layers

Since the rating procedure can provide unreliable evaluations due to a range of different subjective response biases [41,42], additional comparisons were performed which examined an opposing hypothesis which was contrary to the analyses performed in Table 1. We examined whether no differences could be found when considering the same visual conditions as before, but with OLD held relatively constant (i.e., null conditions). This also helped support findings in Table 1, since the visual content across the pairings varied despite matching visual scenes that had similar characteristics to each other.

Table 2. Six images used to create three null conditions. Images have been organised by scenes containing nearby urban, nearby nature, and distant mixed (nature and urban) features.

Nearby urban		**Nearby nature**		**Distant mixed**	
NU(1)		NN(1)		DM(1)	
Ground	✗	Ground	✓	Ground	✓
Sky	✓	Sky	✗	Sky	✓
Nature	✗	Nature	✓	Nature	✓
Urban	✓	Urban	✓	Urban	✓
OLD	35	OLD	63	OLD	670
NU(2)		NN(2)		DM(2)	
Ground	✗	Ground	✓	Ground	✓
Sky	✓	Sky	✓	Sky	✓
Nature	✗	Nature	✓	Nature	✓
Urban	✓	Urban	✓	Urban	✓
OLD	35	OLD	64	OLD	663

MN= Mixed content and some nearby elements with three-layers (1, 2 and 3 denote the image numbers); MD= Mixed content and mostly distant content with three-layers (1, 2 and 3 denote the image numbers).

Table 2 presents the three null conditions. The comparisons are organised by the type of content present across the pairs, whereby the first column contains nearby urban features

(NU(1) and NU(2)), the second column contains nearby nature features (NN(1) and NN(2)), and the third column contains distant mixed (nature and urban) features (DM(1) and DM(2)). Across the pairings, the visual content, number of layers and estimated OLD approximated each other. When these parameters are held relatively constant, we hypothesised there would be no notable differences in the subjective evaluations given across these conditions.

Table 3 presents eight images that were used to determine how nature and urban elements may influence the distance of visual content seen in the window view. To examine this question, two images (U(L1) and N(L1)) were used as reference conditions [43]. These images had the same visible number of layers (i.e., a landscape only and no ground or sky layers) and OLD. One window view image contained nature and other urban visual content in the landscape. The remaining six window view images were arranged in ascending order of OLD in Table 3 to evaluate the differences in the evaluations.

All six window view images had OLD greater than the reference cases and had a wide range of visual characteristics. The analyses were repeated to evaluate differences calculated from the urban and nature reference scenes producing two sets of results.

Table 3. Eight window view images characterised by the features that appear to be predominantly (or completely) urban or of nature, by the number of layers they contained, and whether there is water present. The three layers were: ground, landscape, and sky.

Reference images		Comparisons images					
U(L1)		U(L3)		N(L2/W)		N(L3)	

Ground	✓	Ground	✓	Ground	✓	Ground	✓
Sky	✗	Sky	✓	Sky	✗	Sky	✓
Nature	✗	Nature	✗	Nature	✓	Nature	✓
Urban	✓	Urban	✓	Urban	✗	Urban	✗
OLD	2	OLD	14	OLD	54	OLD	65

N(L1)		U(L2/W)		HBD(L3)		VHD(L3)	

Ground	✓	Ground	✓	Ground	✓	Ground	✓
Sky	✗	Sky	✗	Sky	✓	Sky	✓
Nature	✓	Nature	✗	Nature	✓	Nature	✓
Urban	✗	Urban	✓	Urban	✓	Urban	✓
OLD	2	OLD	31	OLD	63	OLD	851

U(L1)= urban with one-layer; N(L1)= nature with one-layer; U(L2/W)= urban with two-layers and water; N(L2/W)= nature with two-layers and water; U(L3)= urban with three-layers; N(L3)= nature with three-layers.

Although comparisons made to reference cases is an indirect method of comparing different window view images, they allowed for a much easier approach than the method used in Tables 1 and 2. Comparisons msade across window view images with distant visual content (e.g. DM(1) and DM(2) in Table 2) will contain much more information than what can be viewed in nearby scenes [14]). Therefore, it is difficult to equally balance the characteristics found across distant scenes (i.e., the visual content varies considerably more in these window views and it is challenging to provide fair comparisons). On the other hand,

nearby window views will contain less visual content, which makes it much easier to identify scenes that contain only urban or nature visual content (see Table 3 – U(L1) and N(L1)).

2.1.4. Procedure

All subjective responses were collected through the UC Berkeley Qualtrics platform.

Three online surveys were used to evaluate different visual aspects of the images. Participants were asked to rate their degree of satisfaction with each image based on a degree of visual satisfaction [1,14,44]. Ratings were given on continuous scales with seven response labels indicating the degree of satisfaction, which were of identical length. These response labels ranged from, "very dissatisfied" to "very satisfied" (see Appendix). The numerical range of the scale varied from 0 ("very dissatisfied") to 100 ("very satisfied") – this information was masked from the participants when they provided their evaluations. The extreme criteria were equally balanced across a neutral criterion labelled "neither satisfied nor dissatisfied". To prevent responses being anchored towards the extreme response labels [45] (i.e., the final evaluation being bias towards the initial position of the marker), we positioned the slider at the neutral (mid-point) criterion.

In some surveys, ordering effects can occur when the sequence of questions influences the responses given [46] (i.e., ratings are influenced by the sequence of the questions in the survey). Studies have found that the ordering effects are larger when there were fewer questions in the survey [47,48]. To counter this, we used three different surveys and responses to each survey were collected from different group [49]. In other words, participants were asked to evaluate the images by deciding which of the three surveys they would like to provide evaluations to – but, could not provide responses to more than one. The surveys were distributed across the general population in Singapore. We asked participants to imagine each image was their workplace window view [43]. To provide more context, we gave examples of how they might evaluate the images, if they were real windows. For example, if an image showed a view of a busy nearby road containing traffic, then visual privacy may be an issue.

Participants were asked to rate the degree of satisfaction based on three subjective criteria: connection to the outside, visual content, and visual privacy. Only one criterion appeared in each survey. The three survey items were described as following:

- Connection to the outside. Is the desire to have visual contact with the outside environment. This describes how much temporal information (i.e., sky and weather condition, time of the day, visual contact with other dynamic information seen outside, etc.) can be obtained from the image when it is observed from inside the room.
- Visual content. This refers to nearby or distant features in the image that you consider to be desirable. This could be the buildings, trees, water, and the background skyline.
- Visual privacy. Is the unwanted feeling of being observed by people from the outside on a frequent basis. If you think visual privacy is poor, you may want to take action to improve the situation (e.g., draw the blinds or move away from your workstation).

Our previous work showed that when the visual features (i.e., ground, trees, sky, etc.) were evaluated separately, they form a close relationship [50]. Hence, visual content was measured using one survey item.

Three independent groups responded to the three different surveys. Forty participants responded to the survey containing questions regarding the connection to the outside, 13 were female and 27 were male, and the average age was 32 years. Twenty-eight participants responded to questions regarding visual content, 13 were female and 15 were male, and the average age was 28 years. Twenty-three participants responded to the survey containing questions regarding visual privacy, 10 were female and 13 were male, and the average age was 33 years. Since the views selected in this study were taken across Singapore and may

contain unique scenery (e.g. types of nature and architecture), only individuals that resided within the country were asked to participate in the study. The UC Berkeley Committee for Protection of Human Subjects approved the research protocol (CPHS #2018-10-11551).

2.2. Experiment 2: Controlled study
2.2.1. *Window view images*
In addition to collecting survey responses, a controlled experiment was performed to help support the findings used to answer our second research aim: i.e., the comparisons made in Table 3. The same eight images were utilised and were displayed on an artifical window. This served the purpose of repeating the evaluations given to the same window view images under different experimental settings, whereby a similar methodological approach has been used in our previous work to demonstrate the importance of replicating scientific findings that rely on human subject assessments [51].

2.2.2. *Experimental setting*
We carried out an experiment in the SinBerBEST test room at the Berkeley Education Alliance for Research in Singapore. The room contained dimensions of 4.25 x 5.5 x 3.6 m and an artificial window, which was used to provide illumination and displayed the images (Figure 3). For experimental purposes, a small area window was selected. This allowed the background illumination to be controlled and the window view images to be changed with relative ease. The eight images were printed onto films with dimensions of 0.21 x 0.30 m and were mounted behind a window glass pane with the same area. Illumination was provided by an array of light emitting diodes (LEDs). A screen was placed in front of the LEDs to evenly diffuse the light before it reached the image.
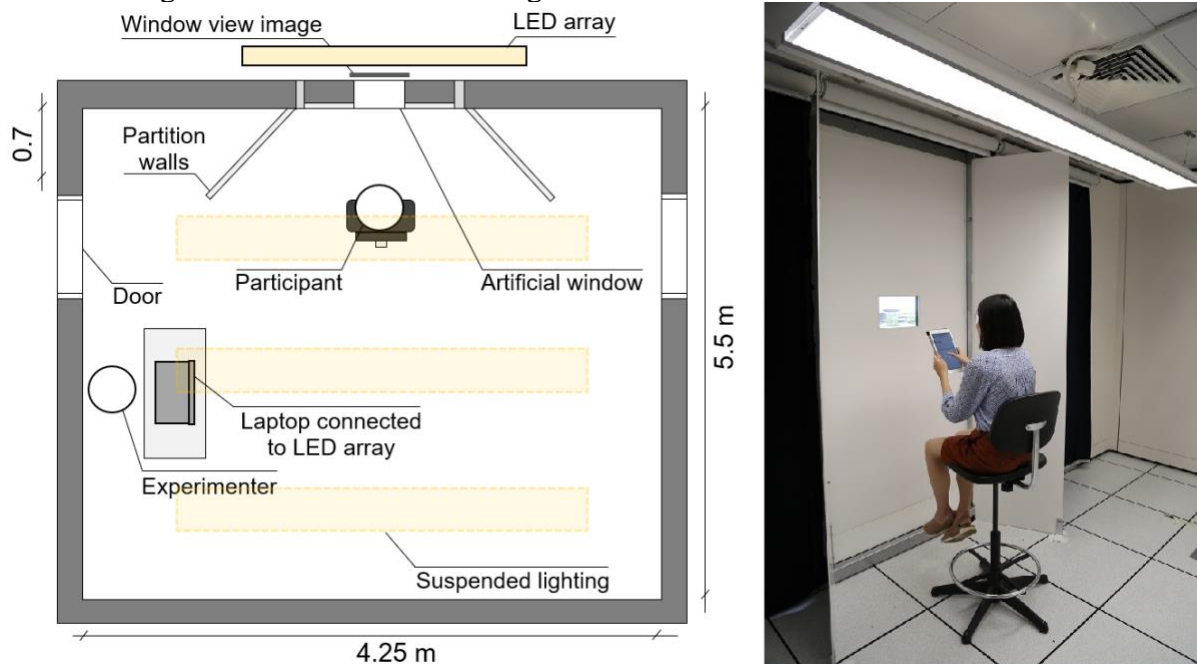
Figure 3. Layout of the experimental apparatus in the test room (*left*) and photograph of participant during the experiment providing an evaluation of the window view image (*right*).

The visible area of the artificial window was place near the centre of a test chamber which was semi-hexagonal in plan [52]. We used two partition walls to help diffuse the light within the participant's visual field. The interior surfaces of the partition walls (2.4 m in height) were matte-white, and inside the room there were three suspended luminaires used to produce background lighting. The surfaces of the test room had reflectances of: $\rho_{wall} \approx 0.56$,

$\rho_{partitionwalls} \approx 0.56$ $\rho_{floor} \approx 0.72$, and $\rho_{ceiling} \approx 0.72$ as estimated by matching colour samples in the Munsell system [53].

The luminance of the artificial window was controlled using Digital Multiplexing (DMX). The DMX was operated using a laptop, which was used to vary the output of the LEDs. From the viewing position, the background luminance was calculated from 44 individual spot-point measurements taken on a regular grid, symmetrical about the artificial window, using a luminance meter (Mavo-Spot 2, GOSSEN, Germany). The mean background luminance was held constant at approximately 117 cd/m2 throughout the experiment.

Because each image produced a different degree of visual contrast, the illuminance of the artificial window at the viewing position was constantly set to 450 lux (measured with an illuminance chromameter (LS-100, Konica Minolta, Japan)).

Participants sat at the centre of the test chamber with their head elevated 1.2 m from the floor, which was the viewing position. Participants were asked to provide their evaluations using a method of central (on-axis) visual fixation [43,54].

2.2.3. Subjective evaluations
Participants assessed the window views using the same three subjective response items: connection to the outside, visual content and visual privacy. The same semantic descriptors and continuous scales were used – as described previously in section 2.1.4.

2.2.4. Procedure
Participants were seated at the viewing position 0.7 m away from the artificial window. A description of the experimental procedure was given. Each participant gave ratings to the three survey items, which were repeated for the eight images. The procedure was divided into eight blocks, with each block containing one image. The order in which the blocks were presented was randomised across the sample of participants. Within each block, participants were asked to provide ratings to the four survey items, which appeared in a randomised order.

A total of 50 participants (22 female and 28 male) took part in our experiment. Participants varied in nationality and cultural background but all were fluent in English, the average age of the group was 32 years (SD= 9.15), 35 wore corrective lenses, 48 participants self-certified themselves as having normal colour vision, and all participants reported that their current health was "good" or "not too bad". The UC Berkeley Committee for Protection of Human Subjects approved the research protocol (CPHS #2019-04-12082).

2.3. Statistical analyses
To analyse the data, we used Null Hypothesis Significant Testing (NHST) [55]. To test the assumption that the distribution of the differences were normal about the mean average, we used the Shapiro-Wilks test [56] and Quantile-Quantile plots [57]. If this assumption was met, parametric tests were selected [55] otherwise, non-parametric tests [58] were used.

Comparisons in Tables 1 and 2 were analysed using paired tests (i.e. *t*-tests or Wilcoxon signed rank test) as there were only two groups [55] to evaluate the differences in visual satisfaction. These analyses were repeated for the three different variables.

To analyse the reference conditions in Table 3, we used the multivariate analysis of variance (MANOVA) test, which is used to examine the differences across the two or more groups when multiple outcome variables were measured. We used this analysis to compare the differences in visual satisfaction calculated between the six images and reference images. This gave six outcome variables (i.e. the differences) produced from both U(L1) and N(L1), respectively. The differences from which the two reference images were calculated was used as the comparative group in the analysis. To test the assumption that the within-group covariances are equal, we used the Box's *M* test [59].

Since NHST relies on the magnitude of the differences and size of the sample [60], emphasis was placed on the effect sizes [61]. In this study, the Pearson's coefficient, r was used as the effect size estimate, which could be calculated from the statistical parameters from each test from recommended methods [62]. To interpret the outcome, the benchmarks proposed by Ferguson [63] were used, whereby differences representing practically relevent influences are classified according to "small", "moderate" and "large" effect sizes ($r \geq 0.20$, 0.50 and 0.80, respectively). Effect sizes below the minimum recommendation of what would be denoted as a "small" magnitude were consider to have a "negligible" influence.

To counterbalance the experiment-wise error rate caused by the significance level inflating across multiple statistical analyses that are related to each other [64], an adjust had to be performed to the alpha-level in which significant results were declared [65]. Since the null conditions in Table 2 sought to examine whether there were no differences, this adjustment would make it easier to accept the null hypothesis. Hence, these needed to be carefully applied. Also in other cases, comparisons were performed across different groups of participants. Therefore, it was not entirely clear how many statistical comparisons needed to be included when performing the adjustment.

To be more conservative in the analyses performed in Table 2, no adjustments were made to the alpha-levels across the null conditions, thereby retaining the conventional threshold (i.e. $p \leq 0.05$) [66]. For all other comparisons in this article (i.e., the analyses performed in Tables 1 and 3), we lowered the conventional threshold to the alpha-level recommended by Benjamin *et al.* [67] to $p \leq 0.005$, respectively.

To plot our data, we made use of box and whisker plots that present both mean (circle) and median (M_{dn} – (line)) central tendencies. The whiskers extend from the upper (75th quartile (Q3)) and lower (25th quartile (Q1)) hinges. The upper whisker extends, from the hinge, no further than 1.5 multiplied by the difference between the upper and lower hinges (inter-quartile range (IQR)) to the largest value, whereas the lower whisker follows this same calculation process only to extend no further than the smallest value [68]. Any points beyond the whiskers are consider as outliners in the plot.

3. Results

Figure 4 plots the responses given on the continuous scales and shows the comparisons between the images presented in Table 1 (nearby vs. distant scenes) and Table 2 (null conditions), respectively. For each comparison, we provide the corresponding descriptive (ΔM) in and inferential statistics (p-value and effect size (r)).

Plot (a) consistently shows that when a distant view was presented in the image, higher ratings of visual satisfaction were given. This is not only consistent when considering the three pairings, which compared nearby and distant visual content, but also, this can be seen across the three response variables. The differences were statistically significant ($p \leq 0.005$) across all comparisons when considering the variables connection to the outside and visual content. For the variable visual privacy, the differences were significant for two comparisons and not statistically significant for the vertical high-rise window view images.

The effect sizes ranged from "moderate" in seven comparisons to "small" in two comparisons. These findings suggest that when OLD was larger and the landscape content seen in the window view images were further away, higher ratings of visual satisfaction were given. These differences are apparent, whereby the central tendencies corresponding to the evaluations given to distant window view images were generally above the criterion "neither satisfied nor dissatisfied" (i.e., these scenes were generally considered to be satisfying).

Plot (b) did not appear to show any notable differences across the images. This indicates that, when OLD was relevant constant across different window view images, there were no notable changes in satisfaction. This is apparent for all three variables in all three null

condition groups and implies that participants had given similar ratings of visual satisfaction to the image pairings. None of the comparisons were statistically significant ($p>0.05$). With the exception of the variable visual content and the distant mixed group, all comparisons had "negligible" effect sizes. However, this comparison was not statistically significant.

Although the results in Figure 4, plots (a) and (b), indicate that OLD does matter (i.e., the distance the landscape is seen from the viewing position), we tried to comparatively compare the visual content across these window view images and vary one parameter (Tables 1 and 2). To understand how nature and urban features seen in the view influence the outcome this brings into focus our second research question, which was to determine how the differences in these types of visual content can influence the effect of visual satisfaction with OLD.
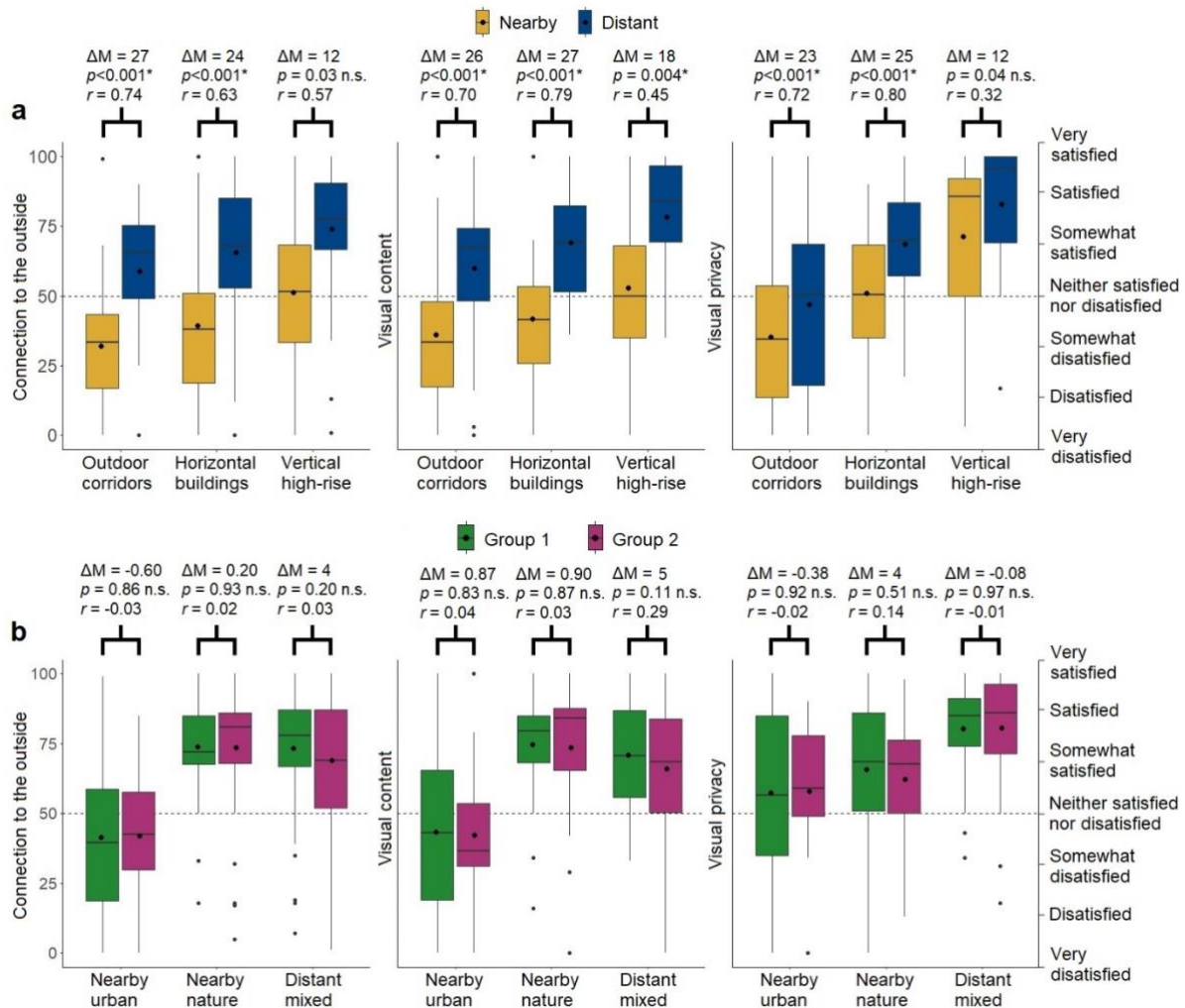

Figure 4. Boxplots showing: (**a**) The central tendencies (mean and median) when plotting the six images by the groups: outdoor corridors, horizontal buildings and vertical high-rise buildings, and the response variables: connection to the outside, visual content and visual privacy; and (**b**) The central tendencies when plotting the six images by the null conditions: nearby urban (NU), nearby nature (NN), distant mixed (DM), and the response variables: connection to the outside, visual content and visual privacy. Descriptive (ΔM (mean)) and inferential (p-values and effect size (r)) are provided for all comparative cases. In all plots, the secondary y-axes show the corresponding ratings of satisfaction on the scales.

3.1. Reference conditions

We first directly compared the ratings of visual satsifaction across the reference scenes containing nature and urban visual content (N(L1) vs. U(L1) in Table 3). These comparisons

were performed across the three variables and two experimental settings. For the survey responses, the differences were: connection to outside, $\Delta M = 60$, $p \le 0.001^*$, $r = 0.80$ (large); visual content, $\Delta M = 57$, $p \le 0.001^*$, $r = 0.89$ (large); and visual privacy, $\Delta M = 57$, $p \le 0.001^*$, $r = 0.86$ (large). For the controlled experiment, the differences were: connection to outside, $\Delta M = 28$, $p \le 0.001^*$, $r = 0.66$ (moderate); visual content, $\Delta M = 36$, $p \le 0.001^*$, $r = 0.76$ (moderate); and visual privacy, $\Delta M = 14$, $p \le 0.001^*$, $r = 0.53$ (moderate).

The mean evaluations made to the reference window view image with nature were consistently higher than the urban scene, whereby higher visual satisfaction ratings were given by participants under both experimental settings. This was also found for the three satisfaction dimensions. When OLD was approximately the same across the reference scenes, there was a substantive influence of the content seen, which suggests larger increases in visual satisfaction are achieved when the reference scene had only urban visual content.
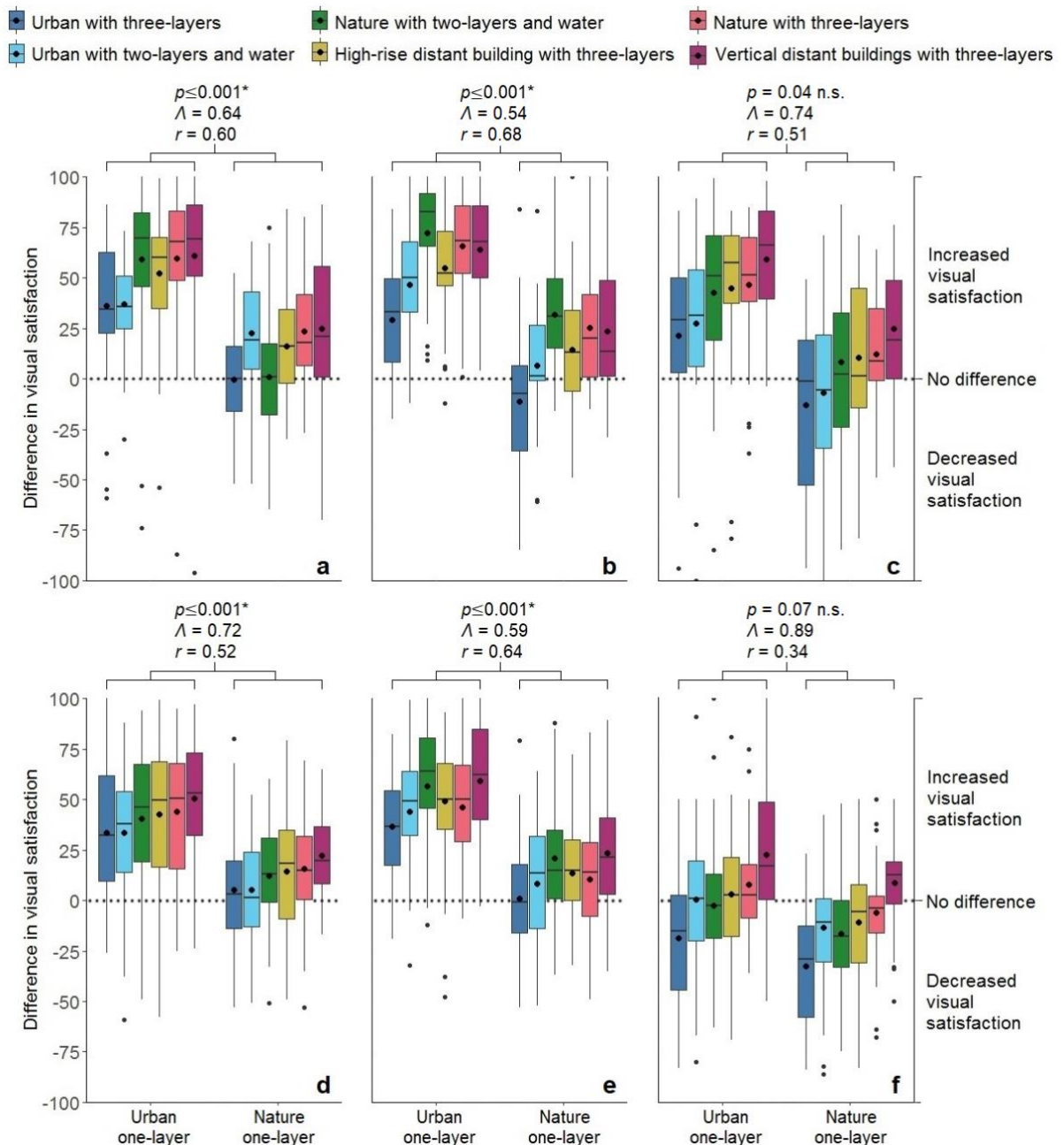

Figure 5. Boxplot showing the differences in visual satisfaction: Evaluations given under the controlled experiment for **(a)** Connection to the outside; **(b)** Visual content; and **(c)** Visual

privacy. Responses given in the online survey for **(d)** Connection to the outside; **(e)** Visual content; and **(f)** Visual privacy. Plots show the differences across the six images for both reference conditions. Inferential statistics (*p*-values, Wilk's, *Λ* and effect size (*r*)) comparing the differences are given above. In all plots, the secondary y-axes show the corresponding calculated difference in the ratings of visual satisfaction.

The difference in content across the reference scenes also appeared to influence percieved levels of visual privacy, whereby higher satisfaction was given when there was nature. The initial analyses suggests that OLD is dependent on whether the visual content in the landscape layer contained nature or urban. To determine how this influences window views that had both distant and a wide variety of different visual content in the landscape layer, we compared the reference window view images to the other six scenes in Table 3.

Figure 5 presents the differences in the subjective ratings given to the three response variables when the six images are compared to the two reference scenes. The comparisons are organised from left to right in each of the figure plots, whereby the OLD of the image that is being compared increases. Across the centre of each figure plot is the no difference line, which represents no change in the subjective evaluations.

The comparisons are separated by those made against the urban and nature reference scenes along the x-axis. Above the plots, we provide the outcome of the MANOVA test, which compares the differences calculated across the two reference scenes against each other.

Figure 5 consistently shows that the differences in visual satisfaction for each variable is higher when the six window view images were compared to the urban reference scene. Most of the differences indicate an increase in visual satisfaction. However, when these same six window view images are compared to the nature reference scene, the differences are lower. These differences are statistically significant with "moderate" effect sizes for the variables connection to the outside and visual content. For visual privacy, the effect sizes were "moderate" (survey responses) and "small" (controlled experiment) but were not statistically significant, which was a consequence of lowering the significance level (i.e. *p*≤0.005).

The effect sizes (*r*) also show how well the findings agree with each other across the two experimental conditions, whereby the differences across the variable visual content are the highest and are the lowest for visual privacy. The effect sizes for the survey responses were larger than the controlled experiment, which indicates that the differences across the references window view images were also larger. Nevertheless, we believed the effect sizes generally produced similar findings, which helped support the results found in Figure 5.

Table 4. Mean averages and differences in visual satisfaction for the three variables and two experimental settings.

Experimental setting	Connection to the outside			Visual content			Visual privacy		
	U(L1)	N(L1)	ΔM	U(L1)	N(L1)	ΔM	U(L1)	N(L1)	ΔM
Survey responses	50	15	35	55	15	40	40	6	34
Controlled experiment	41	11	30	49	13	36	2	-12	14

When aggregating the differences across the six window view images together, we could determine the mean average increases (e.g. positive) or decreases (e.g. negative) in visual satisfaction across the six window view images and the percentage differences (Table 4). To remind, our scales ranged from 0 to 100 units and had seven semantic labels anchored to them. A difference of ~17 units corresponded to a one criterion step-change on the scale.

The differences for the urban reference window view image are positive and larger than comparisons made against the nature scene, which indicates higher increases in visual satisfaction. However, there was one negative difference for visual privacy, which indicated

that higher ratings were given to the nature reference scene. Although the ratings of satisfaction were lower in the controlled experiment, the differences across reference window view images found in both experiment setting were generally similar.

Figure 5 also appeared to show that OLD also influenced the differences in visual satisfaction across the six window view images and both reference scenes. A direct trend can be seen, where larger differences are obseved when the OLD of the compared window view image increased. This trend does not imply that evaluations given to the window view image increased visual satisfaction – as shown in Figure 5. This shows that in some cases, smaller decreases in visual satisfaction are given to window view images when OLD increased.

4. Discussion

In this study, we investigated how the distance at which visual content seen can influence visual satisfaction. Using online surveys and images to represent the window view, we showed that distance does matter. The findings indicated that, distant content seen in similar window views led to higher rating in all dimensions of visual satisfaction: connection to the outside, visual content and visual privacy.

In a follow-up study, we were able to show that there were large differences in how a wide range of distant window view landscapes were perceived when the landscape layer contains either urban or nature features. This result suggests that nature content seen nearby may be perceived in a similar manner to distant content, whereas the distant landscapes were rated higher when the content was urban. This finding was corroborated by similar results derived from the online survey and in a controlled experiment using an artificial window.

This finding also supports our hypothesis that was derived from literature (e.g. [18,21–23]), whereby people generally preferred to be immersed in nature rather than urban. Our findings implied that, building occupants would prefer nature to be nearby and urban features viewed from a distance.

The results also question existing recommendations given in daylighting standards [2,3], which promote the integration distant views in window views without any distinction made between its visual content. While distant visual content has the additional benefit of providing visual relief [5], it may not always be possible to provide these types of window views. If designers are not able to provide distant content in the window view due to barriers imposed by site-selection [69] (e.g. in a city-centre), a countermeasure could be to promote window view quality by integrating nature (e.g. trees and plants) nearby. However, this does not necessarily imply that nature should be viewed as close as possible in the window view as its content might then obstruct other desirable attributes needed in the view [1] (e.g. the sky). Careful arrangement of the visual composition of the window view would still be needed.

Despite our results generally showing that distant landscape layers improve how participants perceived the window view images, we believe that at a certain distance (i.e. OLD), there might not produce any further increases in visual satisfaction. In other words, there should be a point at which the distance of the visual content does not influence how the window view is evaluated. Figure 4, plot (b) showed that, there did not appear to be any notable differences in how connection to the outside or visual content were evaluated for the groups, nearby nature and distant mixed. Although it was not clear whether this was due to differences in visual content (e.g. the amount of nature present), the difference in OLD between these groups was over 600 m (Table 3). It can be implied that there is an upper threshold to which OLD has a maximum influence on how the window view is evaluated.

Since our participants preferred to have nature nearby in the window view, we believe that the original thresholds found in the EN 17037 [2] and SLL lighting guide 10 [3] (i.e. distance≥ 6 m, 20 m, and 50 m) provide satisfactory design targets for natural content (e.g. trees and greenery). In fact, the N(L1) – a one-layered view of nature – had an OLD below

the minimum threshold (6 m) but received relatively similar levels of visual satisfaction with views that had distant content (Figure 5). This indicates that the design thresholds are likely to produce at least a "sufficient" view if nature is in the landscape and when located at further distances from the window, may also provide higher levels of visual satisfaction. Table 4 shows that the same recommendation cannot be made when the content is predominantly or completely urban, and therefore we have proposed a modification to these design thresholds.

To provide a relative weighting factor for urban content, we used data collected from the two reference window view images collected across both experimental methods. Although this method uses the content to modify distance thresholds, we believed this might be the most reliable approach given the window views we had available (i.e., these generally had the most comparable content). On average, the mean difference in the evaluations given was 42 units on our continuous scale. Since the measurement contained 100 units, we assumed that this was a 42 % increase on the scale when nature was present. Applying this as a weighting factor to the distances for the three original thresholds given in daylighting standards [2,3], this gives: $distance_{urban} \geq$ 9 m, 28 m, and 71 m (to the nearest integer), respectively. Our proposed approach also assumes that the differences in distance between each threshold (i.e., "sufficient", "good" and "excellent") are larger when the content is urban. Since Figure 5 shows that the effect of landscape distance is smaller when nature is visible, occupants are more likely to be satisfied with the view and the distant thresholds should also be smaller.

To support our findings, we used two methodological approaches. While the set of results have a good level of agreement with each other, higher evaluations were generally given in the online survey. One potential reason may have been due to differences across the methodological settings. A study by Yildirim *et al.* [70] showed that privacy is perceived more positively (less problematic) when the occupant is closer to the window. Because the surveys asked participants to provide evaluates online, the setting in which the window view images were evaluated may have influenced their responses.

The reasonable level of similarity between the findings derived from both methodologies also suggests that evaluations from only the survey responses would provide a reliable assessment of the window view images. Since this methodology relies on less resources to setup and it is generally easier to replicate the findings, it might be preferable that survey responses are used in future studies.

4.1. Limitations
Some methodological considerations need to be acknowledged that may have influenced the results.

We used images to represent the window view, which were shown to participants using an online survey and in a test room using an artifical window. We did not use a real view from a workspace where occupants would perform their daily work. Although it may not be practical to evaluate under fair and comparable conditions the same range views in this study using a real window, this raises questions as to how representative our findings are to responses given by occupants in buildings. Daylight is highly dynamic [71], which inside buildings, provides occupants with constant changes in both illumination levels and outdoor information (e.g. people, sky condition, etc.) when it enters and is viewed through windows [72]. Since daylight continuously changes due throughout the day, the view from east and west orientated windows could be impaired due to the presence of glare in the morning and late afternoon or early evening. Therefore, a designer should carefully evaluate the placement of some windows, which may produce high quality views when orientated towards a three-layered landscape that contains nature but might also produce issues of view discomfort. Our study used relatively small and static images, which provided participants with static visual information. This may have created some difficulties when participants were asked to

evaluate the subjective parameters. In further studies, the use of videos could also be considered to evaluate the same responses under dynamic visual conditions.

Another limitation might be that window views contain visual depth but images are only able to present this information on a two-dimensional display. However, studies that have used images and daylit windows to represent the outdoor view have generally shown similar results [43,54]. Davydenko and Peetz [32] also showed that evaluations given when viewing less-immersive stimuli (i.e., images and videos) containing nature and urban features had the same influences on assessments given to similar visual content experienced in a high-immersive environment (i.e., when walking outside), although the effect of interest was generally smaller. When comparing an actual office working environment that was replicated in an immersive virtual reality condition, responses given across an array of evaluations – including visual perception – showed no significant differences across the two experimental settings [73]. While there is evidence that suggests the use of images will likely produce similar results to an actual daylit window, further studies are necessary to substantiate these claims.

In our first study, the comparisons were evaluated by pairing images that had similar visual characteristics (e.g. number of layers) but with landscapes that varied in distance from the viewing position. Null conditions were setup using a similar approach. Although these scenes contained similar characteristics, they were not identical. This may explain why one comparison across the null conditions demonstrated a practically relevant effect size (i.e., the visual content varied enough and they received different evaluations).

5. Conclusions

Our study investigated the influence of distant visual content seen within the window view. The methodological approach collected evaluations given by participants on an online survey and from an independent group in a controlled experiment using an artificial window. Visual satisfaction was measured from three subjective parameters: connection to the outside, visual content and visual privacy. The main conclusions from our investigation are:

- Higher levels of visual satisfaction were found for each of the three parameters when comparing landscapes that had distant content to similar visual scenes that had nearby features. The average increases in visual satisfaction as calculated from the effect sizes across comparisons made in Figure 4 (plot (a)) were, respectively, "moderate" for connection to the outside and visual content ($0.50 \leq r < 0.80$), and "small" for visual privacy ($0.20 \leq r < 0.50$).

- These increases in visual satisfaction shown in Figure 5 are much larger when the window view contains urban features. When the view seen comprises of nature, the influence of distant visual content significantly lowers. This finding was supported by evaluations in the online survey and controlled experiment, whereby the differences across the two references views (nature and urban) were "moderate" for connection to the outside and visual content, and ranged from "moderate" (online survey) and "small" (controlled experiment) for visual privacy.

- For the same number of layers (i.e. landscape only) and distance, visual satisfaction was higher for nature against urban. The average increases calculated from the effect sizes were "moderate" for all three parameters measured.

Our findings question the current recommendations made in daylighting standards, which promote distant visual content in window views. In this study, we found that there is a need to make a clear distinction between content that is urban or nature. If the content is predominantly urban, occupants prefer that it is viewed from a distance, whereas this same recommendation does not apply for nature, which can be nearby in the window view.

Declaration of interest

Acknowledgements

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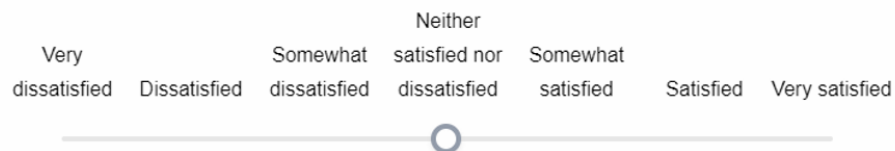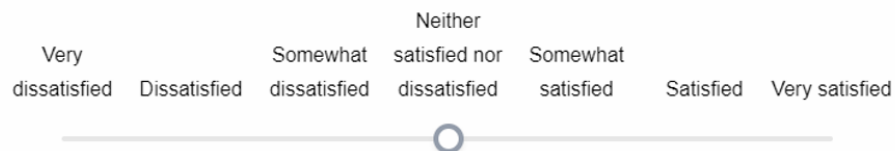
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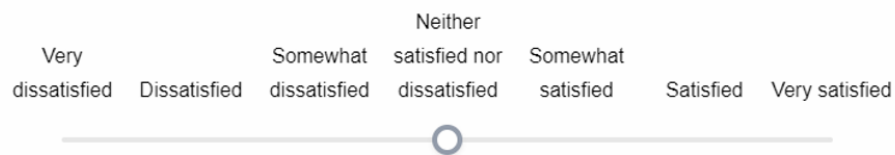
Figure A1. Continuous scales and parameters evaluated in the surveys and controlled experiment