The Assessment of Window Size and Layout Impact on a View Quality perception in a Virtual Reality Environment

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Abstract

Window views are key factors that affect buildings' occupants psychological and physiological comfort and wellbeing. Window design should consider the holistic impacts on building energy, lighting performance, and the connection to the outdoors provided by the view which is usually overlooked. In this study, view perception, stress recovery, physiological, and psychological affect were evaluated in virtual environments of five different conditions varied the physical dimensions of a window located in the same office space with an urban view. This allowed three window-to-wall ratios (i.e., 10%, 20% and 30%) and two different window layouts (i.e. narrow and wide) to be compared. Twenty-five participants were recruited. Subjective self-assessments on view perception (e.g., content and complexity), self-assessment and physiological measures (e.g., skin conductance and heart rate variability) stress recovery besides psychological affect were measured. Participants performed a Stroop-test to induce stress that was immediately followed by a period of recovery facilitated by exposure to one of the five window conditions. Results showed that increased window size advocated higher view perception assessments, increased stress recovery, and positive psychological affect. Measures of skin conductance and heart rate variability also corroborated these findings. Differences in window layout were also revealed, but only for 10% WWRs. Therefore, WWR was not a reliable indicator for view perception for small window sizes, indicating that layout preference is dependent on window size. This study highlighted the importance of considering view perception for occupant health and wellbeing when sizing window openings, since these may not necessarily align with other design criteria.

Keywords: Window view; Visual perception; Virtual reality (VR); Daylighting; Stress recovery

1. Introduction

Windows have a seminal role that permit views to the outside and allow daylight into the building. Daylight also broadly influences energy requirements, regulating building heating, cooling, and artificial lighting loads, and also natural ventilation [1-3]. Many metrics have been developed to evaluate indoor daylighting performance by modelling: illuminance levels (e.g. Daylight Factor, spatial Daylight Anatomy, and Useful Daylight Illuminance [4]), distribution and uniformity [5], and predicting window glare [6, 7]. Despite plenty of methods that are readily available for daylighting and energy performance evaluation, far fewer methods exist that are able to quantify view quality [8, 9]. View quality can be attained by the interaction of several factors, such as content-related factors, design-related factors, dynamic changes in views based on observer-related factors, and view quantity [10]. Informative, high quality views, provide access to environmental information, sensory change, connection to the world outside, and restoration and recovery as explained by the psychological benefits of view [11, 12]. Providing access to views from windows affect people's health and well-being by providing a relief from pain via offering frequent changes in eye focus distance to provide a brief relax for the eye muscles [13, 14] and reduce stress [15] via offering pleasing change to the eye and mind [12] as shown by psychological and physiological studies [16-19].

An important factor influencing both outdoor view access and corresponding energy usage is window size. While some studies have sought to derive optimal window sizes [1, 2, 20], this is usually done to minimise the energy usage and to maximise daylight access into the building [21, 22]. Considerations toward the later entail controlling excess daylight entry through the window via shading devices, reducing the outdoor connection offered by the view. Avoiding these issues in practice might be difficult due to the absence of established methods to counter the negative effects decreased visual availability has on view perception [23, 24]. Despite its importance for both occupant satisfaction and well-being [25-29], existing studies rarely placed emphasis on the view when sizing the window. Without integrating the view into the overall design process, this questions whether window sizes that are derived from energy-based design criteria meet requirements advocating the view. Candidate reasons preventing a more holistic outlook could be difficulties dealing with continuously changes in the daylit environment [30, 31]. Properties for daylight (e.g. intensity, direction and spectrum) inherently vary, and this impedes fair comparisons drawn across a suitable range of window design solutions (i.e., window size and layout), whilst controlling myriad other indoor and outdoor environmental conditions.

A common, and arguably the most straightforward, measure for determining the overall size of the window is the window-to-wall ratio (WWR) [20]. Many studies have been conducted to independently, or simultaneously investigate the impact of WWR on energy consumption and lighting performance (Table 1) [1-3, 20, 22, 32, 33]. Some studies reviewed in Table 1 have arrived at different values for optimal WWRs, varying according to the considered optimisation criteria: climate, and the office window orientation. While some optimal WWRs varied within a relatively small range (e.g., 10% to 20%), view quality was not included amongst the list of optimisation criteria. This could explain why for other studies, which did considered view as an design criteria, occupants had preferred much larger window sizes: 35% [34], 50% [35], 80% [36], 40% [31] and 100% [37], respectively. Assertions could be made that small window areas limit the view to the outside and are the least favoured, while larger window sizes are more often preferred by occupants [31, 34, 38]. This was further confirmed in recent studies on window views as view quality perception was affected by the amount and portion of view content seen through the window [39-42].

Depending on which criteria were used to determine the optimal WWR (Table 1), the resultant window size varied considerably. Amongst these criteria considered in the literature, some variations and similarities were identified for geographical locations. For energy performance, the optimal WWRs for Wuhan, China [1] and Sapporo, Japan [2] across north, south, east and west window orientations were 10% and 25%, while for daylight optimisation, the WWR ranged between 10% and 40% in the United Kingdom [22]. For energy consumption and daylight availability, WWR varied between 20% and 40% for south oriented windows in different climates in China [20], which were similar to values found across European locations (e.g. Rome and Athens), recommending values between 25% and 40%, and 30% and 40% [3]. Besides location, cultural influences may also influence preferred window size [43]. Window size can have a significant influence on the energy and lighting requirements across different climates, which in turn, may affect occupant expectations.

Table 1 Summary of studies on WWR optimisation with used criteria

Location	Climate*	Glazing type	Room dimensions (m)	WWR	Orientation	Optimisation criteria	Ref.
Wuhan (China)	Cfa	Double glazed	-	0.10	E, W, S, N	Energy consumption	[1]
Harbin	Dwa		5 x 6 x 3	0.20	S	Energy consumption and useful daylight illuminance UDI using (<500, 500-2000, and>2000 lux) for insufficient, sufficient, and glare, respectively	[20]
Beijing	Dwa			0.20			
Hangzhou	Cfa			0.30			
Kunming	Cwb			0.20			
Guangzhou (China)	Cfa			0.40			
Manila (Philippines)	Af	Double and triple glazed	6.1 x 4.6 x 3.1	0.25 0.50	N, S, E, W	Energy consumption	[2]
Taipei (Taiwan)	Cfa			0.25 0.50			
Shanghai (China)	Cfa			0.25 0.50			
Seoul, (South Korea)	Dfa			0.25 0.50			
Sapporo, (Japan)	Dfa			0.25			
United Kingdom	Cfb	Double glazed	3 x 6 x 3	0.20-0.40	E, W, N	DA using 250 and 2500 lux for minimum and maximum thresholds	[22]
				0.10-0.30	S		
Oslo (Norway)	Dfb	low-e coated triple glazed with argon in the cavities	3.7 x 5.4 x 3.2	0.37-0.43	E, W, N	Energy consumption, DA using 500 lux for sufficient lighting and UDI for glare risk (>2000)	[3]
				0.50-0.60	S		
Frankfurt (Germany)	Cfb			0.37-0.45	E, W, S		
				0.40-.045	N		

Rome (Italy)	Csa			0.30-0.35	E, W		
				0.25-0.35	S		
				0.35-0.40	N		
Athens (Greece)	Csa			0.30-0.35	E, W		
				0.35-0.40	S, N		
Amsterdam (Netherlands)	Cfb	Double glazed	3.5 x 5.3 x 2.7	0.50-0.70	N	Energy consumption, and a minimum of 500 lux for sufficient lighting, uniformity ≤ 3.5, and Below 22 hours of glare using Daylight Glare Index (DGI)	[32]
				0.50-0.60	E, W		
				0.60	S		

*Climate description according to Köppen–Geiger climate classification system [44]
Cfa: Humid subtropical climate
Dwa: Monsoon-influenced hot-summer humid continental climate
Cwb: Subtropical highland climate
Af: Tropical rainforest climate
Dfa: Hot-summer humid continental climate
Cfb: Temperate oceanic climate
Dfb: Warm-summer humid continental climate
Csa: Hot-summer Mediterranean climate

There is a rising need to assess design considerations beyond building energy and lighting efficiency, also validating the consequences on visual perception (i.e., view perception), due to the new designs that provide architects more freedom regarding window dimensions (e.g., size and layout). When considering the holistic performance of a window, designers should ensure that views meet and exceed minimum acceptable thresholds for view access, while not compromising any energy targets, thereby integrating and balancing several aspects of the building design. This study aimed to start fulfilling these requirements by investigating the influence of window size and layout on self-assessments and physiological indicators (e.g. stress recovery). Stress recovery was selected to assess view perception from different WWRs because of the restorative benefits experienced by the view, using self-assessment stress recovery, and physiological measures. I.e., views can divert the mental attention away from the stressful stimuli by involuntarily capture their mental attention and promote cognitive psychological recovery as can be inferred by the attention restoration [45] and the affective response theories [18].

Using the WWR as an indicator for window size, the resultant view quality was assessed in a virtual environment acting as a proxy for the luminous visual environment. Measurements collected served as proxies of visual perception and view quality for each WWR, which were utilised to evaluate the influence of different window sizes in an office setting with an urban view. Office environment was selected for being a stressful environment where high concentration tasks usually occur [19, 26], hence, increasing the need for views for occupants' well-being.

2. Materials and Methods

2.1. Replicated Office Environment

A validated 3-dimensional virtual reality (VR) method [46] was used to represent an actual office room located in Nottingham, United Kingdom (latitude= 52°N). The use of VR in research experiments has received increased interest as it immerses the observers in realistic visual conditions, which offer realistic visual depth [47], and contrast and colour properties [46]. Experimenters can obtain a higher degree of control over certain environmental parameters (e.g. daylight and temperature) that cannot be held constant in studies that use actual daylit windows [30, 31]. Arguably, VR would be an ideal proxy to evaluate different window sizes and layouts under comparable environmental conditions.

To evaluate view perception, a daylit office room was replicated in a VR environment. The room was on the first floor containing a window with mainly urban (e.g. buildings) content with few natural (e.g. trees) elements [48]. Based on criteria found in BREEAM (Visual Comfort) [49], the window had an "adequate view". The office room had internal dimensions of 4.35 m x 2.85 m and a floor to ceiling height of 3.2 m. The internal walls of the room had reflectance (ρ) properties: $\rho_{wall} \approx 0.7$, $\rho_{floor} \approx 0.1$, and $\rho_{ceiling} \approx 0.8$, as estimated using Munsell values [50]. The north facing window inside the room was double-glazed and had dimensions of 1.40 m x 2.10 m, creating a WWR of 30% (i.e., the maximum obtainable opening area for this study). Cardinal orientation avoided direct sunlight entering the room. The room contained standard office furniture and a visual task was mounted 1.50 m from the participant position located at the centre of the room 2.18 m from the window.

Five experiment conditions were assessed. Windows with three sizes and two layouts were used. Sizes varied the WWR from: 10%, 20% to 30% (Figure 1). Layout described the aspect ratio for the window, which herein are referred to as: N (i.e. narrow) and W (i.e. wide). The layout was altered for two sizes: 10%N, 10%W, 20%N and 20%W. The percentages correspond to the WWR, while the letters denote the window's layout. Larger WWRs and narrow 30% could not be obtained due to physical constraints imposed by the building. Nonetheless, the range of WWR considered (i.e. 10% to 30%) generally coincide with optimal window dimensions for daylight illuminance obtained from previous studies in the United Kingdom [22]. Smaller WWRs were created by altering both the window size and layout using an opaque covering with the same surface reflectance properties ($\rho_{paper} \approx 0.7$) as the surrounding walls [34]. Variations in WWRs were postulated to affect visual acceptability, facilitating notable changes in view perception, stress recovery and psychological affect.

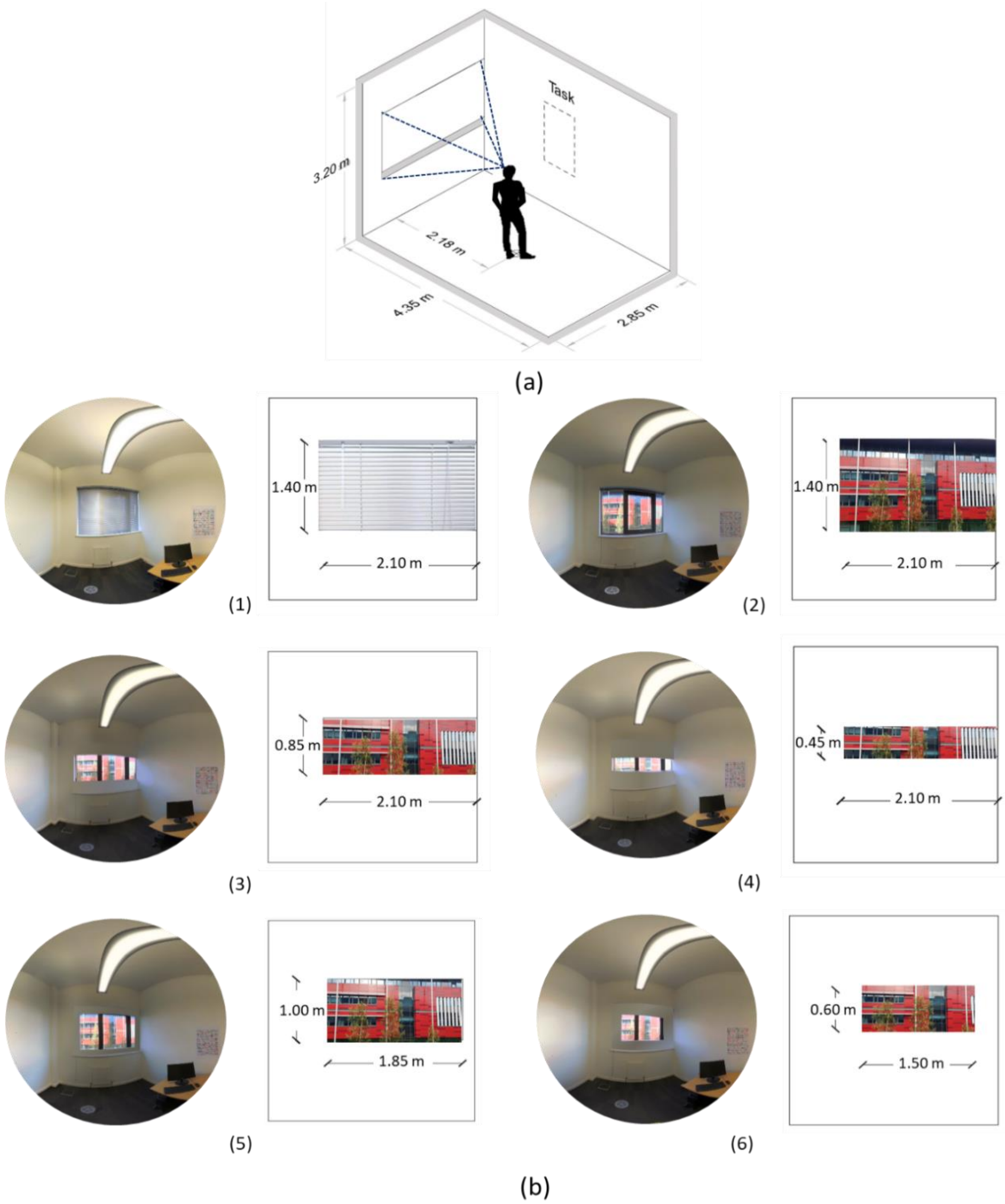

Fig. 1 (a) The test room dimensions and observer location; and (b) the window environment and the corresponding views for (1) the windowless baseline environment, and windowed conditions with different WWR and window layouts: (2) 30%, (3) 20%N, (4) 10%N, (5) 20%W, and (6) 10%W

2.1.1. Physically-Based Virtual Environment

Six virtual environments were created from the participants' viewing position (Fig. ***1***). Although five windowed conditions were used to vary window size and layouts, one additional windowless scenario acted as a baseline condition. To produce a virtual replication of the luminous visual conditions, the following equipment were used to collect photometric measurements: (1) Canon EOS 5D camera equipped with a fish-eye lens (Sigma 4.5 mm f/3.5 EX DG) mounted on a tripod; (2) Minolta Chroma-meter CL-200; (3) Hagner S3 photometer with illuminance sensor; and (4) HTC-Vive VR headset.

The camera was mounted on a tripod 1.5 m from a wall containing a visual task, 2.18 m from the window, and 1.60 m from the floor. When participants observed the window view in the virtual setting, it appeared at the centre of their field of view. All measurements were repeated five times for each condition. To measure the luminances seen within the visual office environment, high dynamic range images (HDRI) were collected [46]. Six 180^{o} HDRI inside the room were collected, which captured the four walls, ceiling, floor and window inside the room. An additional HDRI was created for the floor to mask the tripod. The lowest sensitivity (ISO= 100) was used to reduce the noise in the HDRI. To maintain consistent colour space transitions with fixed white balance (i.e., correct colour temperature (CCT)) [51], a white balance (4000 K) that matched the average room CCT was used. The latter was measured with the Chroma-meter (accuracy ±0.02%). Each HDRI consisted of seven low dynamic range images with different exposure values. These were then combined into one HDRI images that measured a higher range of brightness. The HDRI images were calibrated with spot-point luminance measurements.

Since current virtual head-mounted displays cannot display HDR images [46], tone-mapping was applied to the images displayed in the virtual environment to correct the luminance and contrast values. A tone-mapped with a 2.2 gamma and key value of 0.01 [52] was applied to generate similar contrast values to those found in the real environment. The resulting tone-mapped images were combined into 360^{o} panorama using PTguiPro software [53]. The previous process was repeated twice from two viewpoints 65 mm horizontally apart to replicate the distance between the centres of observer's eyes to produce the depth perception from two-dimensional images [54]. The method used is validated and detailed in previous work [46].

2.1.2. Stress Inducing Task (Stroop-Test)

The Stroop-test [55, 56] was used to temporarily elevate stress levels [56-58]. It is a colour-word conflict test often used for cognitive work assessment, including a selective attention feature that emulates some mental processes (e.g., occupants ignore irrelevant distractions and focus on task-relevant information [59]) similar to office-based work tasks [60, 61]. While immersed in VR (Figure 2), participants were required to name the colour for each word, as quickly and accurately as they could, attempting those that they were uncertain of within a period of 45-seconds [57]. The rate of stress recovery, while observing the view, was an indicator of quality [40] (i.e. higher rates translated to increased quality). To counterbalance learning effects, five different versions of the same test were randomly allocated to each WWR condition. This prevented participants from viewing the exact same version of the Stroop-test more than once.

Fig 2. The Stroop-test used to elevate stress levels within the VR.

Each Stroop-test consisted of 15 rows with five words in each row. Text font size was 20 mm, creating a 0.76° angular size produced by character height, which was within the range needed for fluent reading (i.e. between 0.2° to 2°) [62]. Four typeset font colours were used: Red, Green, Blue (RGB), and black; the former representing the three main components of the

RGB colour model used in lighting studies [63, 64]. The selected colours had positions on the chromaticity chart identical to those used in a previous VR study [46].

2.2. Physiological Measurements

When immersed in the VR setting, the several physiological measurements were recorded. Three measures were collected to evaluate stress recovery levels after completion of the Stroop-test: Skin Conductance (SC), Heart Rate (HR), and Heart Rate Variability (HRV). The selected physiological measures could continuously monitor nervous system activity [18, 65-68].

Both SC and HR data were collected at a rate of 32 samples per second (SPS) using sensors connected to the Mind Media Nexus-10 MKII acquisition device. SC sensor electrodes were attached to left-hand index and ring fingers of the participant to detect increased sweat gland activity, signifying states of elevated stress [69, 70]. On the same hand, the HR sensor was connected to the middle finger to measure different measures for HRV from blood flow rate, including: LF-HRV (low frequency) and HF-HRV (high frequency), and a ratio (LF/HF) of both. The aforesaid are all expressed in milliseconds squared (ms^2) for a particular Hertz (Hz) band. Two additional HRV measures were collected: Heart Rate Variability amplitude (HRV_a) and Blood Volume Pulse Amplitude (BVA). HRV_a measures the variations in duration between two successive heart beats, whereby decreased HRV_a signals mental load (e.g. periods of work induced stress [71]), while increased HRV_a is related to lower performance anxiety [71, 72]. BVA measured changes in the blood volume in vessels controlled by branches of the autonomic nervous system. Contractions in finger micro-vessels are caused by elevated stress, signalling decreases BVA, and dilations caused by expansions, increases BVA [73].

2.3. Subjective Evaluations

View perception was recorded using self-assessed questionnaires that evaluated: view restorative ability, view content, view size, view valance and arousal, visual interest, and complexity [74]. All questions (Appendix A) were measured on a continuous scale ranging from, “Not at all” (= 0) to “Very much” (= 10), which were explained to participants in the procedure. The positive and negative affect schedule (PANAS) [75] was disseminated before and after the Stroop-test was performed to gauge self-reported stress levels. Since participants were immersed in the virtual setting, verbal responses to each question were recorded using Dictaphone [30, 76]. The questions were randomised across the five conditions to minimise order bias [77]. Reported simulator sickness symptoms produced from immersion in the VR setting were assessed using the Simulator Sickness Questionnaire (SSQ) [78], which were completed both at the beginning and the end of the experiment.

2.4. Experimental Procedure

The study was conducted from January to February 2020. Indoor air temperature and humidity were measured for each session at the position of the participant. The average temperature and humidity readings across the entire duration of the experiment were 20.7°C and 38.3%, varying from 18.4°C and 32.5% (i.e. minimum recorded values) to 22.5°C and 46% (i.e. maximum recorded values). These measurements were taken as buildings’ occupants are simultaneously exposed to multiple indoor stimuli (i.e., visual, thermal, etc.), and their perception of the indoor environment cannot be separated from the interaction of these stimuli. I.e., thermal comfort might affect occupants’ visual perception [79].

Using a repeated measure design [77], the same participant gave evaluations to each of the experimental conditions. The order in which participants evaluated the experimental conditions was randomised to reduce unwanted procedural effects [77]. The experimental procedure was approved by the University of Nottingham Ethics Committee. Participants were volunteers of academic staff members and students and were recruited via online advertisements and posters. All participants were unaware of the actual purpose of the study. I.e., the actual aim was kept vague to prevent any experimental bias. A total of 25 subjects from different ethnic backgrounds voluntarily participated to the experiment: 14 males and 11 females with a mean age 27 years (SD= 5.26). Similar number of participants has been used in related studies on lighting perception [30, 40, 80] which has revealed significant influences and agreeable effect sizes in this study as shown by the inferential analyses. None of the participants reported any colour vision problems, and 15 participants wore corrective glasses during the experiment. After screening the physiological data, recordings from two participants were removed due to noise embedded in the recorded signals, making information unsuitable for further analysis [40]. The final sample size for the physiological data analysis was 23 participants, 13 males and 10 females with mean age 26 years (SD= 5.82).

The experimental procedure is shown in Figure 3. Upon arrival to the study location, participants read the experimental instructions and signed a consent form. They then completed surveys for vision acuity (i.e. for corrective eyewear and colour blindness), demographic information, and completed the first SSQ. Participants were required to abstain from drinking alcohol 24-hours and caffeine eight hours prior to the test [81]. Individuals prone to migraines, epilepsy, motion sickness, sleep disorders, dizziness, or blurred vision were excluded from the study [82]. The aim of this study was hidden from participants.

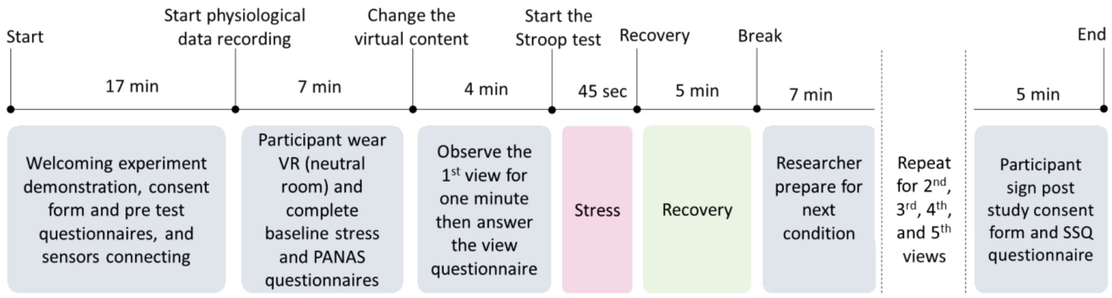

Fig. 3 Overview of the experiment procedure from start to the end of a single test session

Participants sat on a chair upon arrival to the test-room and were instructed to limit any hand movements and remain silent during the experiment. This reduced noise signals recorded by physiological measurements [83]. Participants familiarise themselves with the VR environment by observing the baseline windowless scene, in which they completed the Stress and PANAS questionnaires. These responses served as baseline measurements. Physiological measurements were monitor for 5-minutes, which was longer than the recommended length of 2-minutes [66, 84-86].

For each WWR condition, participants were immersed within the VR setting for 1-minute before completing the view perception survey. This was followed by stress induction (i.e. Stroop-test) and recovery (i.e. observing the window view) periods, whereby variations in physiological measures were monitored. The VR headset was connected to a monitor via which the researchers were able to observe what the participant looked at during the stress recovery to ensure that participants were recovering from stress while observing the view. To be used as a subjective measure of recovery, participants then repeated the stress and PANAS questionnaires. Procedures were repeated until all five conditions were assessed. A 7-minute break was provided between each condition to avoid fatigue [68, 83].

An overview of the experiment methodology is provided in Figure 4.

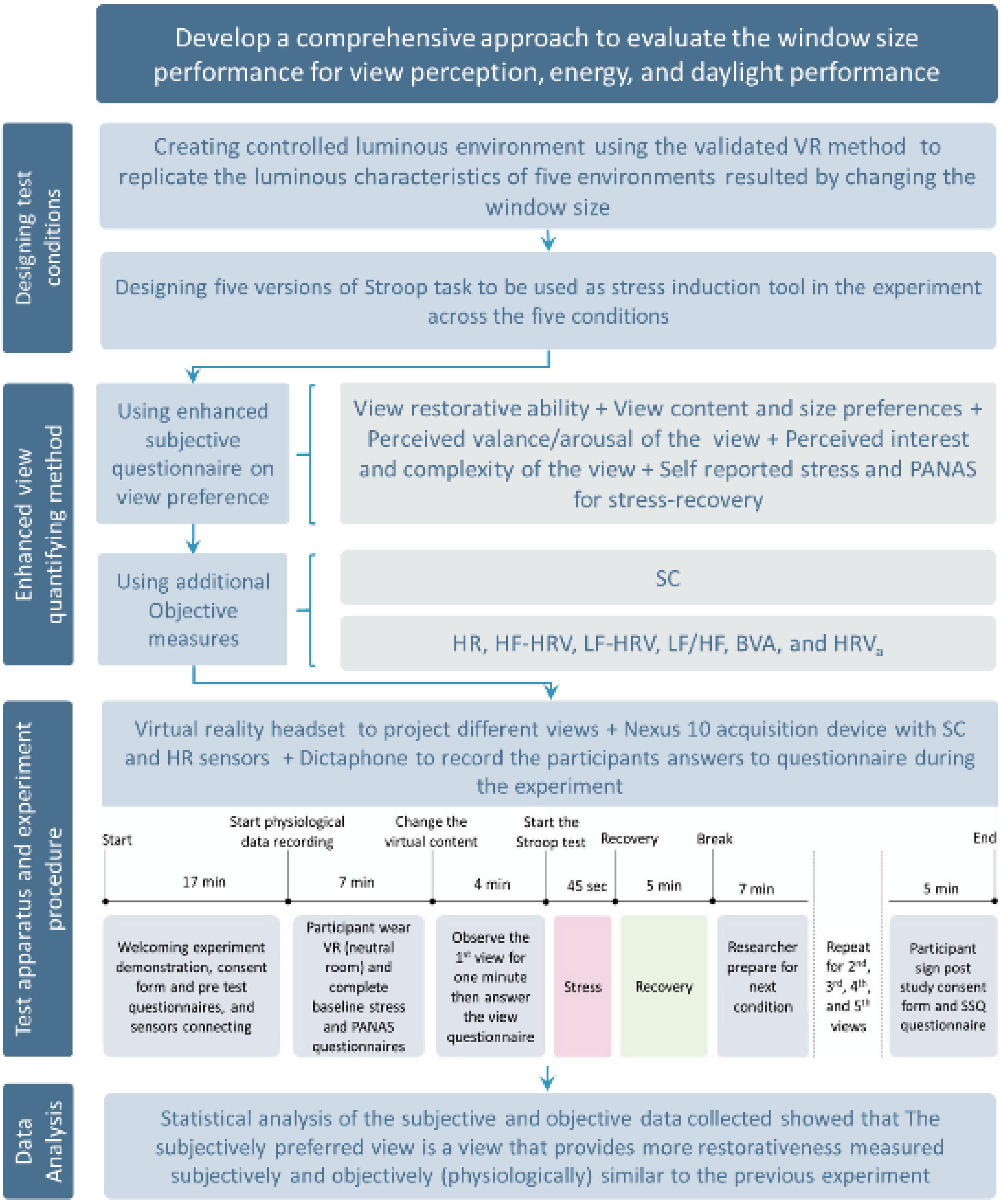

Fig 4. An overview of the experimental methodology used in this paper.

2.5. Statistical Analyses

Physiological response data at points of interest were extracted to obtain both baseline response (i.e., windowless condition) [70, 84, 87] and initial response (i.e., participant first observed the window view) conditions [68, 69, 85]. Changes in both SC and HR were calculated by subtracting measures recorded at the initial response and during stress recovery periods from baseline measurements. These differences allowed for comparisons to be performed across different WWR conditions [69]. SCR data were extracted 1-4 four seconds after presenting the window view, with a minimum amplitude of 0.01 μS [69, 70, 88], while HR and HRV data were assessed using the mean values calculated from the first 30 seconds recorded after the initial response. Baseline measurements were again subtracted across points of interest for SRC and HRV, which were also compared across different WWR conditions.

The evaluation of stress induction and recovery were obtained using SCL, HR and HRV measurements. Changes in the abovementioned measures were recorded within the first minute of recovery (i.e. exposure to the window view [40]) and used to imitate short breaks occupants take between office tasks. Since the length of short breaks was not pre-emptively known, this was verified by asking participants how often they spend looking at their window view for relaxation. A majority (i.e. 60%) indicated their usual breaks were 2-minutes or less.

The first minute of data, representing recovery, was subtracted from the last minute of the baseline condition to obtain the degree of change [18, 48, 56, 58]. Measurements for SCL, HR and HRV, during the stress induction (i.e., 45-seconds dedicated to completing the Stroop-test), were subtracted from baseline values to indicate elevated stress levels, while the task was being performed [48]. Measures could then be compared across the different conditions.

To determine whether survey items measured the same construct (i.e. view perception), the Cronbach's alpha (α) test for reliability [89] was used. The questionnaire revealed high reliability, Cronbach's α= 0.97. Since this values was greater than the accepted range (i.e. 0.70-0.80) [89], questionnaire items were generally considered to have high reliability.

Since physiological data were measured on different scales that prevented equivalent comparisons, these were transformed into standardised *z*-scores by subtracting the individual values from their sample mean and dividing this by the standard deviation. This is a recommended method for analysing physiological data [69, 90]. Since questionnaires related to view perception and reported stress and PANAS were measured using continuous scale, one-way repeated measure analysis of variance (ANOVA) test is adequate for data analysis when assumptions of normality of the sampling distributions and sphericity (i.e., the equality of variances across repeated conditions) are not violated [77]. Assumptions of normality and sphericity were evaluated using the Kolmogorov-Smirnov [91], Shapiro-Wilks [92] tests and Mauchly's test [89]. Whenever normality was not met, the non-parametric Friedman's ANOVA [58] was used in-lieu of the ANOVA test, while the correction method [93] was applied when sphericity was violated [104]. Bonferroni-Homs corrections were applied [94] to control the experimental-wise error rate, and effects sizes measured the standardised differences [89] across the different conditions. The effect sizes Pearson's, r and partial eta squared (η_p^2) were used. Recommendations given by Ferguson [95] were used to denote effect sizes as either: small, moderate or large ($r \geq 0.20$, 0.50 and 0.80; and $\eta_p^2 \geq 0.04$, 0.25 and 0.64). Values $r<0.20$ and $\eta_p^2<0.04$ were negligible in size.

3. Results

3.1. View Perception Assessments

Figure 5 presents the self-assessed ratings for view perception given by participants to each of the five conditions, ranging from Not at all (=0) to Very much (=10). The central tendencies (i.e. mean and median) tend to correspond to higher ratings of view perception for the eight parameters considered (e.g. fascinating and complexity), particularly when participants observed larger window views. This tendency also applied for wide orientated windows, but interestingly, only when comparing self-assessments across the smallest WWR (i.e. 10%). When participants viewed the largest window view (i.e. WWR= 30%), they gave the higher ratings. The ANOVA tests (Table 2) appeared to corroborate these observations, showing that differences for subjective ratings across the five windowed conditions were highly significant and moderate in size ($0.25<\eta_p^2\leq0.64$) for all eight parameters. The data analysed suggested that for these measured parameters, window size and layout have a considerable influence on subjective view perception.

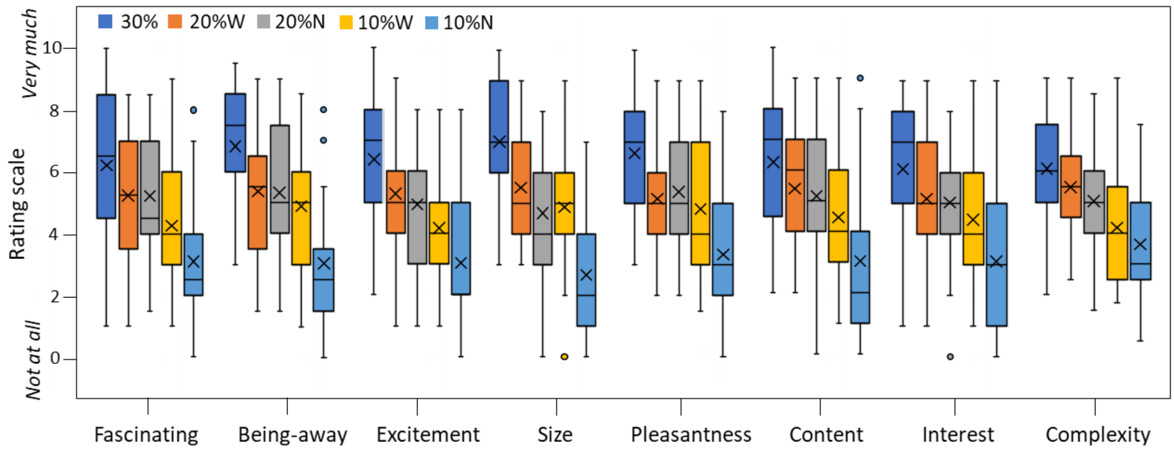

Fig. 5 Boxplots of view perception parameters for each test session according to the five WWR sizes. Note: the crosses indicate the mean of the group condition

Table 2 ANOVA and effect sizes for the eights view perception items

Parameter	*F* (degrees of freedom)	*p*-value	Effect size (η_p^2)
Fascinating	13 (3)	0.00***	0.36
Being away	20 (4)		0.46
Excitement	16 (3)		0.40
Size	29 (4)		0.54
Pleasantness	16 (3)		0.41
Content	16 (4)		0.40
Interest	11 (4)		0.31
Complexity	16 (4)		0.41

***highly significant (*p-values*); $\eta_p^2\geq0.25$= moderate (effect size)

Since it was not practical to individually evaluate every nuance for each pairwise comparison, two WWRs (i.e. 20%W and 20%N, and 10%W and 10%N) of interest from Table 2, were examined in further detail. While comparisons generally showed that larger WWRs significantly increased view perception ratings, Table 3 showed that when the WWR was the same, but aspect ratio (i.e. wide and narrow) varied, diverging results were produced. For the smallest WWR 10%, statistically significant and moderate effect sizes were found across the wide and narrow conditions. This influence favoured a wide orientated window view over its narrow counterpart. Differences across the two layouts for the WWR 20% were much smaller, revealing one weakly significant difference, and small and negligible effect sizes. Although it is difficult to ascertain why these results occurred, increases in view perception for layouts may have saturated or plateaued at the WWR 20%, or at a size between the former and >10%. Remarkably, this showed that WWRs ≤20% may not be a reliable indicator of window size for overall view perception.

Table 3 Pairwise comparisons and effect sizes for wide and narrow windowed conditions

Parameter	Comparison	Mean		ΔMean	*p*-value	Effect size (*r*)
		Wide (SD)	Narrow (SD)			
Fascinating	20%W and 20%N	5.23 (2.08)	5.22 (2.17)	0.01	0.98 n.s.	0.01 negligible
Being away		5.36 (2.10)	5.32 (2.18)	0.04	0.91 n.s.	0.02 negligible
Excitement		5.28 (2.11)	4.92 (2.10)	0.36	0.29 n.s.	0.21 small
Size		5.52 (1.91)	4.55 (2.46)	0.84	0.05*	0.39 small
Pleasantness		5.16 (2.13)	5.38 (2.18)	-0.22	0.56 n.s.	0.12 negligible
Content		5.40 (2.06)	5.16 (2.23)	0.24	0.46 n.s.	0.15 negligible
Interest		5.16 (2.07)	5.04 (1.92)	0.12	0.76 n.s.	0.06 negligible
Complexity		5.48 (1.81)	5.04 (1.73)	0.44	0.13 n.s.	0.30 small
Fascinating	10%W and 10%N	4.25 (2.15)	3.10 (2.05)	1.15	0.03 n.s.	0.42 small
Being away		4.88 (2.21)	3.04 (2.18)	1.84	0.00**	0.64 moderate
Excitement		4.16 (2.13)	3.04 (2.30)	1.12	0.03 n.s.	0.43 small
Size		4.88 (2.11)	2.68 (2.03)	2.20	0.00***	0.72 moderate
Pleasantness		4.82 (2.29)	3.34 (2.36)	1.48	0.01*	0.50 moderate
Content		4.46 (2.35)	3.04 (2.47)	1.42	0.01*	0.50 moderate
Interest		4.48 (2.22)	3.12 (2.55)	1.36	0.02 n.s.	0.46 small
Complexity		4.17 (1.82)	5.04 (1.73)	0.53	0.16 n.s.	0.28 small

Bonferroni-Holms corrected: n.s. not significant; *weakly significant; **significant; ***highly significant

Valance and arousal also revealed similar observations for view perception across the five conditions. Figure 6 shows changes in mean ratings plotted on the Circumplex model of affects. The location for each mean rating reveals changes in perceived affect across the five conditions. When participants observed the WWR 30%, they reported more pleasantness and arousal compared to other the conditions, thereby creating stimulating affect. For the remaining scenarios, mean ratings drifted toward the dull criterion when window size decreased. When the WWR was the same, the arousal and valance ratings were similar between 20%W and 20%N, but differences were much larger across 10%W and 10%N. This again elucidated the importance of aspect ratio for the smallest window size, showing that this influence ceased to influence view perception when WWR increased from 10% to 20%.

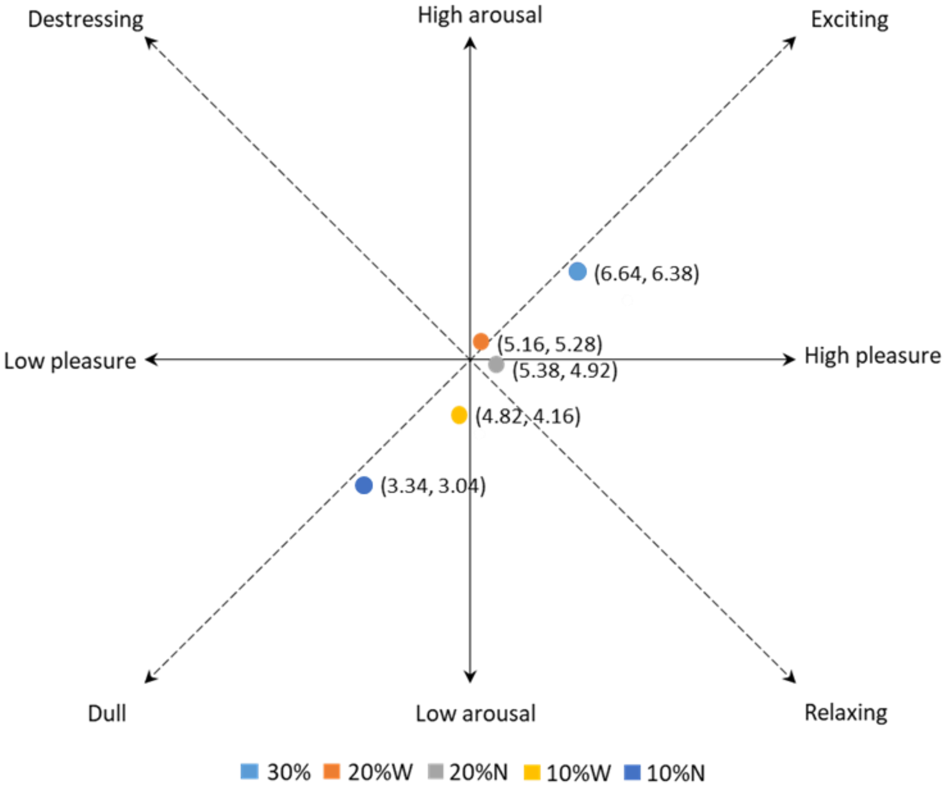

Fig. 6. Locations of mean ratings of view perceived valance/arousal on the Circumplex model of affects adopted from [96]

3.2. Self-Reported Stress and PANAS

The Friedman's ANOVA indicated significant differences across the five conditions for:

- Self-reported stress (ΔStress): $\chi^2(4)=19.65$, $p<0.01$**
- Positive affect (ΔPA): $\chi^2(4)=16.99$, $p<0.01$**
- Negative affect (ΔNA): $\chi^2(4)= 14.58$, $p<0.01$**

These indicators measured the differences in response by subtracting the baseline from the point when participants observed the window view. Preliminary results inferred that window size and layout influenced self-reported stress recovery, and positive and negative affect. Since it could not be established which conditions facilitated these differences, Wilcoxon signed-rank tests were used to isolate the effects originally detected for each of the three indicators. Table 4 reports the median and interquartile range (M_{dn} and IQR), *p*-value, ranks (i.e. positive, negative and ties), and the effect size (*r*).

The Wilcoxon signed-rank tests showed that 22 of 30 comparisons across the three parameters and five conditions were not statistically significant. While a majority of cases produced no statistically significant differences, this may have been attributed to the large number of comparisons and the stringent correction applied by Bonferroni-Holms method. Eight comparisons that demonstrated statistical significance are shown in Table 4. Interestingly, seven of the eight differences denoted as statistically significant were for WWRs compared to 10%N, while the remaining case was for 10%W. This suggested that perceived stress recovery and positive affect were higher for larger window sizes, while negative affect was also lower. Further, the small size and narrow window layout 10%N was not perceived equally to its wide counterpart 10%W, since similar statistically significant differences were not found for the latter when compared to other windowed conditions.

Table 4 Wilcoxon signed-rank tests and effect sizes for subjective recovery parameters

Parameter	Comparison	M_{dn1} (IQR)	M_{dn2} (IQR)	*p*-value	Positive	Negative	Ties	*r*
∆Stress	30% vs. 10%N	0 (20)	10 (20)	0.00***	2	18	5	0.53 moderate
	20%N vs. 10%N	0 (13)	10 (20)	0.01*	5	15	5	0.35 small
∆PA	30% vs. 20%N	1 (6.50)	-1 (6)	0.00***	18	4	3	0.40 small
	30% vs. 10%W	1 (6.50)	-1 (6.50)	0.01*	16	6	3	0.38 small
	30% vs. 10%N	1 (6.50)	-2 (6)	0.00***	17	5	3	0.49 small
	20%W vs. 10%N	1 (4)	-2 (6)	0.00*	16	6	3	0.44 small
∆NA	30% vs. 10%N	0 (3)	0 (3.50)	0.00***	3	15	7	0.41 small
	20%N vs. 10%N	0 (3.50)	0 (4.00)	0.00****	2	13	10	0.41 small

Bonferroni-Holms corrected: n.s. not significant; *weakly significant; ***highly significant

The influences were overtly greater when comparing the largest WWR 30% to the smallest size 10%, with effect sizes ranging from moderate ($0.50 \leq r < 0.80$) for ΔStress, and small ($0.20 \leq r < 0.50$) for ΔPA and ΔNA. Therefore, it can be inferred that window size influenced self-assessed stress recovery and affect, enhancing mental restoration and positive psychological affect for WWRs 30% and 20%. However, it is important to note that these influences do not appear to be widespread across every condition considered.

3.3. Physiological Data

3.3.1. Initial Response to Window View

Friedman's ANOVA showed no significant differences when the participants first observed the view for the different windowed conditions for: SRC, HF-HRV, HR, LF-HF and BVA. Since no significance differences were found, no further analyses were conducted for those measures. However, statistically significant differences were found for the following:

- LF-HRV: $\chi^2(2) = 13.28$, $p < 0.01$*
- HRV_a data: $F(4,96) = 3.95$, $p < 0.01$**

Pairwise comparisons were conducted for the two indicators to explore the magnitude of differences across the five different conditions. Wilcoxon signed-rank test were conducted for LF-HRV (Table 5a) and *t*-test pairwise comparisons for HRV_a data (Table 5b). The results showed that a majority of comparisons were not statistically significant (i.e. eight out of 10 conditions for LF-HRV and seven out of 10 conditions for HRV_a). The differences in LF-HRV across different conditions were statistically significant when comparing 20%W and 10%W, and 10%W and 10%N. While it is unclear why these results revealed significant differences and other comparisons did not, the latter comparison showed that window layout (i.e. wide and narrow) exerted a larger influence on LF-HRV, when participants first observed the view for the smallest size WWR 10%. This same influence on LF-HRV was not found for the WWR 20%, suggesting that layout only influences this physiological response for smaller window sizes.

Table 5 Wilcoxon signed-rank tests and effect sizes for LF-HRV

5a: Wilcoxon signed-rank tests for LF-HRV results

Parameter	Comparison	M_{dn1} (IQR)	M_{dn2} (IQR)	*p*-value	Positive	Negative	*r*
LF-HRV	20%W vs. 10%W	0.00 (0.19)	0.08 (0.25)	0.02*	9	16	-0.32 small
	10%W vs. 10%N	0.08 (0.25)	-0.05 (0.18)	0.00*	21	4	-0.42 small

5b: *t*-tests for HRV_a data results

Parameter	Comparison	$Mean_1$ (SD)	$Mean_2$ (SD)	ΔMean	*p*-value	*r*
HRV_a data	30% vs. 10%N	-0.22 (0.52)	0.13 (0.49)	-0.34	0.00***	0.51 moderate
	20%W vs. 10%W	-0.21 (0.41)	-0.06 (0.35)	-0.28	0.01*	0.48 small
	20%W vs. 10%N	-0.21 (0.41)	0.13 (0.49)	-0.34	0.00***	0.51 moderate

Bonferroni-Holms corrected: n.s. not significant; *weakly significant; ***highly significant

HRV_a generally decreased for the larger WWRs. This indicated that participants had lower cognitive work for the same task, indicating decreased physiological stress. HRV_a revealed significant differences when the smallest WWR 10% was compared to larger window sizes, whereby the magnitude of these effects were moderate ($0.50 \leq r < 0.80$) or bordered this threshold. Interestingly, results that denoted statistical significance in Table 5 showed that lower stress, as indicated by measures of LF-HRV and HRV_a, were only present when the WWR 10% was compared to a wide orientated window, or was the largest possible window size available. These paralleled results derived from subjective assessments and LF-HRV, indicating that wide orientated and larger window sizes leveraged higher view quality.

3.3.2. Physiological Stress and Recovery

Figure 7 shows the results of SCL during recovery and stress induction. The y-axis shows SCL for stress induction (i.e. induced by the Stroop-test) and recovery periods displayed on x-axis, along with the five different conditions: 30%, 20%W, 20%N, 10%W and 10%N. While no discernible differences or trends were revealed for the stress induction period, statistical parameters for the recovery period had a tendency to correspond to higher SCL values when participants observed larger window sizes, whereby SCL was lowest for the WWR 10%N and highest for WWR 30%. ANOVA tests verified these observations, showing that SCL measurements during stress induction were similar across the five conditions: $F(4,96)= 13$, $p>0.05$ (not significant); but were statistically significant difference for the recovery data collected: $F(4,96)= 20$, $p<0.05$, with a small effect size.

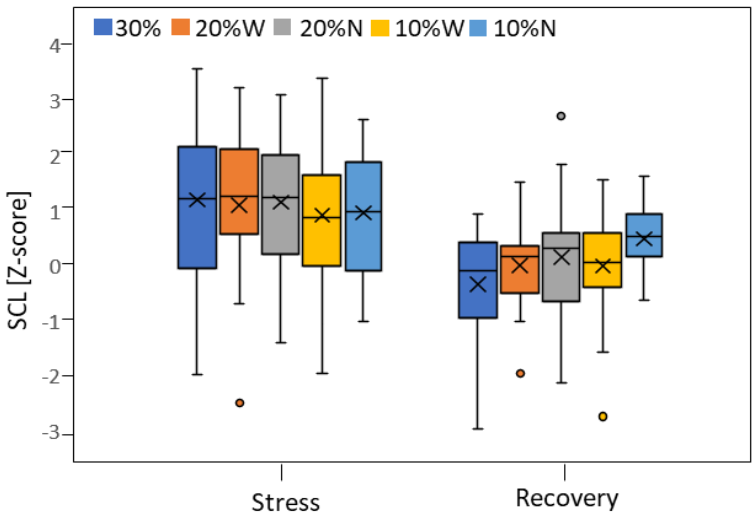

Fig. 7 Boxplots of SCL at each test session (variation of window size). Note: the crosses indicate the mean of the group condition

The pairwise comparisons revealed that two of 10 comparisons were statistically significant: 30% and 10%N, ΔMean SCL= -0.82*** (highly significant), $r= 0.56$ (moderate effect); and 20%W and 10%N =, Mean SCL= -0.48* (weakly significant), $r= 0.44$ (small effect), indicating significant increases in stress recovery as window size increased. The results indicated lower recovery rates for when participants observed the WWR 10%N. Interestingly, the differences for the same WWR showed that stress recovery responses were different. For larger WWRs, the difference in layout of stress recovery was smaller: 20%W and 20%N, ΔMean SCL= -0.15 (not significant), $r= 0.10$ (negligible effect); while for the smaller WWR, stress recovery was notably larger: 10%W and 10%N, ΔMean SCL= -0.49 (not significant), $r=$ 0.42 (small effect). Both results indicated that differences were not statistically significant, albeit for the latter WWR 10%, findings would have been (i.e. p=0.03), prior to being adjusted by the Bonferroni-Holms correction method.

ANOVA tests that compared HR, LF-HRV, HF-HRV, and HRV_a data across the five conditions, for both stress induction and recovery stages, revealed no statistically significant differences. LF/HF and BVA measures were analysed using Freidman's ANOVA. While BVA also showed no statistically significant differences, LF/HF identified a significance difference during the recovery period: $\chi^2(4)= 11$, $p= 0.03$ (weakly significant), but not for the stress induction stage. Wilcoxon signed-rank tests showed that the difference initially detected was for the comparison across the WWR 30% and 10%N: $p<0.001$ (highly significant), $r= 0.36$ (small effect), while remaining comparisons were not statistically significant. Since this comparison compared the largest and smallest WWRs, this explained why an effect was only found for this comparison, but not for others that compared smaller variations in window size.

In summary, subjective assessments showed that window size and layout have a substantial influence on self-reported view perception, stress, and psychological affect. A majority of these influences were supported by statistical inferences, revealing that larger window sizes generally promoted view quality. While physiological data supported similar inferences resulting from self-assessments, the effects were noticeably smaller. Further, not all parameters were influential when used as proxies for view quality (e.g. HR, LF-HRV, HF-HRV and HRV_a). Nonetheless, both subjective and objective measurements generally indicated that the WWR 30% leveraged the highest view perception assessments and stress recovery. A wide orientated window also demonstrated higher view quality compared to a narrow layout, but these effects were only found for WWR 10% and not for 20%. Therefore, WWR may not be a reliable indicator for view perception for small window sizes.

3.4. Simulator Sickness Symptoms

SSQ before and after the experiment were collected using ordinal scale and analysed using the Wilcoxon signed-rank test (Table 6). Since other symptoms, including: 'General Discomfort', 'Headache', 'Difficulty Focusing', 'Salvation Increasing', 'Sweating', 'Nausea', 'Dizziness', 'Eyes Open', 'Dizziness Eyes Closed', 'Vertigo', 'Stomach Awareness', and 'Burping' were not statistically significant (p>0.05), these have not been reported here.

Table 6 showed symptoms that were statistically significant when the differences reported by participants were compared before and after they took part in the study. All differences are denoted by small effect sizes, yet for some comparisons, there were a considerable number of ties (i.e., when the evaluations across both conditions were the same). Most of these symptoms are generally to be expected following exposure to virtual conditions [40, 46], and all participants were briefed on the potential occurrence of discomfort that was likely to happen during the VR trial. While these symptoms occurred for some participants, they subdued shortly after they finalised the experiment [40].

Table 6 Reported symptoms for simulator sickness

Parameter	Before (M_{dn})	After (M_{dn})	*p*-value	Positive	Negative	Ties	*r*
Eyestrain	1	2	0.00***	0	17	8	0.55 moderate
Difficulty Focussing	1	1	0.01**	0	9	16	0.39 small
Difficulty Concentrating	1	1	0.01**	1	11	13	0.40 small
Blurred Vision	1	1	0.01**	1	9	15	0.35 small
Dizziness /Eyes Closed	1	1	0.00**	0	9	16	0.41 small

n.s. not significant; **significant; ***highly significant

4. Discussion

Using a virtual environment, this study evaluated the impacts of window size and layout on view perception, stress recovery and psychological affect. Findings found substantial differences for subjective measurements and similar, yet weaker influences for physiological indicators of view quality, all of which were created by changes in WWR and window layout. Measures revealed that higher view quality for the same outdoor view was found when window size increased [31, 34, 38]. While this result was generally expected, effects for window layout depended on window size. When the WWR was 20%, there were no notable differences across wide and narrow orientated windows. However, for the smallest WWR 10%, larger differences across the two window layouts were found. These differences were detected for multiple measurement parameters, including subjective assessments for view perception (Table 3) and objective indicators for stress recovery (Figure 6). This showed that WWR was not always a reliable indicator for view perception, questioning its usefulness when sizing windows that integrate view quality as a design criterion.

Although underlying causes that influenced window layout were unclear, it may be related to saturation effects caused by window size. Keighley [97] found an exponential increase in satisfaction when the window area increased from 10% to 20%, which plateaued around 30%; whereby any increases in size after that point, yielded no further changes in view quality. It is conjectured that the WWR values are dependent on the content seen from the window, varying if the view contains different elements (e.g. green or blue spaces). Nonetheless, assuming that the saturation point for layout applied to the view used in this present study (Figure 1) resided between 10% and 20% WWRs, this may explain why effects were only present for the smallest size used. This may have important implications when sizing windows for building envelopes or facades with limited surface areas. To promote view quality for small windows (i.e. WWRs less than 20%), designers should opt for wide orientated windows rather narrow (i.e. landscape instead of portrait views), since they are conducive for producing higher view perception (e.g. valance/arousal), increased stress recovery, and greater positive affect. If design intentions for smaller windows were to advocate view quality, it will likely provide a less stimulating working space if it has a narrow layout. For larger sized windows (i.e. WWR≥20%), layout may not have a significant influence on overall view quality and designers may decide to select either layout based on other design criteria (e.g. daylighting).

Differences between 30% and 10%N were also larger than those found between 30% and 10%W (e.g. Table 4) and by their positions situated on the Circumplex model (Figure 4). While this supported the notion that layout had a larger influence when the window was narrow compared to wide, it showed that the greatest influences for size occurred when the smallest and largest WWRs were compared. Similar increases, for some aspects of view quality, were also revealed when the WWR 30% was compared to 20%N for ΔPA, but not for 20%W, indicating that the wider window layout and the largest window size have similar influences on positive affect. An important question remaining, which may influence generalisation for some findings, was whether this applies across a wider range of visual content. Previous research [38] that had also used a wide orientated window with a 20% WWR showed that observers preferred this layout when the outdoor view showed a built environment, while a narrow layout was considered acceptable when the view contained a distant landscape (e.g. sky and ground layers). View content that is seen further away in the view generally produces higher level of visual satisfaction than nearby objects [98]. Depending on how the opaque wall envelope frames the glazing that permits visual access to the outdoor view (e.g. landscape or portrait), features of varying sizes and/or seen at varying distances may be perceived differently through the window by occupants.

Subjective assessments for stress recovery and positive affect (i.e. ΔStress and ΔPA) were elevated when participants viewed larger window sizes. Besides producing working environments that support occupant health and wellbeing, results showed that larger WWRs may enhance workplace productivity. In other words, there was a greater degree of psychological restoration within the same time period of relaxation. Physiological makers for view quality (e.g. LF-HRV and HRV_a) showed some significant influences, signifying higher recovery following stress induction. Initial responses for when participants observed WWRs 30% and 20%W both showed lower HRV_a, which suggest increased mental work [71] and greater cognitive engagement with the window view. While it is important to emphasize that for a majority of parameters considered, no statistically significant differences were found, this may have been due to the relatively short period stress was induced (i.e. 45-seconds) or that the view contained some, but not a lot of nature (e.g. greenery). Viewing nature is favourable for promoting many beneficial influences, including stress recovery [99]. Observing a view saturated with nature may have induced a greater stress recovery response. Given also that a relatively small sample size and stringent analytical correction approach (i.e. Bonferonni-Holms) were used, this may have further hindered some influences from being detected by the inferential analysis. For other comparisons not reported, statistical values were not lower than the predefined threshold (i.e. $p<0.05$), yet still highlighted substantive differences (e.g. $r>0.20$) across window size and layout.

From a practical standpoint, results from this study may not necessarily support recommendations for window size given by BREEAM [49], advocating a 20% WWR for rooms with a depth ≤8 m. On the Circumplex model (Figure 6), larger differences in arousal and valance ratings were shown, separating the WWR 30% from those that had both 20% WWRs with narrow and wide layouts. Similar differences emerged for the eight ratings given view perception in Figure 3, albeit it is difficult to establish which threshold on these scales translates to an “adequate view” described by BREEAM. This indicates that higher levels of view quality were achievable when the WWR was increased beyond the recommended level of 20%. To guarantee adequate views, a 30% WWR might be preferrable. Nonetheless, these considerations may need to be carefully balanced with energy and lighting performance larger windows, since they may introduce issues of overheating and glare.

Some limitations for this study need to be acknowledged. Firstly, a limited number of WWR and only one window view could be feasibly investigated to determine their influence on view perception. While this barrier was largely enforced by physical constraints for building selected (i.e., it was not possible to create larger window sizes), this could be overcome in future studies by selecting buildings that inherently have bigger windows (e.g. fully glazed facades). Another limitation of this study were simulator symptoms reported by participants. Despite the many benefits VR environments offer, adverse effects after being immersed in these settings may be unavoidable. Similar symptoms are seldom, if not ever present, using real windows. Although these symptoms are usually associated with the application of VR environments [30], they are however, generally minor and short-lived [100]. Additionally, participants were exposed to views during recovery for short period of time to mimic the short breaks usually taken in office environment. The longer exposure time to the views might reveal different results which is limited in the VR to alleviate simulator sickness symptoms.

5. Conclusion

In this study, a virtual environment was used to represent five different windowed conditions, with the same view seen from inside a daylit office. Several subjective and physiological measures were used to quantify the differences in view perception, stress recovery and psychological affect. The findings confirmed statistically significant differences in overall view quality when window size and layout were varied. The main findings were:

- Window size had a significant influence across self-assessed parameters, whereby increased view quality perception was reported for the largest the window observed in virtual environment. Across eight different parameters (e.g. content, interest and complexity), an average increase of 51% in overall view perception was found when the WWR increased from the 10% narrow orientated window to the largest size of 30%.
- Some statistical evidence was uncovered showing decreases in physiological stress levels. Following a stress induction test (i.e. Stroop-test), stress recovery was influenced more when viewing the 30% WWR compared to smaller window sizes. Although not every

parameter revealed this influence, both skin conductance level and low /high frequency ratio for high rate variability showed signs that stress recovery was significantly higher when participants viewed larger windows.

- Changes across narrow or wide windows also influence subjective and objective indicators of view quality perception. This effect appeared to be dependent on window size, highlighting that WWR was not a reliable indicator of view perception for small window sizes. For the WWR 10%, there was a 26% average difference between narrow and wide orientated windows across the eight self-assessed parameters for view perception, while there was only a 4% difference when the WWR was 20%. These differences showed that view quality was percived higher for the 10% WWR with a wide layout.

The results from this research endeavour showed that WWR can influence view quality perception. Not only did larger window sizes increase view perception, stress recovery and positive affect, layout also had a seminal role for perceive the view. For smaller windows (i.e. <20% WWR), wider windows should be advocated to create desireable landscape views that are preferred over narrower ones. Although the results from this study were derived from one window view, further studies with a wider assortment of visual content are necessary to substantiate some of the findings from this study. This would help evaluate other important facets (e.g., privacy and control) that may not have been considered in this present work.

Appendix

Table A1 List of the view perception questionnaire items used during the experiment.

Parameter		View Perception Questions	Scale descriptors	Reference
View restorative ability from	Fascination	• This view is fascinating • My attention is drawn to many interesting things in this view	"Not at all" – "Very much"	[101-105]
	Being away	• Looking at this view would give me a break from the work routine		

perceived restorativeness scale	• Looking at this view helps me to relax my focus on getting things done	
View content	• I like the view provided by the window	[101-104]
View size	• How satisfied are you with the amount of view in this space?	[30, 31, 35, 97]
View valance/arousal	• How pleasant is the view? • How exciting is the view?	[30, 35, 76]
View interest	• How interesting is this view? • How complex is this view?	
View complexity	• The view provided by the window has variety of elements	[74]

Table A.2 Experiment detailed procedure and duration.

Time progress (minutes)	Activity	Duration (minutes)
0-5	Welcome and introduction, sign the consent form and complete Pre-test questionnaires (demographic and SSQ)	5
5-8	Demonstration of the experiment in the test room to make sure subjects understand the procedures and familiarise with VR	3
8-10	Connect SC and HR sensors to non-dominant hand and start physiological recordings	2
10-13	Participants wear VR and answer questionnaire (stress and PANAS)	3
13-17	Take baseline measurements	4
17-28	View the first condition and answer questionnaire (view perception), complete the Stroop-test, and then look at window view to recover and answer the questionnaire (stress and PANAS)	11
28-35	Participants rest outside the experiment room and experimenter prepare for second condition	7
35-39	Take baseline measurements	4
39-50	View the second condition and answer questionnaire (view perception), complete Stroop-test, and then look at window view to recover and answer the questionnaire (stress and PANAS)	11
52-59	Participants rest outside the experiment room and experimenter prepare for next condition	7
59-64	Take baseline measurements	4
64-75	View the third condition and answer questionnaire (view perception), complete Stroop-test, and then look at window view to recover and answer the questionnaire (stress and PANAS)	11
75-82	Participants rest outside the experiment room and experimenter prepare for next condition	7
82-86	Take baseline measurements	4
86-97	View the fourth condition and answer questionnaire (view perception), complete Stroop-test, and then look at window view to recover and answer the questionnaire (stress and PANAS)	11
97-104	Participants rest outside the experiment room and experimenter prepare for next condition	7
104-108	Take baseline measurements	4
108-119	View the fifth condition and answer questionnaire (view perception), complete Stroop-test, and then look at window view to recover and answer the questionnaire (stress and PANAS)	11

119-123	The participants sign post-study consent form and SSQ questionnaire	4
123-125	End of experiment. The participant will be thanked for their time, led to the door and told they are free to leave	2

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Disclosure statement

The authors report there are no competing interests to declare.

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