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## Developing and Testing Visual Privacy Metrics

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### ABSTRACT

The dense redevelopment of inner cities (intensification) has been accompanied by a dramatic surge in the development of multi-unit residential buildings (MURBs) within ever shrinking proximities to one another. Modern multi-unit residential building design often embodies conflicting desires for daylighting and visual privacy, or designers simply do not consider collective occupant discomfort factors. Thus, the focus of this project was to develop and validate conceptual and quantitative variables influencing visual privacy, such that future and existing residential designs can be analyzed from a visual privacy perspective. This paper formulates an approach that combines building physics (visual angles and relative brightness) with social and psychological factors to avoid conflicts between competing aspirations for sustainable and resilient buildings that promote occupant wellbeing.

### KEYWORDS

Visual privacy, occupant discomfort, visual angles, relative brightness, occupant wellbeing.

### INTRODUCTION

Visual privacy is a common perception that is influenced by different cultural, psychological and physiological experiences (Kennedy and Buys, 2015). It is a perceptual progression that occurs between an individual and 'others'. Studies show that visual privacy can be a major influence on a building inhabitant's awareness of comfort (Kang and Kim, Lee et al Lee, 2014). Practically speaking, this means that perceptions of privacy differ among cultures, age groups and sexes, and all variables should be considered in the design-appropriate levels of privacy. Globalization, urban intensification and the trend to larger glass areas in residential buildings are making visual privacy an increasingly critical consideration. Canada is a suitable "living laboratory" for examining visual privacy because it has among the highest percentage of foreign-born citizens who hold diverse perceptions of privacy due to their various religious, cultural and psychological backgrounds (Roy, 2013). Combined with a growing trend toward the use of large windows and glazed facades around the world, visual privacy is being recognized as a major problem in dense urban environments, such as the large cities in Canada where multi-unit residential buildings predominate. Architects and developers put little to no attention towards visual privacy when designing these residential buildings because the metrics of visual privacy are not part of their design vocabulary.

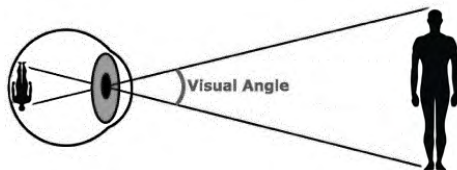
Theoretical approaches to privacy consider the human psychology, culture, and behaviour. Privacy has been split into different categories by theorists, where each defines the comfort level of a person with regards to being observed or touched. Since most individuals seek more privacy at home than anywhere else, the meaning of "solitude" (being free from the observation of others), defines a major need for visual privacy metrics in residential designs (Lang, 1987). When the achieved privacy is less than the desired privacy, a situation known as crowding, adaptive solutions are implemented to counteract the discomfort (Lang, 1987).

The optimum privacy can be difficult to achieve as the desired privacy from one individual to another may differ, causing the achieved privacy to result in social isolation or crowding (Altman and Grove, 1978). Meanwhile, prioritizing privacy through architectural design (e.g., small or translucent windows and moveable shading systems) may compromise views, daylight, and sense of spaciousness. The theoretical privacy mechanism mentioned by Altman is the nonverbal privacy mechanism (1978, pp.34). It suggests that body language reflects upon the level of comfort from non-verbal intrusion to one's privacy (through seeing or touching). The delinquency for someone's ability to visually step into another's private space can have no limitations. People may look into others' houses intentionally or unintentionally; but to the occupant, intention is irrelevant and still results in discomfort for the occupant. An essential factor of living in a multi-story apartment is the amount to which everyday routines are affected by "proxemics and sharing" (Kennedy and Buys, at el Miller, 2015). The connection between proxemics and privacy in housing raises the concern for personal space and the longing for a place that is acknowledged as one's own (Deasy and Lasswell, 1985). People often seek privacy and connection to the community, which creates a challenge for designers, as limits differ from one person to another. However, the connecting base-line to privacy for the occupants is usually their ability to control the privacy.

This research takes a conceptual and quantitative approach to visual privacy in multi-unit residential buildings and analyses the perception of privacy through a series of survey questions of real-life privacy related situations.

## METHODS

This research is focused heavily on peoples' perceptions of privacy which is influenced by their lifestyle and background. Therefore, this research focused exclusively on field data, and initiated the process by conducting a survey to facilitate the quantification of visual privacy comfort levels. The survey consisted of 32 questions where respondents evaluated real-life visual privacy-related scenarios. The aim of the survey was to produce a realistic setting (based on photographs and renderings) where responders were able to rate the privacy feeling with a scale value. Some of these images were taken of existing residential units in downtown Toronto. These images were then used as part of the questions in the survey to guide the responses to a personal level. Each question from the survey was defined by two visual privacy metrics that were identified to affect the visual privacy rating. These metrics are the visual angle and the brightness level. Visual angle is the viewpoint at which an object spans at the eye of an observer (COSMOS, 2003). It is the angle at which our eyes perceive the size of an object in real life, by incorporating the size of the object and its distance from the observer (see Figure 1 below). Using the equation below considers a small angle approximation.



$$\text{Visual Angle} \approx \frac{\text{Object size}}{\text{Distance}}$$

Figure 1: Visual Angle

The farther away a human is, the more private that human/occupant feels. Thus, distance is a variable that is considered in this calculation. Visual angles were chosen as the initial metric used to determine the equation for optimum visual privacy level, since it is dependent on the distance and the angle at which it is viewed. Multiple visual angles can be determined for

each window in a unit, but in this research the highest visual angle value has been utilized and ascribed to each scenario.

The brightness level is another crucial metric that defines the visibility of inside and outside. Figure 2 consists of two pictures of the same condominium, in Vancouver, in the morning and at night. In the morning, views into the condominium are very limited, whereas at night one can clearly see well into the condominium.

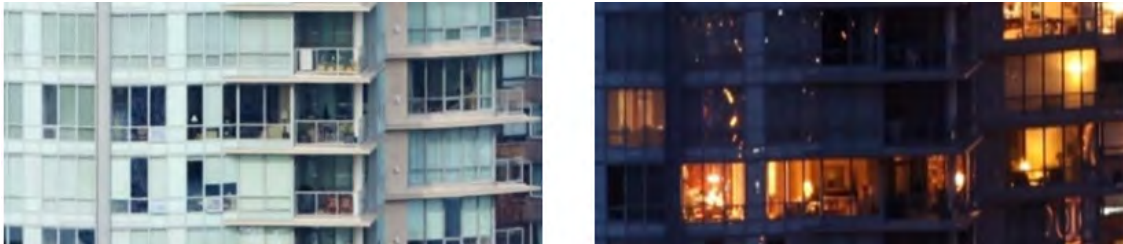


Figure 2: Appearance of condominium in Vancouver in the morning and at night (Gigapixel)

A brightness factor defines the light conditions that affect the privacy rating of housing design. This brightness factor is determined from a range of 1 to 5 which is applied to both the inside and outside conditions simultaneously to obtain a brightness ratio (see Figure 3). The brightness level outside and inside is dependent. For example, the sight conditions when it is bright inside and outside differ greatly compared to bright inside and dark outside. Hence, both conditions were applied as a factor, and then the ratio of what is observed inside to outside was identified.

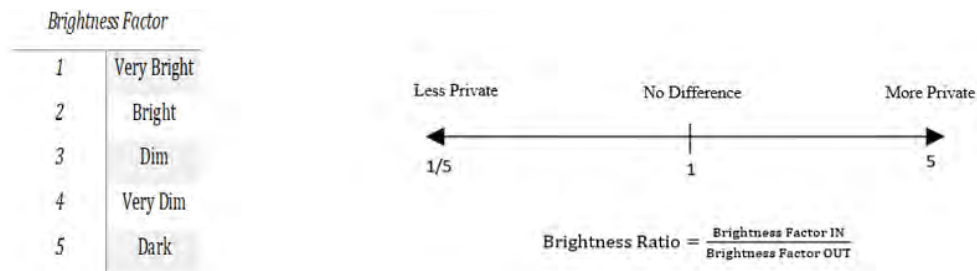


Figure 3: Brightness factor rating from 1 to 5 and brightness ratio calculation.

When the brightness ratio approaches a value of 1/5 (very bright inside and dark outside) the occupied space is considered less private, and when the ratio approaches 5 (dark inside and very bright outside) the occupied space is considered more private. This method for estimating the brightness ratio has been created in support of this research and there are no known prior studies that calculate such factors.

The survey has been created upon the consideration of both the visual angles and brightness levels. Various scenarios were created in SketchUp and from images taken of the field study in Toronto, for the different views at which people would feel comfortable or uncomfortable in. Observers were placed in a hypothetical real-life setting (pedestrian walking, neighbour’s balcony, etc.) at different distances away from occupants for visual angles to be calculated at diverse configurations. Figure 4 shows one observer looking at an occupant’s window from two different horizontal distances.

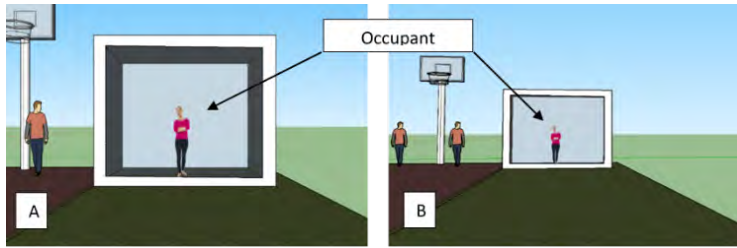


Figure 4: SketchUp model. “A” from observer 5m away and “B” from observer 15 m away.

Most of the questions are scalar, meaning that pictures (like those in Figures 2 and 4) were presented and participants were asked to rate the situation by a scale of 1 (not very private) to 10 (very private). A sample question can be seen in Figure 5.

Q25) On a scale of 1 (not private) to 10 (very private), how private would you feel if you lived in this condominium at this time of day?  
Mark only one oval.

1 2 3 4 5 6 7 8 9 10

Not Very Private           Very Private

View into your condominium

 Figure 5 displays a sample survey question with a Likert scale from 1 to 10. Below the scale are ten radio buttons for selection. To the right, a photograph titled 'View into your condominium' shows an interior view through a window at night, with lights on inside and dark outside.

Figure 5. Sample question from online survey.

Overall, the survey consisted of 32 questions of this type. It was presented to a variety of age groups, genders and persons from different cultures to enhance the understanding of visual privacy in relation to identity and background. A relationship between visual privacy rating (dependent variable) and visual angles and brightness levels (independent variables) can then be established from survey answers, by graphing the results of the three variables together.

## RESULTS

Numerous relationships have been interrogated through the 32 survey questions to examine the relationships between the visual privacy metrics and age, gender, and culture. The survey was completed by 214 people varying in age, gender, background. The results were processed and modelled, using MATLAB and Excel, aiming to create an equation for visual privacy rating. To confirm the affiliation and viability of the privacy metrics, a graph was created for both the brightness levels and visual angles against privacy ratings.

Figure 6 below shows the relationship between brightness ratio levels and participant-rated privacy ratings. As seen in the graph, the hypothesis based in Figure 3 earlier is confirmed: perceived privacy decreases as the brightness ratio decreases (it is brighter indoors than out) – particularly below 1. The most critical values lie where the brightness ratios are lower than 0.5. This is where it is bright inside and dark outside, which is considered the high stakes of visual privacy issues as so much detail can be seen inside. Brightness ratio is primarily dependent on weather conditions and indoor electric lighting intensity.

Unlike brightness ratios, visual angles are influenced by geometric factors such as window size, orientation, balcony size, etc. Nonetheless, the affiliation of the visual angles with privacy ratings, from the conducted survey, shows a relatively linear relationship (see right side of Figure 6) – beyond certain angles privacy is not affected.

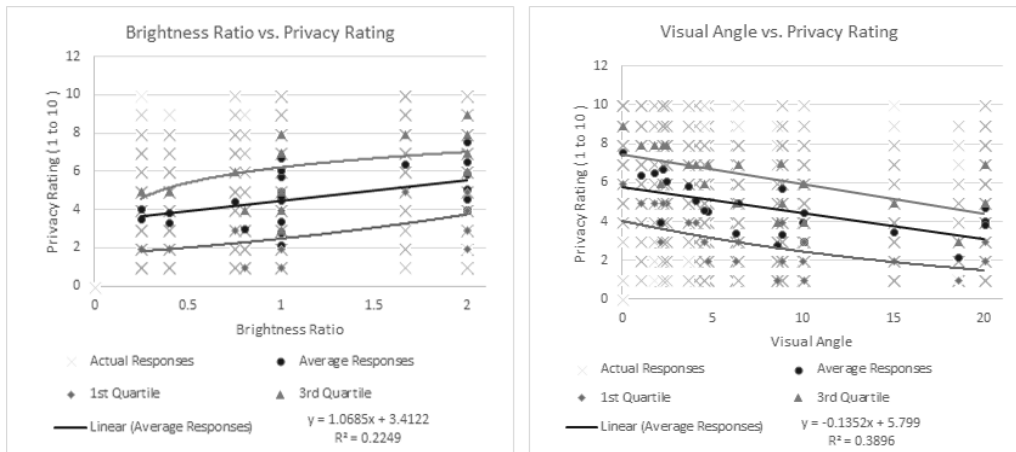
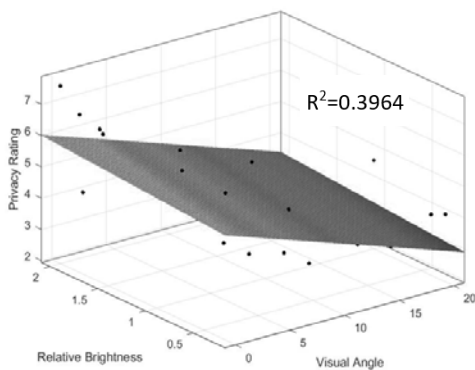


Figure 6. Comparison of relationship between Brightness Ratios and Privacy Ratings versus Visual Angles and Privacy Ratings.

The first and third quartiles in the graphs above lie within reasonable distance to the mean, meaning that generally the privacy is favoured under most circumstances. The quantity at which the amount of visibility (visual angle) is considered acceptable from one person to another is mutable. Cultural influence, for example, plays a key role in the value of privacy and explains the divergence between the data from one person to another, which is discussed later. Thus, the distribution of data in Figure 6 implies a combination of two observations. The first is that people feel differently about privacy and hence answer differently, while the second is that people interpreted the survey questions inconsistently. Further analysis is required understand the variability of responses.

Through MATLAB, the linear relationship between Visual Angle, Relative Brightness, and Privacy Rating was obtained (see Figure 7). Visual angles and relative brightness values can be used to estimate the privacy ratings for any room or unit in residential buildings.



$$PR = 5.375 - 0.1195 (VA) + 0.2471 (RB)$$

Where: PR: Privacy Rating = ranges 1: Not Very Private to 10: Very Private

$$RB: \text{Relative Brightness} = \frac{\text{Brightness Factor In}}{\text{Brightness Factor Out}}$$

$$VA: \text{Visual Angle [0 to 32]} = 2 \arctan \left( \frac{\text{Object Size}}{2 \times \text{Distance}} \right)$$

Figure 7. Graph and equation for visual privacy rating as a function of visual angle and relative brightness.

## DISCUSSIONS

One of the aims of this research was to compare the visual privacy rankings between the different genders, age groups, and cultural standards. The limited length of this paper does not permit presenting the statistics, however several relationships were found. First, culture plays a significant part in privacy ratings, hence in multi-cultural and densely developed urban regions designers should address the full range of cultural values. Second, age was

also found to be a determining factor for visual privacy standards. In this research, perceptions of privacy were more closely correlated for two age cohorts, ages 18-29 and 50+, while a difference in response was reported for the age group of 30-50 years. Young people, and especially females, demand higher levels of visual privacy to feel comfortable. The relationship between room types (e.g., bedroom/bathroom versus living room and clothing levels (e.g., fully dressed versus sleep wear) was not surveyed, but it is reasonable to assume different expectations of privacy based on these parameters. The multi-unit residential building design challenge is to recognize the importance of daylighting and views for occupant wellbeing (Veitch and Galasiu, 2012), while still providing acceptable visual privacy.

## CONCLUSIONS

Visual privacy in residential design has been an issue in various countries for many years (Kennedy, Buys and Miller, 2015). However, there has been very minimal research to develop practical design metrics for visual privacy. This paper indicates that both relative brightness and visual angle are important predictors for visual privacy. However, the large spread in the data indicate two possibilities: 1) that there are many other predictors for privacy (as preliminary examination on demographics has revealed); or 2) that there were multiple interpretations of survey questions. Field studies are needed to confirm the visual privacy metrics advanced in this paper are effective in predicting the need for mitigating measures such as plantings, screens or blinds, frosted glass, etc., and to help determine the potential tradeoffs between daylighting, views and visual privacy. In the future, a visual privacy metric could be incorporated into architectural design software tools as well as building standards (e.g., WELL™ Building Standard).

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