The Effects of Visibility on Fear of Crime in Schools' Interior Environments

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Abstract
In any given environment, visibility is a critical element that affects fear of crime. This study provides empirical evidence of the effects of visibility on fear of crime within elementary schools using a quantitative analysis. Spots in which children felt fear were identified, and their characteristics were analyzed according to the four visibility dimensions of: visual connectivity and visual integration, each with and without visible distance restrictions. One finding was that fear of crime was high in the areas where visibility was either extremely low or extremely high, resulting in a relationship that can be expressed as a U-shaped graph. In addition, fear of crime was associated with visibility in relation to human behaviors as well as built environments. Finally, the visibility distance was also found to be an important element affecting fear of crime.

Keywords: fear of crime; visibility; school interior environment; space syntax; geographic information system (GIS)

1. Introduction
In environmental criminology, visibility is considered a critical element affecting fear of crime (Andrews and Gatersleben, 2010, Fisher and Nasar, 1992, Loewen et al., 1993, Nasar and Fisher, 1993, Wang and Taylor, 2006). According to previous studies, fear of crime is high at low visibility levels. However, in a study by Lee et al. (Lee and Ha, 2015, Lee et al., 2012), fear of crime was reported not only in places with poor visibility, but also in those with very good visibility. To investigate these different findings, the present study uses quantitative analysis techniques including automated computer routines to analyze visibility.

Despite being criminal hot spots, schools have received little attention in relation to crime (Kautt and Roncek, 2007, Roman, 2002). However, according to research conducted by the Seoul Metropolitan Government (2010), Seoul citizens' first priority in terms of education policy was "school safety" (31.8%). In addition, according to a previous study by Salmon et al. (1998), children who experienced criminal behavior felt high rates of anxiety and depression, and those who fell victim to criminal behavior tended to be in their early school years. Therefore, more in-depth research into criminal behavior and visibility within elementary schools would be valuable to the field of environmental criminology.

The purpose of this research is to provide empirical evidence for the effects of visibility on fear of crime in school environments, using an automated quantitative analysis. The objectives of this study are as follows: (1) to investigate the effects of visual connectivity and visual integration on fear of crime, (2) to investigate how limited visibility distances affect the relationship between visibility and fear of crime, and (3) to investigate the effects of visibility in environments on the degree of fear of crime.

In suggesting the scope of this research, several aspects must be considered. First, the interior areas of elementary schools need to be investigated. Previous studies (Kishimoto and Taguchi, 2014) have emphasized the influence of schools' indoor environments on the welfare of students. In addition, despite the significant amount of time students spend in these areas, few environmental criminology studies have focused on these environments. Furthermore, in terms of the interpretation of visibility, scale, and morphology, interior areas differ from urban and exterior areas (Turner, 2003).

Fear of crime is considered in its cognitive and emotional dimensions (Ferraro and Grange, 1987). In addition, as previous studies (Garofalo et al., 1987) indicate that severe crimes are relatively rare in schools, while minor instances of victimization are common, the definition of crime was broadened to include...
school violence. According to a previous study (Hong, 2008), which investigated juvenile victimization, crimes included property crime (fraud, theft, pickpocketing), violent crimes (threats, assault, robbery), sexual incidents (sexual harassment, attempted and/or completed rape, sexual molestation), and peer violence (gang assault, bullying, emotional bullying).

A survey of the spots associated with fear of crime was conducted on elementary school students in order to identify the spots where the children actually felt fear of crime. The surveys were completed anonymously by children aged 12 (fifth-graders) and 13 (sixth-graders).

2. Methodology

2.1 Subjects

To select elementary schools to take part in this study, the numbers of students who had been victims of crime or who had experienced peer bullying in 2011 were compared in 25 districts of Seoul, Republic of Korea (Ministry of Education, 2012). The area displaying the highest numbers was the Songpa district, where 1,586 students had experienced peer bullying (mean of the 25 districts = 785.64, std. deviation = 334.166) and 1,114 students had been victims of crime (mean of the 25 districts = 553.40, std. deviation = 214.404).

To select the schools involved in the survey out of the 37 elementary schools in the Songpa district, the shapes of the school buildings were considered. As previous studies (Batty, 2001, Desyllas and Duxbury, 2001, Hillier, 2012, Turner et al., 2001) have noted that visibility graph analysis (VGA) results are related to the morphologies of buildings, 37 schools are broken down into 6 different categories based on the similarity in their floor plans to explore a type representing each category. Fig.1. shows the various shapes of the selected six schools, and Table 1. summarizes the major features of the schools.

A total of 501 (A: 82, B: 77, C: 108, D: 85, E: 78, and F: 71) surveys were distributed to two randomly selected classes in each school, and 418 answers (A: 69, B: 74, C: 64, D: 86, E: 57, and F: 68) were included in the analysis. Table 2. presents the distribution of the participants.

| Site area (m²) | A    | B    | C    | D    | E    | F    |
|---------------|------|------|------|------|------|------|
| Building to land ratio (%) | 22.36 | 22.69 | 9.81 | 41.06 | 15.93 | 15.45 |
| Floor area ratio (%) | 99.57 | 75.35 | 61.15 | 143.76 | 66.82 | 46.55 |
| No. of classrooms | 43   | 47   | 32   | 38   | 50   | 30   |
| Year of construction | 1996 | 2007 | 1981 | 2008 | 1984 | 1988 |

2.2 Spots of Fear of Crime

The survey was conducted at the six selected schools in December 2012. Each survey lasted 50 minutes. As it was sometimes difficult for the elementary school students to respond to the questions, a simplified drawing of the third floor, which was the standard floor for all schools, and a visual analogue scale (VAS) were provided. This type of VAS is used as a measuring tool for phenomena in fields where few objective measures are available (Cox and Davison, 2005), and several environmental studies (Arneill and Devlin, 2002, Devlin, 2008) have used the VAS before to analyze feelings associated with environments. In this study, the VAS scores measured the degree of fear of crime. Fig.2. shows an example of student answers.

Fig.1. Plans of the Six Selected Schools (Not to Scale): (a) A school with an “□” form, (b) B school with an “H” form, (c) C school with an “—” form, (d) D school with a combined form, (e) E school with an “L” form, and (f) F school with a “T” form

Table 1. Major Features of Selected Schools

Table 2. Features of Participants

|                | Fifth-graders (12 yr.) | Sixth-graders (13 yr.) | Total          |
|----------------|------------------------|------------------------|----------------|
| Males          | 130 (31.1%)            | 71 (17.0%)             | 201 (48.1%)    |
| Females        | 151 (36.1%)            | 66 (15.8%)             | 217 (51.9%)    |
| Total          | 281 (67.2%)            | 137 (32.8%)            | 418 (100%)     |

The surveys were self-completed following the procedure: (1) the researchers explained the concept and the scope of “crime”. As the scope of crime included serious crimes, peer violence, cognitive feelings, and emotional feelings, the participants were told that minor issues could represent important information. (2) The floor drawings of the students’ own school interior areas were provided on the survey paper. (3) Students marked the spots in which they felt fear of crime on the drawings. Due to space constraints, the number of spots was limited to three. (4) To investigate the degree of fear of crime, a 10-cm VAS was used. Students were asked how fearful they...
felt at the spots, and they placed an "x" on a 10-cm line to denote the intensity of the fear, with 0 cm indicating least fearful and 10 cm most fearful. (5) Students wrote why they felt fear of crime in each spot.

All of the data were input into ArcGIS for analysis. Through the program, the density and degree (with 0-10 cm recoded into 0-100) of the fear of crime results were visualized, evidencing the fear of crime "hot spots". The fear of crime was measured in two ways: the density (frequency per grid) of spots (DS), and the sum of the values for the degree per grid (DG).

2.3 Visibility Graph Analysis
The walls of the buildings were used in the VGA analysis. Fig.3. is an example of a drawing used in the study. We used Depthmap, a program designed to perform visibility graph analyses (Turner, 2001). Visibility graphs were made at a resolution of 1m x 1m for a good approximation of a human scale (Pinelo and Turner, 2010). This yielded around 15,088 grid spaces in the interior areas of all six schools. Additionally, graphs were created for the visual connectivity which is "how many locations each node can see" (Turner 2001, page 10) (the term "connectivity" was suggested as "visual connectivity" to distinguish it from other methods of space syntax), and visual integration, which is "the number of visual steps it takes to get from that point to any other point within the system" (Turner 2004, page 1). Visual connectivity is related to the primary isovist concept and visual integration showed a good correlation with the occupancy in building scenarios.

It was difficult to determine the visibility distance for the VGA, as there have been few related studies (Desyllas et al., 2003). According to previous work related to surveillance (Loukaitou-Sideris et al., 2001) which posited a distance of 50 feet for crime reduction and a distance of 40 feet to distinguish facial expressions (Spireiregen, 1965), this study used a visibility distance of 50 feet (15m). The relationship between visibility and fear of crime was analyzed in four ways: visual connectivity with no visible distance restriction (CON_NO), visual connectivity with visible distances restricted to 15m (CON_RES), visual integration with no visible distance restriction (INTG_NO), and visual integration with visible distances restricted to 15m (INTG_RES). Fig.3. shows examples of VGAs for these four ways.

2.4 Visibility and Fear of Crime
To investigate the effects of visibility on fear of crime with a regression analysis, the analysis is conducted as follows: 1) the visibility value of each school was divided into 50 levels with equal intervals to adjust the various levels of visibility in the six schools; 2) the 50 levels was recoded as an ordinal variable ranging from 1 to 50; 3) The number of fear spots, the sum of all the values for the degree of fear, and the number of grids at each level were then investigated. To determine the number of levels to be used as the sample size for the regression analysis in this study, a similar previous study that had used 10 levels (Lu and Zimring, 2012) and studies that had analyzed approximately 50 rooms within the Tate Gallery in London (Turner et al., 2001, Turner and Penn, 1999) were reviewed; to increase the statistical significance, the level was set to 50.

3. Results
3.1 Hot Spots for Fear of Crime in Interior Areas of Schools
The aggregated data showed a total of 904 spots for fear of crime. Based on the types of crime analyzed in view of the fear of crime, the emotional and cognitive feelings account for 316 (34.96%) and 588 (65.04%), respectively. In the cognitive feeling, the fears of severe and minor crime account for 16 (2.72%) and 572 (97.28%) respectively.

As shown in Fig.4., which was created with ArcGIS, some common fear of crime hot spots were visualized. These hot spots included restrooms, stairwells, cul-de-sac areas, locker rooms, storage areas, halls, and gymnasiums. Although classrooms are referred to as hot spots in previous studies (Park and Ha, 2012), they do not stand out as hot spots in this paper due to their distribution of large areas even though they cause a lot of a fear of crime. In addition, the figure shows that the degree and the density of fear did not necessarily match. The mean of the fear of crime degree for all 904 spots was 52.21 (std. deviation = 26.506, min. = 1, and max. = 100). Fig.5. shows examples of hot spots in the interior areas of the schools.

The fear frequency and sum of the values for the degree of fear were then calculated for each level of the four visibility dimensions, and were recoded with an ordinal variable ranging from 1 to 50. Figs.6. and 7. present the sums of the values for the six schools, showing that the distribution of the frequency and sum of the values for the degree of fear were generally positively skewed (or minutely bimodal) for all visibility variables; this implies that, although students mainly felt fear in locations with lower levels of visibility, they also felt fear in locations with higher levels of visibility, albeit to a lesser degree.
3.2 Visibility Graph Analysis of Interior Areas of Schools

The VGAs of the four visibility dimensions in the six schools are shown in Fig. 8. The four visibility analysis values of each school were also divided into 50 levels. Fig. 9 shows the sum of the grid frequency of the six schools for each of the 50 levels.

Generally, the grid frequency distribution was concentrated in areas of lower visibility. The visual connectivity with visible distances restricted to 15m (CON_RES), the visual integration with no visible distance restriction (INTG_NO), and the visual integration with visible distances restricted to 15m (INTG_RES) were positively skewed (INTG_RES was actually minutely bimodal, reflecting the positively skewed shape), while the visual connectivity with no visible distance restriction (CON_NO) was bimodal.

Fig. 4. Distribution of Fear Hot Spots According to Survey. The Functions of the Spaces are Labeled as follows: R stands for restrooms, SR for stairwells, C for cul-de-sac areas, L for locker rooms, SG for storage areas, H for halls, and G for gymnasiums.

Fig. 5. Fear of Crime Hot Spots in School Interior Areas: (a) restroom, (b) stairwell, (c) cul-de-sac, (d) locker room, (e) storage area, (f) hall, and (g) gymnasium.

Fig. 8. Distribution of Fear Hot Spots According to Survey.
Fig. 6. Frequency of Fear of Crime Spots for Each Level of Visibility, Separated into 50 Levels at Equal Intervals

Fig. 7. Sum of the Values for the Degree of Fear for Each Level of Visibility, Separated into 50 Levels at Equal Intervals

Fig. 8. VGAs of the Six Schools in Terms of (a) CON_NO, (b) CON_RES, (c) INTG_NO, and (d) INTG_RES (Lighter Colors Represent Higher Values)

Fig. 9. Grid Frequency for Each Level of Visibility, Separated into 50 Levels at Equal Intervals
In terms of CON RES, INTG NO, and INTG RES, schools comprised lower visibility areas, while in terms of CON NO, schools mainly comprised lower and higher visibility areas than middle visibility areas.

3.3 Effects of Visibility on Fear of Crime in Interior Areas of Schools

The results from the regression analysis of the four visibility analysis values and the two fears of crime values are summarized in Table 3. As regression analyses yield a much higher R² value in quadratic models than in linear models, the correlations between visibility and fear of crime are more appropriate in quadratic models, which are upwards, than in linear models (Figs. 10. and 11.) (McDonald, 2009, Park et al., 2004). Among the four visibility dimensions, INTG_RES yielded the highest R² value (R² = 0.714, p < 0.01). Furthermore, when the visible distance was restricted, the R² values were found to be higher than the non-restricted values. Considering the density (frequency per grid) of spots (DS) and the sum of the values for the degree per grid (DG), all the visibility analysis values were significant (CON_RES, INTG_NO, INTG_RES were significant at p < 0.01, and CON_NO was significant at p < 0.05), but the DG did not show a much higher R² value than the DS only. Cook’s distance is used to search the outlier and there were none to remove.

4. Discussion and Conclusions

Although previous studies (Andrews and Gatersleben, 2010, Fisher and Nasar, 1992, Loewen et al., 1993, Nasar and Fisher, 1993) found that fear had been reported in locations with lower levels of visibility, this study showed through precise quantitative analyses of visibility that fear of crime rebounded in what could be expressed as a U-shaped graph in areas of very high visibility. In a study by Lee et al. (Lee and Ha, 2015, Lee et al., 2012) fear of crime was reported both in places with poor visibility and in those with very good visibility. People tend to gather where visibility is high, and these situations make children fearful. Similarly, when investigating the reasons why students experienced fear of crime in places ranking in the top 10% in terms of visibility in this study, over 80% of the answers indicated that there were many bullies or bully-like peers in those areas. This result echoed the findings of Lee et al. (Lee et al., 2012), which indicated that "peers" were the top cause of students’ fear of crime. Aliu and Adebayo (Aliu and Adebayo, 2013) also argued that overcrowding made the built environment prone to crime. Therefore, future studies should investigate the reasons for fear of crime depending on the degree of visibility.

Table 3. R² and Coefficient Values from Quadratic Model Regression Analyses of the Visibility Values and Fear of Crime Values

| Visibility | Fear of crime | R² | Coefficient | DS | DG |
|------------|---------------|----|-------------|----|----|
| CON_NO     | CON_NO        | 0.164* | -0.005      | -0.281 |
|            | (CON_NO)²     | 0.000 | 0.004       |
| CON_RES    | CON_RES       | 0.562** | -0.015      | -0.757 |
|            | (CON_RES)²    | 0.000 | 0.012       |
| INTG_NO    | INTG_NO       | 0.352** | -0.010      | -0.519 |
|            | (INTG_NO)²    | 0.000 | 0.008       |
| INTG_RES   | INTG_RES      | 0.714** | -0.015      | -0.792 |
|            | (INTG_RES)²   | 0.000 | 0.016       |

* p < 0.05.
** p < 0.01.
The model of visual integration with visible distances restricted to 15m set against fear of crime gave the best correlation. Visual integration showed a good correlation with occupancy in building scenarios (Turner and Penn, 1999). Therefore this result suggested that, in interior areas, people's movements and the occupancy level are important elements in either inciting or reducing the fear of crime. Therefore, school environment designers responsible for interior areas should pay special attention to human behavior related to fear of crime. The "hottest" spots in the interior areas of elementary schools were restrooms, which are typically located in areas of low visibility. However, restrooms with high visibility are naturally uncommon, as restrooms are private places. Therefore, the use of translucent materials such as frosted glass and/or the installation of partitions to reduce the visibility while still allowing for sounds is both feasible and recommended for restrooms. In addition, in places of high visual integration, the hot spots were gymnasiums and halls, where many students tend to congregate. Teachers and school officials must pay special attention to students' behavior when they congregate in those areas. Considering the overall floor plans, ends and crossings were also hot spots. In this regard, to minimize the spots associated with fear of crime, it is recommended that floor plans be sufficiently clear with a simple shape.

Restricting the visibility distance improves the correlation of the visibility and fear of crime models. However, there have been few studies of visibility distances, especially regarding the relationship between fear of crime and visibility distances. Valuable data on visibility and fear of crime may be gained by conducting more in-depth studies of visibility distances. In particular, lighting and natural daylight can influence the visibility distance. In the current study, the visibility distance showed a significant difference when lights were on or off. Moreover, in school corridors, due to the contrast effect of the background light in the daytime, when the light levels outside were much higher than those inside, even the face of a person at close range could not be identified.

As the degree of fear models did not show a much better correlation than those for density only, it could be concluded that the degree of fear of crime was only slightly related to visibility. In other words, visibility does not heighten or lower the degree of fear of crime. It is assumed that the multiple and combined elements suggested by previous studies (Lee et al., 2012, Park and Ha, 2012, Yoo and Ha, 2011) including human factors, maintenance, and darkness are more related to the degree of fear than visibility alone.

This study has several limitations. Materials were not considered in the present analysis despite being among the most important factors in interior design, and several studies (Ha, 2011, Park and Ha, 2012) having noted that they were related to crime. For example, if glass walls, which are transparent, had been distinguished from non-transparent walls, the results of the analysis may have been different. In addition, to calculate visual connectivity and integration the space should be open. As it is postulated that the doors of all rooms are open, the rooms whose doors are mostly closed (e.g. storage) could not be analyzed accurately.

This study is significant in that it provided empirical evidence of the relationship between visibility and fear of crime and built on previous research about fear of crime and environments following a more precise approach through the use of quantitative and automated analysis techniques. Furthermore, through its use of surveys completed by students, this study suggested substantial hot spots for fear of crime which may not be noticed by teachers, designers, and other stakeholders. The methods and results of this study may help school environment designers to plan safer environments and to improve existing environments by considering visibility conditions in a systematic and relevant way.

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