Effects of Various Spatial Elements on the Intensity of Attracting People to Stay in an Open Space by the Computer Graphic Prediction Method

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Abstract
In reality, an open space comprises various spatial elements, and people choose a place for sojourn according to the attraction created by the spatial elements. In the first stage, this study develops a simple computer graphic prediction method, where the prediction results of computer graphics are compared with that of the reality. After confirming the reliability of the method, it was applied in the second stage in order to analyze the degrees to which the spatial elements attract people for sojourn. Fifty subjects participated in the actual space experiment, and another group of 50 participated in the computer graphic experiment. Three hundred and twelve subjects participated in the second stage experiment.

Both the actual space and the computer graphic experiments show that people tend to choose a place featuring "seating", "trees", "shade" and "the front of a wall" for sojourn. The result of the computer graphic experiment is very similar to the actual space experiment, which proves that the computer graphic prediction method is feasible in predicting the places of sojourn of a real space. The priority of people's choosing a place to stay is: "a corner + a place to sit" > "a corner" > "the shade" > "a place to sit" > "the front of a wall".

Keywords: position; security; psychology; priority; space

1. Introduction
According to Sommer, there is an invisible personal space around a person, and when others or an object enter the space, the person opts to move to a new empty space to keep his/her personal space intact1). According to the famous Prospect-Refuge theory (P-R theory) by Appleton, a person tends to remain in a place out of biological instinct, where others are visible to him/her, while he/she is invisible to others2). However, the P-R theory fails to provide the principles applicable to space design. Some studies have explored the specific size of personal space through experimentation3), while others have probed into the effects of ceiling height and room size on personal space4-6). Ohno and Matsuda studied the effects of walls and columns on where a person chooses to sit, and found that people prefer staying by walls and columns5). Similar results were obtained in the study by Peng et al.4), which studied the effects of partitions in interior spaces regarding where a person chooses to sit6). While the conclusion reached by Ohno and Peng was consistent with the P-R theory, both focused on the influence of a selected position, but paid little attention to the effects of the physical conditions of spatial elements. Through observation, Lee et al. noticed that people tend to sit by walls or in a place where a seat is available7); while Tsunita's on-site observation found that people were inclined to remain in a place where there were seats or trees8).

Hsieh and Lee went a step further and explored the feelings and comments of people who sat beside the six spatial elements of an open space. According to the results, "bench" and "emptiness" received the least favorable remarks, while "tree" won the most favorable remarks. The reason why people made their remarks on "bench" and "emptiness" was the lack of covering in the surroundings, which failed to meet their demand for a sense of security and privacy; and even though "tree" failed to offer seating, its branches created shade and covering, which made it popular9).

In reality, an open space comprises various spatial elements, and people choose a place for sojourn according to the attraction created by the spatial elements. To date, while various studies have summarized favorable spatial elements for sojourn, they failed to distinguish the attractions of different spatial elements, and thus, failed to predict where people would choose to stay in an environment with various spatial elements. Although Hsieh determined the degree to which spatial elements attract people for sojourn, he failed to provide a direct account of the
effects of spatial elements on people's choice in the spatial axis.

The methods to explore a location for sojourn fall roughly into two types -- on-site observation and experimental simulation. While the former features a higher level of reality, its environmental factors cannot be standardized, which would lead to unsystematic conclusions and restrict the comparison attractions among the spatial elements. Regarding the latter, it is difficult to conduct simulation in a space (1:1), as it requires much time, labor, and space. Therefore, in the first stage, this study develops a simple computer graphic prediction method, where the prediction results of computer graphics are compared with that of the reality. After confirming the reliability of the method, it was applied in the second stage in order to analyze the degrees to which the spatial elements attract people for sojourn, thus, offering more principles applicable to space design.

2. Methodology

If sojourn spaces created by designers fail to attract people, the expected functions of these spaces will not be used, and the spaces will be left idle; hence, it is necessary to determine methods that would lead to accurate predictions in the design stage. Computer graphics may address this issue, as such programs can serve as important tools for space designers to predict their finished works during the design process, meaning its visual effects can create a virtual space as vivid as an actual space. To determine if computer graphics can replace an actual space and enable designers to make accurate predictions regarding the scope of sojourn positioning for users, this study develops a simple method to predict sojourn positions in the first stage, and demonstrates its accuracy.

First, this study selects an actual open space, and randomly asks passers-by about their preferred sojourn positions in the space. Then, the computer graphics of the selected space are drawn, and another group of people are asked about their preferred positions in the computer graphic. Finally, the sojourn positions chosen by the two groups are compared.

If the preferred sojourn positions in the actual space are similar to that of the computer graphic, it could be demonstrated that the computer graphic could effectively predict sojourn positions. In the second stage of this study, the method is adopted in order to compare the degrees of attraction for sojourn positions among the different spatial elements.

3. Computer Graphic Prediction Method

3.1 Experimental Design

To facilitate analysis, this study divides the experiment into two groups -- the actual space group and the computer graphic group. The open space for the actual space group is a college campus area of 670m² (50m in length and 14m in width). The north and west sides of the space are adjacent to a 4.5m-wide
path, a bungalow is located on the east side of the space, and there is a high wall on the south side, thus, there are many spatial elements in the space, including walls, steps, trees, benches, indented and raised spaces, and floors, where the walls are made of washed stones (Fig.1.).

The on-site experiment is undertaken from 3pm to 5pm on a cool summer day, and 50 passers-by are randomly-selected to receive interviews. When asked the question "If you have to wait for a friend for 10 to 15 minutes but you don't know from which direction he/she will come, which position will you choose to wait?", and the respondents are free to move to any position to test if a position is suitable to stay. After the respondents made their decisions, the positions were recorded on a grid plan (cut into grids of 2m x 2m) (Fig.2.).

Then, based on the actual space, computer graphics were drawn and taken as the image for the computer graphic group, and another group of 50 people were asked the same question. In order to prevent people from being influenced by a previous visit, this study selected 50 subjects that had never visited the open space and were not included in the actual space group. After being shown six computer graphics, as recorded from different angles on a 7" tablet (IPS, 1920 x 1200), the subjects were asked to select their preferred sojourn positions from the image (Fig.3.). In order to fully show each spatial element in the space, the visual angle of computer graphics in this study is not...
controlled, so it may be different from the visual angle of actual spaces.

### 3.2 Comparison of the Actual Group and the Computer Graphic Group

The positions chosen by the subjects of the actual space group are scattered in nine areas. Area 1 (38%) is a space with three big trees, two long benches, and shallow steps as the boundary on one side. Area 2 (16%) is similar to Area 1. Area 3 (12%) is comprised of an outdoor table and chairs. Area 4 (8%) has wooden steps above ground level. Area 5 (8%) and Area 6 (6%) are similar to Area 1. Area 7 (2%) has indented steps. Area 8 (6%) includes low walls and steps near columns. Area 9 (4%) is an area near a wall (Fig.4.).

The positions selected by the subjects of the computer graphic group lay in seven areas. In terms of proportion, Area 3 (36%), Area 1 (24%), and Area 2 (22%) are the top three selected areas, while areas 4-7 account for less than 10% (Fig.5.). According to a comparison of the results, both groups shared 7 areas, with the exception of Area 8 (6%) and Area 9 (4%), as selected by the actual space group. The possible reason for the absence of Area 8 and Area 9 in the computer graphic group is that the two areas seem to be invisible corners, due to the angle of the recorded computer graphics. Thirty-six percent of subjects chose the outdoor table and chairs (Area 3) to stay in the computer graphic group, but only 12% chose the same area in the actual space group. The possible reason is that outdoor tables and chairs (Area 3) in the actual space look much older and dirtier than that in the computer graphic group, and reduced people's willingness to choose them (Figs.6.-7.). Area 1, Area 2, and Area 3 are the top three areas shared by the two groups, indicating that the two groups share similar sojourn positioning preferences, which suggests that the prediction method is accurate. In other words, computer graphics can be used to predict preferred sojourn areas in actual spaces during the design stage.

Moreover, a comparison between areas 1-9 and the shade scope shows that nearly all the preferred areas are in the shade (Fig.2. and Figs.4.-5.), which implies that people tend to choose a space featuring "seating", "trees", "shade" and "the front of a wall" for sojourn. The conclusion of this study is consistent with that of many other documents, which indirectly demonstrates that the prediction method is simple and reliable.

### 4. The Influence of Spatial Elements on Position Choice

#### 4.1 Research Settings

This study took the urban square as the representative open space to discuss whether there are different choices of position, given the different size, position and type of spatial elements, when people are waiting in a square. Since the physical factors in the actual space were too complicated to control, in order to minimize the interference of the non-research variables, this study utilized the computer graphic prediction method discussed above, and added different spatial elements to the same scenario to produce various still images, in order to simulate different forms of open space. Sunlight in the image was illuminated from a 45-degree angle to create a shadow. To minimize the effect of the spatial elements color, all images are presented in monocolored.

#### 4.2 Spatial Elements

This study chose two spatial elements, a wall and a bench, as subjects. A high wall forms a space that has a backrest, and a low wall or a bench forms a space where people can sit. All of them are the preferred spaces of waiting. This study examined 25 spatial types, which are further classified into Groups A, B, and C. Group A consists of walls in two different heights (3m and 1m) and two different widths (5m and 1.67m), and aims to determine whether the people's chosen position conforms to the theory so far to confirm the credibility of this prediction method once more (Fig.8.). In order to systematically discuss the effect of the wall size, and show two obvious gaps in the scale, the height and length of the two walls are set to 3: 1. The height of the two walls is 3m and 1m. The higher wall is taller than a human beings, and can provide a complete covering in the surroundings. The lower wall has poor covering in the surroundings,
and an insufficient backrest. Since the subjects do not know exactly the size of the wall on the perspective, they can only take the two passers-by in Fig.8. as a scale, so the lower wall looks like a place to sit as well. The length of the two walls is 5m and 1.67m. The 5m length wall is just equal to the length of five squares in the ground, and the 1.67m length wall is 1/3 of the 5m length wall. Group B is an extension of Group A, with two additional walls, and aims to determine the priorities of different spatial elements. Wall A means the wall with the same position as Group A, and Wall B means the added wall in Group B (Fig.9.). Group C includes five combinations of walls and benches, with different relative positions, and aims to determine the priorities of a wall and a bench (Fig.10.). Moreover, in order to eliminate the influences of shade, Group C is not provided with shade, whereas Groups A and B have shade.

4.3 Subjects
A questionnaire was conducted in this study. Subjects' profiles were first surveyed, and then, 25 simulated photos of open spaces were randomly presented to the subjects. From 25 1m x 1m squares (Figs.8.-10.), subjects were asked to select which one they would prefer to stay in, while waiting alone for 15-30 minutes for a friend. There were 312 subjects, aged from 16 to 40; 176 males (56.4%), and 136 females (44.6%).

4.4 Group A: A Single Wall
Figs.11.-13. show the bar diagram of statistical results for the position choices within 25 types of spaces, according to the 312 subjects. As seen, for Group A (Fig.11.), when the wall is 3m high, individuals prefer to remain 1-2m in front of the wall. When the wall is 1m high, they will remain nearly 1m in front of the wall. Of the 5 positions in front of the wall, the right center position is the most preferred. When the wall width is reduced from 5m to 1.67m (A-03), with A-01 as the benchmark, the percentage of individuals choosing to remain in the
center position, and 1m in front of the wall, increases from 28% to 62%, while the percentage of individuals choosing to remain to either side is significantly reduced. When the wall is reduced from 3m high to 1m (A-02), the percentage of individuals choosing to wait in the center position, and at points 4 and 5, remains nearly the same, however, the percentage of individuals choosing to remain at points 1 and 2 doubled. When both wall height and width are reduced by 1/3, then, 74% of the individuals choose to remain in the center position, which has the greatest significance in Group A. Higher walls provide shade, and lower walls provide places to sit. The result of Group A implies that individuals prefer to remain in the shade or a place to sit or the front of a wall. This result is consistent with the relevant research conclusions so far, and confirms the reliability of this prediction method once again.

4.5 Group B: Two Walls

With reference to A-01 and B-01, note that for Wall A, individuals usually prefer to remain within the 1m x 1m corner area of the two walls (point 5), rather than in the center position of Wall A. The percentage of individuals choosing to remain in front of Wall A is a percentage of the preference for a corner which is observed for B-02, B-05, and B-06, revealing that corners are more attractive than areas in front of walls, particularly when one of the walls is low. This means that a place to sit (lower walls) with shade is the most popular position to stay. In terms of position choices of B-01 and B-03, a percentage peak is observed again for the center area in front of Wall A, when Wall B becomes narrower and has no intersection with Wall A. When the height and width of Wall B are reduced by 1/3 (B-04), the percentage peak remains at the Wall A center position, and with a more even distribution than in B-03. Positioning for B-09 to B-16 has very similar percentages. The center area of Wall A has a high percentage peak (48-64%), which is quite similar to A-03 and A-04, and the same as A-03 and A-04, where, these 8 types of Wall A are all narrow walls. It can be concluded that, when Wall A is narrow and has no intersection with Wall B, the choice of preferred positioning by individuals is to remain at Wall A, regardless of the size of Wall B. Comparing B-09 and B-13; B-10 and B-14; B-11 and B-15; and B-12 and B-16, it is found that the percentage of individuals choosing to remain in the center area is increased by 5-10%, on
average, when the height of Wall A is reduced to 1/3. The percentage for B-03 and B-04 is similar to that of A-01; and the situation for B-07 and B-08 is similar to that of A-02 (Fig.12.).

In general, the result of Group B shows that, when a corner area exists, people tend to choose the corner area first, particularly when one of the walls provides a place to sit (the lower wall). When two walls do not intersect, then individuals would choose a place in the shade (the higher wall, Wall A) or a place to sit (the lower wall) or the front of a wall.

4.6 Group C: A Wall and a Bench

To eliminate the possible influence of shade, and compare the intensity of influence caused by a wall and bench, Group C is provided with a non-shade setting. Comparing A-01 and C-01, it is noted that when an additional bench is placed in front of the 3m high and 5m wide wall, the percentage of individuals choosing points 2 and 3 are significantly increased, and the total preferred percentage for the area within 1m in front of the bench increases from 48% to 76%. However, when the bench is placed a little farther away from the wall (C-02), the percentage of individuals choosing points 2 and 3 is redistributed to points 3, 4, 6, and 13, which are all within 1m of the bench. If the bench is placed even further from the wall (C-03), individuals tend to remain in a vicinity within 1m of the bench, especially points 13, 16 and 23. If the bench is placed perpendicular to the wall (C-04 and C-05), individuals tend to remain 1m in front of the bench, particularly in the center area. Although C-04 has an opposite direction compared to C-05, the tendency for position choices remains the same. Overall, a bench is more attractive to waiting individuals, compared to a wall, which reveals that individuals have a stronger need to be seated than to lean while waiting (Fig.13.). Although a bench is more attractive, the position of the wall has an influence on an individual's position choice. For C-01, 76% of the individuals choose to remain near the bench, 69% choose C-02, and only 62% choose C-03. In other words, the farther the bench is away from the wall, the less an individual would choose to remain there.

5. Discussions

The results of Group A, B and C show that people prefer to choose "the shade", "a corner", "the front of a wall" and "a place to sit" to stay, which is consistent with Appleton's P-R theory\(^2\) and the relevant research conclusions so far\(^7\)\(^-\)\(^11\); however, this study further analyzes the difference in intensity of attraction between different spatial elements.

The percentage of the corner in B-02, B-05 and B-06 is higher than that in B-01, thus we can know that people prefer "a sittable corner" to "a corner". The corners in B-02 and B-05 are both formed by 5m x 3m and 5m x 1m walls, the only difference is the amount of shadow. The corner in B-02 has much more

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Fig.13. Results of Position Choice (Group C)

Fig.14. The Decision Mechanism of Choosing a Place to Stay
Both the actual space experiment and the computer graphic experiment show that people tend to choose a place featuring "seating", "trees", "shade" and "the front of a wall" for sojourn.