THE EFFECT OF SPATIAL STRUCTURE ON VISUAL SEARCH BEHAVIOR

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People's voluntary movement through an environment is essential for their comprehension of three dimensional space. It may be hypothesized that they move and look around in order to pick up wanted information at the time. This study investigated the following more specific hypotheses by an experiment using a user-controlled space-sequence simulator and the analysis of the subjects' behavioral data recorded by the simulation system:

(1) The strategy of visual search behavior (body movement and viewing direction) is influenced by spatial structure (form and organization).

(2) The strategy can be explained by the amount of visual information in the environment, i.e., people move and look in a certain direction in order to maximize effective information at a given moment and position.

If these hypotheses are supported, we can predict people's behavior in an unfamiliar place on the basis of the spatial structure.

METHOD

Using a user-controlled space-sequence simulator, an experiment was conducted to reveal search behavior in model spaces of different floor-plan types, and the strategy of visual search behavior was examined in terms of amount of visual information.

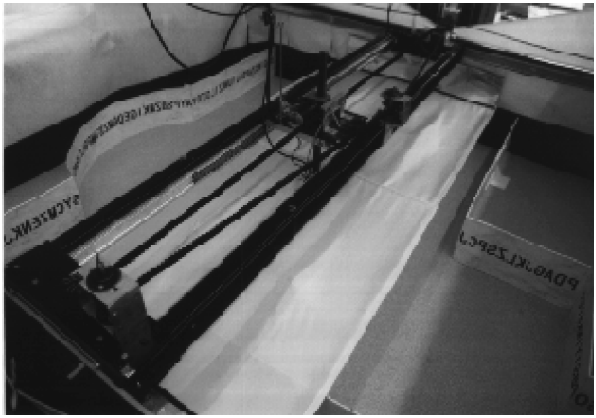


Figure 1
An overview of the user-controlled space-sequense simulator.

Figure 2
The CCD tv camera head in the scale-model space.

Figure 3
The experimental setting of the display room. A subject can move through the model space and look around with a set of "Joy-sticks" for viewing the scene as projected on 100-inch CCTV screen.

The User-Controlled Space-Sequence Simulator

This simulator was designed to allow a subject to move through a model space and look around, to experience a visual sequence. With a set of ”Joy-sticks”, a subject controls a small CCD (Charge Coupled Device) color TV camera-head supported by a gantry, for viewing the scene as projected on 100-inch CCTV screen (Figures 1-3). Maximum size of an applicable scale model is 2.36m x 2m in horizontal dimension and 0.5m in vertical dimension. The movable area of the CCD camera head is 1.5m x 1.5m. Maximum speed on movement is 30mm/sec, and angular velocity of rotation is 72 deg/sec. The horizontal and vertical angles of the visible field of the CCD camera are 112 degrees and 88 degrees respectively.

The control system of the simulator records all signals generated by the ”joy-sticks” every 0.01 second, while it operates three stepping motors: two for horizontal movement and one for rotation (Figure 4). Thus the exact position within the model space and the viewing direction at given moment can be stored in the computer memory, which is then used to analyze the subject’s behavior.

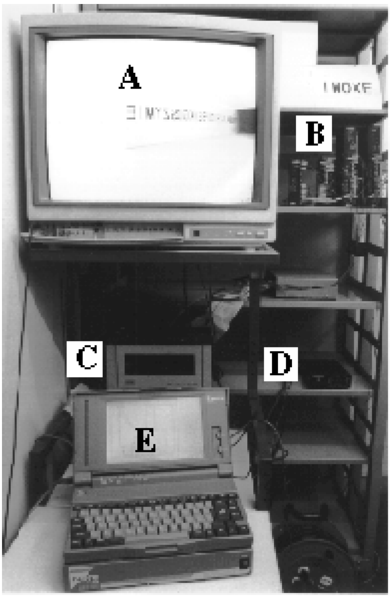


Figure 4
The control system of the simulator: TV monitor (A), stepping motor drive (B), video tape recorder (C), CCD TV camera control unit (D), host computer (E).

In order to keep the camera head away from the model wall, the data of the model's floor-plan is input into the computer beforehand so as to stop the motion and sound an alarm when the camera head comes too close to the wall.

AN EXPERIMENT

Three scale models (1/20) of interior spaces (47m x 40m) of different floor-plan types (cross corridors, plaza with colonnade, connected plazas) were made and set in the simulator. On the model's walls and columns, letters are displayed in random order with equal density.(Figure 5) The task was to find a target letter as soon as possible. Three plan types, each with four different target and start position, for a total of twelve setting were tested by each of ten male and twelve female subjects (university students). The time allowed was 180 seconds. Both sides of the scene were shaded off and the horizontal angle of vision which is clear enough to read the letters was limited to 80 degrees in order to urge the subject to move or look around.

Results

The traces of movements and viewing directions for each of twelve settings for each of twenty-two subjects were examined in the printouts of the computer display. Al-

Figure 5
The experimental setting of the model space. Letters are displayed on the model's wall in random order with equal density.

though the traces seemed to be complex, they could be analyzed as a composition of some typical patterns. It was found that there are at least four typical patterns of search behavior as classified in *Figure 6*.

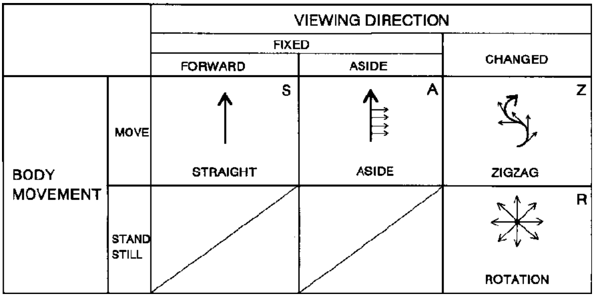
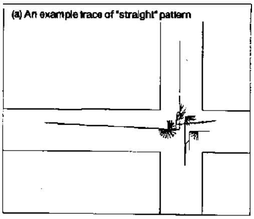


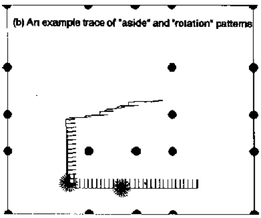
Figure 6
Typical patterns of search behavior.

Most of the result were combination of one or two dominant patterns with minor patterns (*Figure 7*). The occurrence of dominant patterns was found to vary according to floor-plan types.

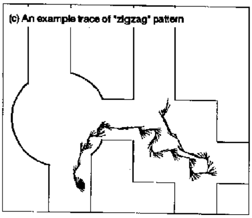
Figure 7
Some examples of the result. The printouts of the trace of movements and viewing directions.



a: An example trace of "straigt" pattern.



b: An example trace of "aside" and "rotation" patterns.



c: An example trace of "zigzag" pattern.

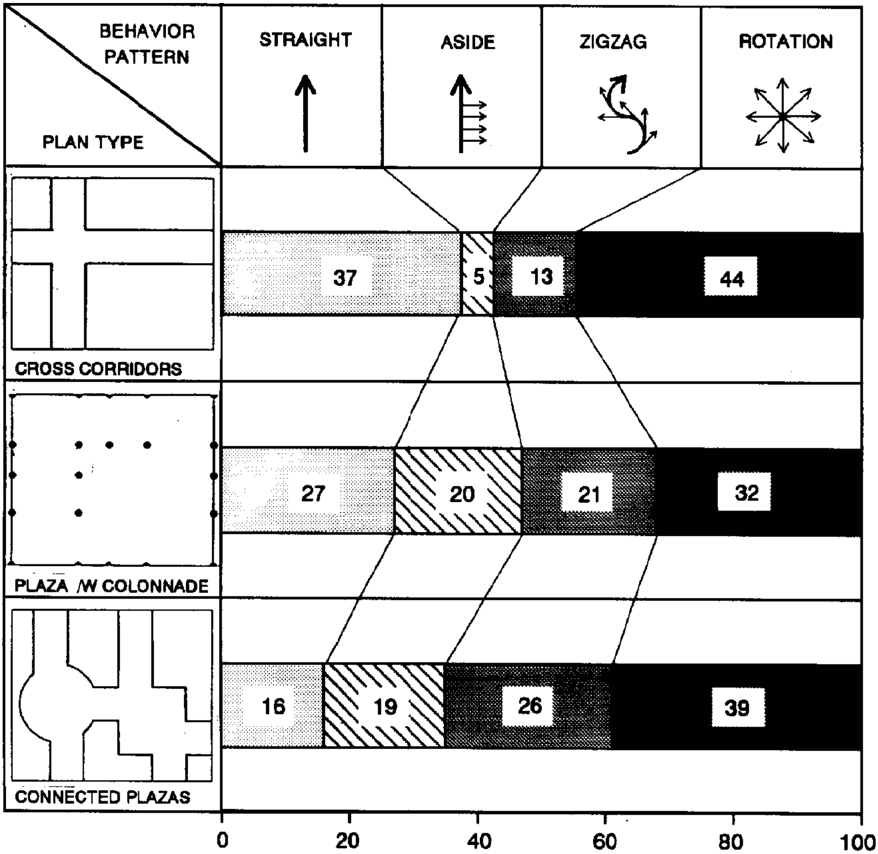


Figure 8
Ratio of observed behavioral patterns for different floor-plan types

Figure 8 shows the ratio of observed dominant patterns for each different floor-plan types. In the ”cross corridors” type, people often choose those patterns of ”straight” and ”rotation”, while in the ”connected plazas” type, the ”straight” pattern is less common, and patterns of ”aside” and ”zigzag” are more frequent.

ANALYSIS

The results of the experiment suggest people choose a search strategy according to the spatial structure. This tendency was examined by calculating the amount of visual information.

Measurement of the Amount of Visual Information

The amount of visual information can be measured by number of recognizable letters within the visual field at a given moment. This value is correlated with the wall length where recognizable letters appeared because letters were displayed with equal density in this experiment. However, according to information theory, a letter already seen and recognized has no information. This suggests that it is essential to consider the time factor when we discuss information. In our experiment, among recognizable letters in a given visual scene, those letters which appeared in the previous scene have less information than newly seen letters. Thus, the amount of visual information was operationally defined by a measure obtained by the following procedure.

Using a personal computer, the visible wall length from a given station-point was first measured, and the readability of the letters was judged based on both the distance and the degree of slant of the wall to the station point. Thus the part of the walls where recognizable letters appeared at the given moment can be identified. The same analysis was conducted for the next scene obtained 0.1 second later, and then it was compared with previous result to identify which part previously appeared. This operation was repeated to all the scenes obtained every 0.1 second. Those parts of the wall previously seen were given a weight (less than 1) which was varied according to how long it had appeared in the scene. The amount of visual information was therefore defined by the sum total of weighted length of the walls with recognizable letters. If the station-point and the viewing direction are unchanged, i.e. the visual scene is not refreshed, then the value of the measure will soon become zero.

Subjects' Choice of Search Behavior and Amount of Visual Information

When searching for something, people move and look at a certain direction in order to maximize effective information at a given moment and position. In order to examine this hypothesis, the amount of visual information of those four typical behavioral patterns in each of the three floor-plan types were calculated (see Figure 9). As shown in Figure 10, a linear correlation was found for each of three floor-plan types between the ratio of observed behavioral patterns and average value of the amount of visual information. However, except for the floor-plan type of "connected plazas", the correlation was not very evident. This unclear relation in two floor-plan types is believed to result from the differences in local spatial features within the floor plan

CONCLUSION

The present study generally supports the hypotheses: the strategy of visual search behavior is influenced by spatial structure, and it can be explained by amount of incoming visual information from the environment. However, more

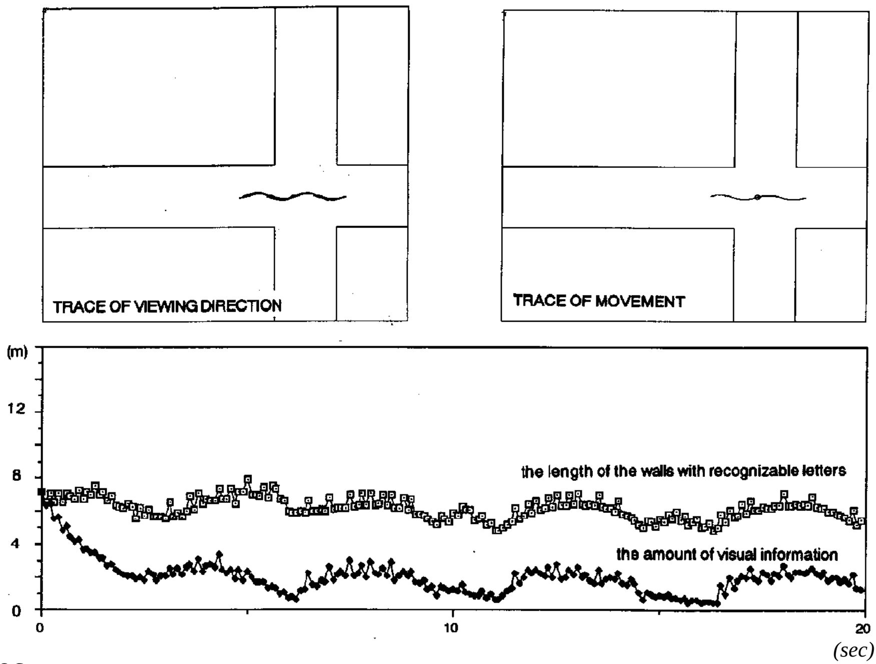


Figure 9
The length of the walls with recognizable letters and the amount of visual information of "zigzag" pattern in "cross corridor" floor-plan type.

systematic experiments are necessary for a clearer definition of the amount of visual information related to search behavior and for predicting people's behavior in an unfamiliar place on the basis of the spatial structure.

This study also suggests a new research technology in which an environmental simulator is used not only for predicting behavior in a new space-design, but also for analyzing human behavior in simulated space.

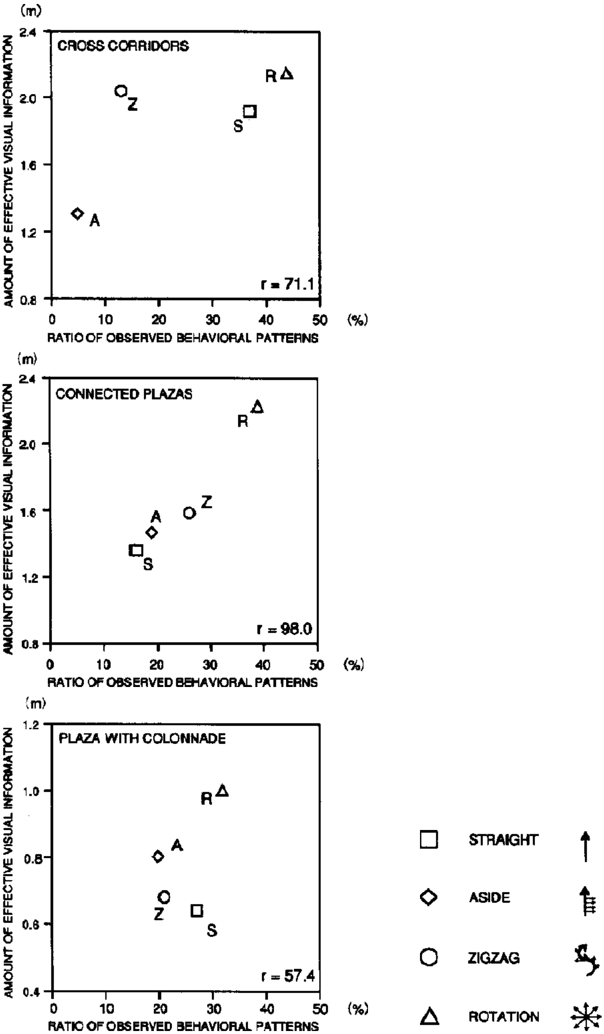


Figure 10
The relation between the ratio of observed behavioral patterns and the amount of visual information.