International Journal of Technology (2015) 3: 400-409
ISSN 2086-9614

VISIBILITY ANALYSIS OF HOSPITAL INPATIENT WARD

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(Received: June 2015 / Revised: June 2015 / Accepted: July 2015)

ABSTRACT

The objective of this study is to evaluate the performance of hospital inpatient ward spatial configuration in relation to visibility. Visibility is an important aspect in a hospital inpatient ward, and could support healthcare performance. Visibility is required in an inpatient ward for the purposes of control, surveillance, interaction and communication among patients and nurses, and it could be affected by the spatial configuration of the ward. Based on isovist as a way to visualize the visual experience in surrounding environments, we developed an analytical tool to evaluate the visibility of an inpatient ward in a planned university teaching hospital. The findings illustrate the visibility as experienced by the users in the everyday operation of the hospital ward. Some recommendations for improvement were suggested to the existing spatial configuration for better visibility.

Keywords: Inpatient ward; Isovist; Spatial configuration; Visibility

1. INTRODUCTION

The hospital inpatient ward is a place where patients are cared for by medical staff, for a certain period of time, for healing or curing. The design of an inpatient ward should consider various aspects that might affect the patients' experience of care, which eventually might affect the healing and curing process. This paper addresses the spatial configuration of a hospital inpatient ward in relation to the degree of visibility as an important aspect of patient care in the ward. Historically, the early layout of a hospital ward ('Nightingale ward') consists of a long space with a large number of patients' beds on both sides. While this layout allows nurses to easily supervise patients, it tends to cause a lack of the patient's privacy and increases the risk of cross-infection among patients (Hughes, 2000). Current trends in hospital-ward design tend to provide a fewer number of patients' beds per room, with more single-patient rooms provided to ensure privacy, and reduce infection and other risks (Ulrich et al., 2008). However, the ward layout with separated rooms for patients may also mean more effort for medical staff to perform visual supervision toward the patients under their care.

The design of healthcare facilities, including the inpatient ward, should be based on evidence. Research findings should inform design decisions regarding the spatial arrangement of the facilities including which layout of ward is better. Research has indicated that certain types of layout are more desirable than others; for example, a decentralized layout is better than a centralized layout (Gurascio-Howard & Malloch, 2007) since it could reduce the risks of patients' falls, reduce the staff's walking time and increase time for patient care (Ulrich et al, 2008). However, design decision should not be based simply on the knowledge of general

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Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v6i3.1458

typology of ward layout, because such typology cannot describe what is really going on (Cai & Zimring, 2012). Further analysis is needed to understand what is actually going on in the design of a hospital ward based on the experiences of the users.

The objective of this study is to analyze the degree of visibility in an hospital inpatient ward. This study is an attempt to understand in more detail the performance of a ward's spatial layout in supporting the efficient work of medical staff in supervising the whole ward. This paper describes the development of an analytical tool for a hospital ward based on isovist (Benedikt, 1979). Isovist provides a useful way to analyze visibility because it was generated from individuals' points of view, as they perceive, interact, and move through the spatial environment (Turner et al., 2001). The use of isovist for visibility analysis has the potential to support the user-centric design approach in order to achieve better performance of spatial organization (Derix, 2014).

2. VISIBILITY IN INPATIENT WARD

The design of an inpatient ward consists mainly of the patients' rooms, the nurse station, and some supporting facilities (supplies room, equipment room, resting room, pantry, consultation room etc). The degree of visibility is an important aspect of inpatient ward design. It is important that the layout of the ward allows the nurses to be in "visual proximity with patients" – which means that they can work as well as check on the patients, including supervising the patients in the evening without disturbing their sleep (Reiling et al., 2008).

Regular checking on patients' condition is an important part of the nurses' responsibility while working in a hospital ward. A study of time and motion of nurses (Hendrich et al., 2008) found that the largest proportion of the nurses' time was spent on documentation (around one-third of time), medication administration, and care coordination, with less time spent for patient care activities and patient assessment. Typical nurses' activities are described as follows: "moving between patients' rooms, moving from nurse station to supply closet and back to room, spending a minority of time on patient care activities and a greater amount of time on documentation, coordination of care, medication administration, and movement around the unit" (Hendrich et al., 2008). The study also found that nurses spend more time in the nurse station compared to in the patients' rooms or anywhere else, in or off the ward. These findings indicate that the nurse station becomes an important center of the nurses' activities and thus should be designed thoroughly.

While the nurses spend most of their time in the nurse station doing documentation work, the surveillance of patients' condition remains important. The degree of visibility towards the patients is determined by the spatial configuration of the ward. Research has indicated that a radial layout type of inpatient ward is better than double and single corridor layout, because it allows nurses in the nurse station to visually supervise patients better and to walk less distance (Ulrich et al., 2008). A more detailed analysis on the spatial configuration of the ward indicates that radial wards tend to have higher visibility in terms of the number of beds visible from the corridor and from the nurse station, followed by the double-corridor layout (Lu & Zimring, 2010). Another research explored the role of spatial configuration of the ward and how it affects the interaction and co-awareness of the nurses toward the patients and their peers, by considering the distances between nurse station, nurse alcoves, and patients' rooms (Cai & Zimring, 2012). The study also found that nurses could experience conflict between the need to have interaction with other nurses and the responsibility to be close to patients.

Findings from previous research indicated the importance of spatial configuration of the ward to support both the nurses' activities in the nurse station and the surveillance toward the patients in every room. There are a number of factors that may modify the degree of visibility, such as the

exact position of the nurse station in relation to the whole configuration, and the presence of various boundaries throughout the unit. This study will assess the performance of a hospital inpatient ward in terms of visibility due to its spatial configuration, by considering these factors.

3. METHODS OF VISIBILITY ANALYSIS

3.1. Research Setting

In this study we evaluate the visibility in an inpatient ward in the design of a new university teaching hospital through isovist visualization and analysis. The ward has an 'H' shaped corridor layout (Figure 1.), consisting of two single corridors of patient bedrooms connected by a middle corridor where the staff areas, including the nurse stations, are located. There are three areas of nurse station. Two stations are located in each corner of the corridors; these are designated to provide control toward the bedrooms along the corridor. The third area of nurse station is located between the other two nurse stations; it has a larger space area and no direct access to bedroom corridors, and is designated as the working area of the nurse. The ward could be accessed by visitors through an elevator hall located at the end of the corridor, which also acts as the entrance to the ward.

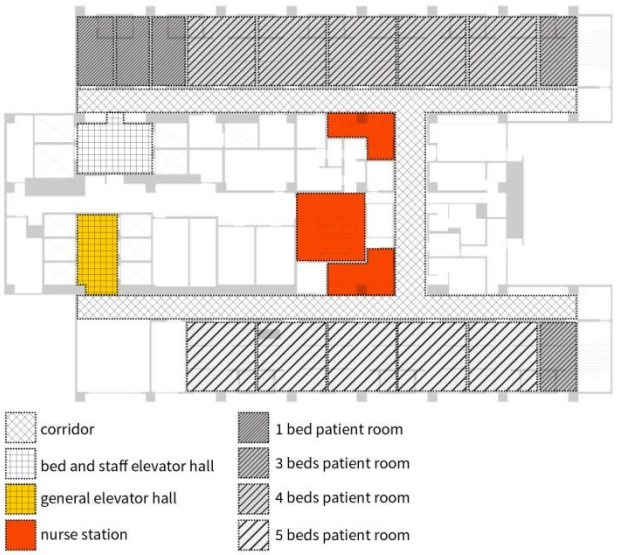

Figure 1 The general layout of the inpatient ward

3.2. Isovist Visualization Method

Isovist could be defined as an area in a spatial environment directly visible from a point of location within space (Turner et al., 2001). Isovist can be used to visualize the users' visual perception of certain space. There are many ways to represent isovist, and we argue that the differences among the methods might affect the reading of the isovist. The representation of isovist will determine the method of visualization. Visualization holds an important role in the analysis because it can obtain an insight into the efficiency and effectivity, and may also enable us to detect interesting features and patterns in a relatively short time (Van Wijk, 2005). Isovist can be represented as a closed polygon (Figure 2.) which contains all sets of points that are visible from one location (Benedikt, 1979). The shape of the polygon can describe which areas are visible from a particular point, however, there are limitations in visualizing the effect of the distance on the visibility itself. The polygon representation cannot directly visualize the visibility but must be formulated at first from its geometric properties.

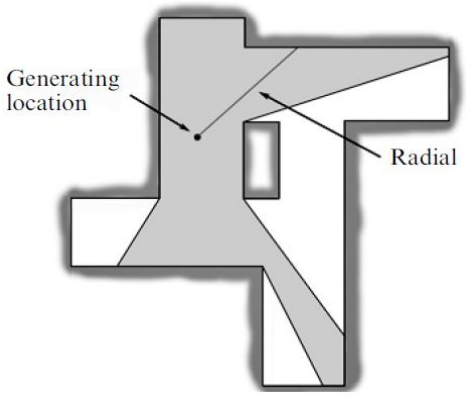

Figure 2 Polygon representation of isovist, and the limitation in visualizing the distance effect (Source: Turner et al, 2001)

Another way to represent isovist is by applying Gibson's idea of optic array (Gibson, 2015), which is illustrated as an array of lines surrounding one point of observation (Figure 3). Benedikt (1979) hinted at some relationships between isovist and Gibson's idea of optic array but left those ideas unexplored. The optic array provides more interesting features in isovist visualization, because the array of lines are radially generated from one particular point of observation. This radiating act gives the effect of the distance, illustrated by increasing distance between the lines. This effect directly visualizes the decrease of visibility related to distance from the point of observation, hence becomes a better visualization of isovist.

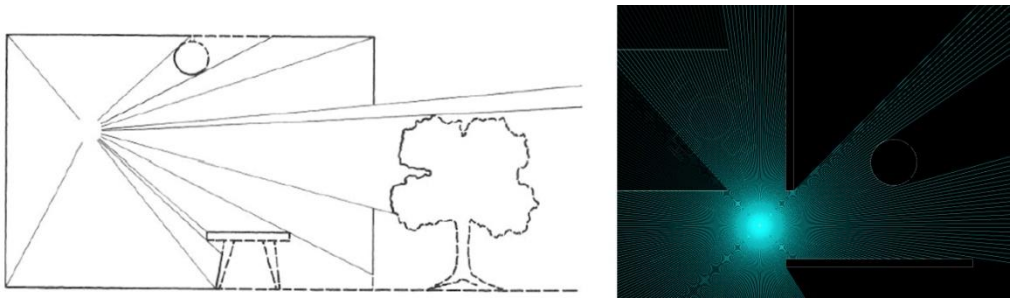

Figure 3 Visualization of the isovist based on the optic array generated from a point of observation to the surrounding environment (Source: Gibson, 2015)

Based on the idea of isovist as an array of lines radiating from one point of observation to the surrounding environment, we developed isovist visualization tools (Figure 4.) in *Processing* programming environment. The visualization provides controls over the visual properties of isovist, such as hue, saturation, brightness, and opacity, to provide a wide range of visualization results. The array of lines radiates in 360^{o}, segmented every 1^{o} from the generating point to the surrounding environment defined in the space plan. This method results in an isovist that can visualize the degree of visibility and visual access of the environment from one particular location.

Whilst single isovist alone is not sufficient to measure the whole configuration of space (Turner et al., 2001), the analysis could use multiple isovists to describe different scenarios of spatial experience. The isovists can be generated from different locations to visualize the visibility and intervisibility in a particular spatial scenario. The isovists can also be configured as a series following a path to visualize the movement through the environment.

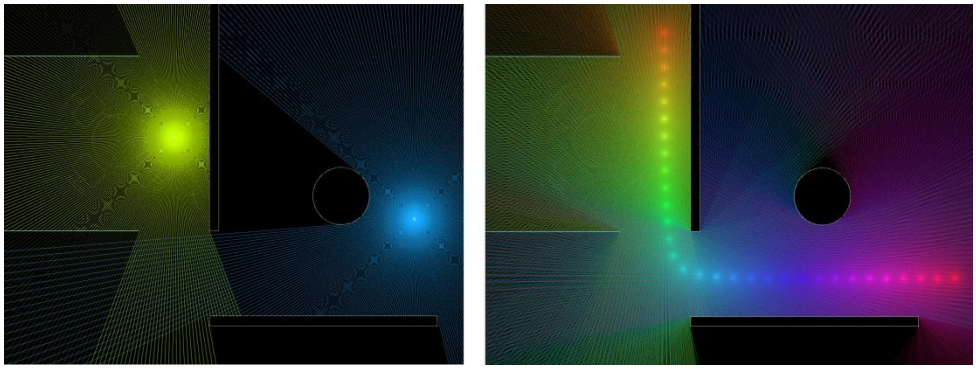

Figure 4 Multiple isovists combined together to visualize the inter-visibility and the visibility during movement along a path

By using these two modes of visualization, the analysis can provide qualitatively the description of the visibility of the environment in various scenarios. In this study, the analysis was applied to evaluate visibility in the inpatient ward, consisting of: the visibility from the nurse stations (when the nurses are in static position), the visibility during nurses' movement along the corridor, and the visibility between nurse station and visitors' access. These three analyses together will form the overall visibility of the inpatient ward.

4. FINDINGS

4.1. Visibility from the Nurse Stations

The first visibility analysis was conducted to visualize the sight from the two nurse stations where the nurses were seated (See Figure 5.). The isovists of each nurse position show that the spatial arrangement does not provide sufficient visual access for the nurses along the full length of the corridor. The sight of the nurses who sit further away from the corridor was blocked by the wall located next to the station. The column in the middle of the nurse station also blocks the sight of the nurses who sit to the left of the column, and who watch the corridor differently. These columns also create barriers among the nurses, and this is something that is undesirable in the design of a nurse-station layout (Harvey & Pati, 2012), which should preferably guarantee communication among all stations.

The finding suggests that in this single corridor layout with H-shaped arrangement, with a nurse station placed in the middle corridor, some visibility issues may arise due to the design of the nurse station position and the space boundaries. While the nurses spend most of the time in the nurse station, it is important that they are given visual access throughout the ward as much as possible. Higher visibility in the nurse station can increase the response and control of the nurses, because they can see more easily what happens throughout the ward, and this will then increase and facilitate communication.

Figure 5 Visibility from the nurse stations

4.2. Visibility during Nurses‘ Movement through the Corridor

Visibility during the nurses’ movements along the ward corridors is likely to be important, because the nurses are continuously on the move during their activities and should remain constantly aware of the condition of the patient (Lu & Zimring, 2010). Figure 6 shows the visualization of isovists following the hypothetical path of nurses’ movements. The analysis shows the patient bedrooms that are included in the visual access of the nurses when they are walking along the corridor.

The result indicates that the patient bedrooms at the end of the corridor are unlikely to be seen easily during the nurses’ movements. The situation is made worse by the patient bedroom door being situated on the further side of the corridor. These rooms are not on the path of continuous circulation of the staff (Harvey & Pati, 2012), and thus the nurse has to move to the very end of the corridor just to access the room. This finding suggests the importance of considering the positioning of the patient bedrooms in relation to the corridor, including the exact position of the doors, which should enable the nurses to control the patients easily during their movements.

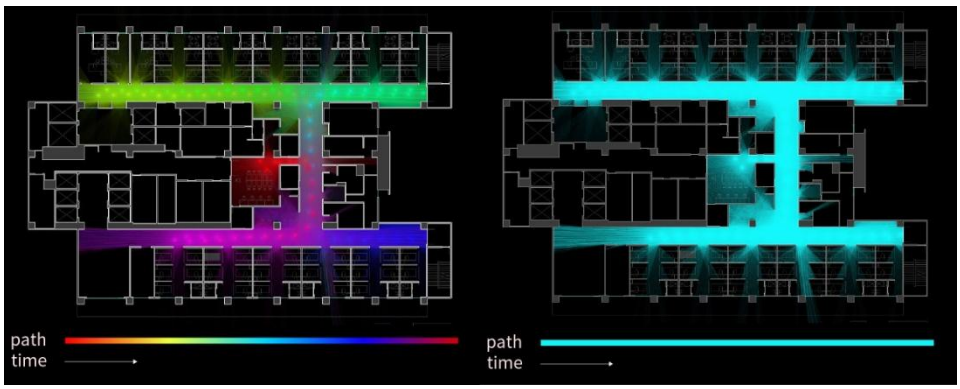

Figure 6 Visibility during nurses’ movement

4.3. Visibility between Elevator Hall and Nurses‘ Station

Visibility is also important in relation to the control of visitors’ access to the ward. In the inpatient ward analyzed here, the general elevator hall also functions as the entrance hall for the

ward visitors. Figure 7 clearly shows that there is no direct inter-visibility between visitors in the elevator hall and the staff located at the nurse station. This situation indicates the issue of monitoring of the visitors by the staff. In addition, there is also potential confusion for the visitors in finding their way towards the ward, since they cannot directly meet and communicate with the staff when entering the ward. However, it is also not desirable to move the staff closer to the elevator, since the elevator hall is quite remote to the core area of the ward, and this may create the feeling of isolation for the staff (Trzpuc & Martin, 2010).

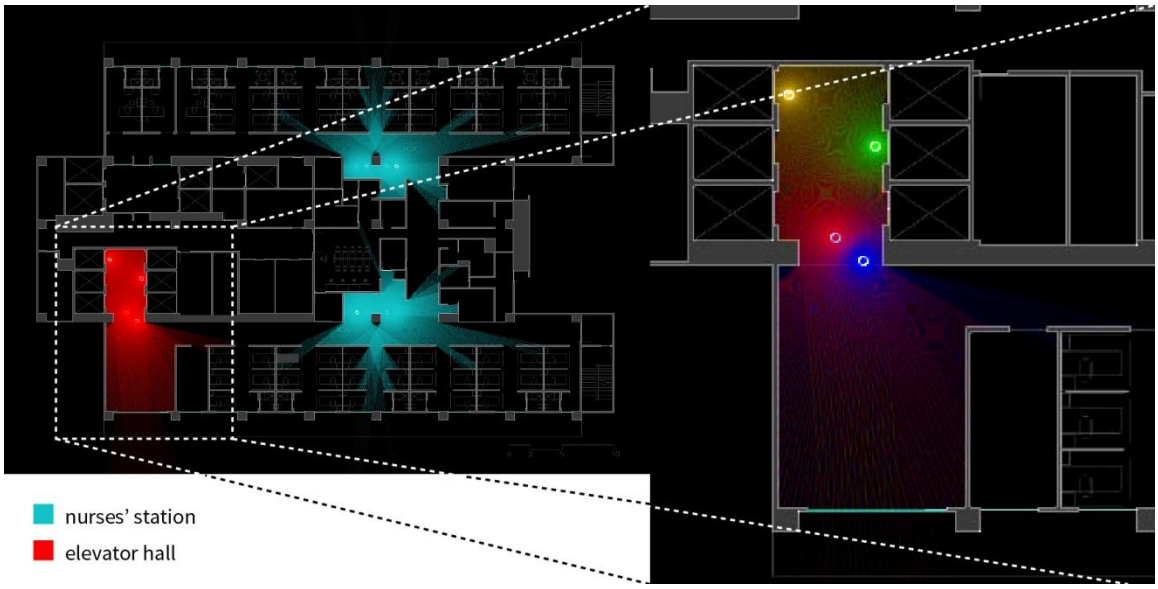

Figure 7 Visibility in the ward entrance area

Figure 8 General visibility of the inpatient ward

4.4. Visibility around the Inpatient Ward

The above analyses are then combined to visualize the overall visibility in the inpatient ward (Figure 8.). From the analysis, we could highlight the situation of the nurse station which has reasonably poor visibility to other areas in the inpatient ward.

This situation is contrary to the suggestion that the nursing unit visibility and accessibility should be enough to support face-to-face communication and clear line-of-sight among the members of the patient care team (Harvey et al., 2006; Trzpuc & Martin, 2010). The configuration of the ward also affects how the nurses can control the patients assigned to them. The single layout corridor means the nurses have to walk quite a distance to reach the patients. The further the patient bedrooms are located from the nurse station, the more effort is needed to control the condition of the patients. As current inpatient population acuity level tends to increase, the visibility and auditory connection with the patients' rooms becomes important (Harvey et al., 2006). Proximity to the rooms in order to hear activity as well as to see through the doors of patient bedrooms is essential in order to increase the spatial performance of the inpatient ward.

These findings show consistency with findings from other research, in that the visibility index in the single corridor and double corridor units is comparably less than radial corridor unit layout (Lu & Zimring, 2010; Ulrich et al., 2008). While the single and double corridor unit might be more efficient in terms of ward design, it has some visibility issues, as demonstrated in this study. The length of the corridor also contributes to the whole of visibility in the inpatient ward (Harvey & Pati, 2012) and might increase the nurses' walking distance to access the patients' bedrooms.

While the activities within the ward are already complex, the ability of the nurses to control the visitor and the patients' family members remains important. There is a necessity to control the visitor entrance of the inpatient ward as well as the patients' rooms, however the current configuration shows that the entrance area is quiet remote to the nurse station which makes the control difficult. While visitor control could be done by restricting accessibility to the ward outside visiting time, communication between visitor and inpatient ward staff still remains distant, and this could increase risks during critical times.

5. CONCLUSION

The study has demonstrated the use of isovist to visualize the visibility of an inpatient ward, by analyzing the visibility from the nurse station, the visibility during the nurses' movement along the corridor, and the visibility of the ward entrance area, which all together illustrate the general visibility of the ward. Some issues of visibility arose from the existing spatial arrangement of the ward, such as the position of the nurse station in relation to the whole ward layout, the presence and positioning of space boundaries such as walls, columns and doors, and the distance between areas where the visual connections are required. The positioning of a nurse station in relation to the patients rooms, other nurse stations, and the ward entrance needs to be considered carefully as it may create conflict between the need for control of patients, surveillance of the visitor, and interaction between staff.

The findings of the study have some implications for improving the performance of spatial organization of hospital inpatient wards in terms of visibility. Identification of the areas that are less visible to the nurses could suggest re-arrangement of the space, especially the positioning of the nurse station, as well as the possibility of locating surveillance equipment such as CCTV to ensure the visibility of all ward areas. This study also indicates that the visibility degree in an inpatient ward can be analyzed using the visualization of isovist in different scenarios of everyday routine in the ward. The visualization of isovist becomes a useful instrument to figure

out the degree of visibility in an environment from a particular location. The current visualization method is still limited to the basic geometry of the isovist. Some visual perception parameters, such as the visual field, could be included in order to get more comprehensive visualization. Further research is needed to develop better isovist representation and visualization to create a more robust analytical tool of visibility.

6. ACKNOWLEDGEMENT

This study was funded by Research Cluster Grant Universitas Indonesia 2015 for Hospital and Healthcare Design and Engineering Research Cluster.

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