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Perceptual Effects of Physical and Visual Accessibilities in Intensive Care Units: A Quasi-Experimental Study

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Abstract

This paper reports the findings of a two-phase quasi-experimental study looking at the perceptual effects of physical and visual accessibilities in intensive care units (ICUs). In a previous *CCNQ* paper [1], the first-phase of the study was reported comparing, among other things, physical and visual accessibilities and their associations with staff perception in 2 ICUs with the open-plan and racetrack type layouts. The data for that phase of the study was collected in December 2014, which included the data on physical and visual accessibilities collected using the spatial analysis techniques of Space Syntax, and the data on staff perception collected using a questionnaire survey. Since then, the open-plan ICU has been completely redesigned using a layout composed of 4-bed pods (each dubbed as a HYPERPOD ® by the designer). However, the racetrack ICU has remained unchanged. In August 2016, more than one and a half years after the data for the first phase of this study was collected, the authors went back to the study sites to collect similar data using the methods of the previous study [1]. The purpose of the two-phase study was two-fold: (1) to see if staff perception and their associations with physical and visual accessibilities observed in the racetrack ICU during the first phase would remain unchanged during the second phase of the study; and (2) to see if staff perception and their associations with physical and visual accessibilities observed in the open-plan ICU during the first phase would change in the new ICU during the second phase of the study. The findings of the study comparing the racetrack ICU of the first and the second phase show that while staff perception in this unit changed, its associations with the physical and visual accessibilities of the unit did not change during the period between the first and the second phase of the study. In contrast, the findings of the study comparing the open-plan ICU of the first phase and the new ICU with 4-bed pods of the second phase show that staff perception as well as its associations with the physical and visual accessibilities of the unit changed in a positive direction from the open-plan ICU to

the new ICU. It is concluded that staff perception is likely to change overtime even in the absence of environmental changes, but any change in staff perception can be made more effective when it is associated with thoughtful environmental design changes.

Keywords: Intensive care unit; Physical and visual accessibilities; Open-plan layout; Racetrack layout; ICU pods; Clinicians' perception; Space syntax

1. Introduction

Rashid et al [1] defined the physical and visual accessibilities of an environment using physical and visual connectedness of the spaces in the environment, and argued that such environmental accessibilities may be important for several reasons even in today's technology-enabled intensive care units (ICUs). First, it is hard to treat ICU patients remotely using technology only. Therefore, easy physical and visual access to the proximate environment – people, space, and technology – remains essential in critical care practice [2]. Second, while technology can help improve patient monitoring, it can also become overwhelmingly complicated creating cognitive overload for ICU staff. Concerning this, easy physical and visual access to people, space, and technology in ICUs can help reduce the stress resulting from cognitive overload [3-5]. Third, the available empirical evidence indicates that physical and visual accessibilities can affect patient and staff outcomes in ICUs [6-11].

Despite the apparent importance of physical and visual accessibilities in ICUs, recent reviews indicate that most award-winning best-practice example ICUs built between 1993 and 2012 have private patient rooms only [12, 13] to control visual and physical accessibilities for improved privacy and safety. Along with privacy and safety, direct access to natural light and outside view has also become important in recently built ICUs for various positive psychological, behavioral and health benefits of ICU patients and staff [12, 13]. Underscoring the need for natural light and outside view, the *2012 ICU guidelines* require that each ICU patient care space should provide visual access to the outdoors, other than skylights, with not less than one window of appropriate size per patient bed area [14, p1589]. Similarly, the *2010 FGI guidelines* require each patient bed to have natural light by means of a window(s). The guidelines also requires that there shall be no more than one intervening patient cubicle between any patient bed and the window(s) in a multiple-bed room with patient cubicles, and that distance from the patient bed to the window shall not exceed 50 feet (15.24 meters). [15, p100]

As a result, private patient rooms with natural light and outside view become the norm in ICUs in the United States, and the open-plan ICU with no permanent separation between patient beds (**Figure 1,** reprinted from [1]) is being phased out and is not being considered as a viable option for a new ICU. In its place, the racetrack ICU is becoming common among ICUs, accounting for 73.33% of all the award-winning best-practice example ICUs built in the United States and Canada between 1993 and 2012 [12]. It should be noted here that a racetrack ICU commonly has patient rooms around the perimeter wall of the unit, a service core with nursing station/s and other support and service functions in the center, and a circulation ring separating them (**Figure 1,** reprinted from [1]).

Therefore, the purpose of the first phase of a two-phase study, reported in [1], was to learn more about the physical and visual accessibilities of open-plan and racetrack ICUs and their effects on staff perception. The data for this phase of the study was collected in December 2014. Since then, the open-plan ICU has been completely remodeled into an ICU with 4-bed pods (henceforth, the new ICU) but the racetrack unit has remained unchanged (**Figures 2 & 3**). In August 2016, more than one and a half years after the data for the first phase of the study was collected, the authors of this present study went back to the study sites to collect similar data using the methods of the earlier study. The purpose of the two-phase study was two-fold: (1) to see if the associations between physical and visual accessibilities with staff perception observed in the racetrack ICU during the first phase of the study would remain unchanged during the second phase; and (2) to see if the associations between physical and visual accessibilities with staff perception observed in the open-plan ICU during the first phase would change in the new ICU during the second phase of the study.

This paper describes the study outlined above in the next few sections below. First, it provides a synopsis of the first phase of the study reported in [1] as relevant to the study being presented here. Following this, the remodeling of the open-plan ICU is described. After this, the second phase of the study is described. Then, the differences between the ICUs in the first and second phase of the study is described in terms of physical and visual accessibilities and their associations with staff perception in these units.

2. The First Phase of the Study

Rashid et al [1] conducted the study in 2 adult ICUs—one 32-bed open-plan unit and another 28-bed racetrack unit (**Figure 1** reprinted from [1])—of a university teaching hospital. These units were located next to each other on the same floor of the hospital with similar patient-to-nurse ratios and clinical practice models at the time of study. As noted above, the data for the first phase of the study was collected in December 2014.

To explore the differences in the visual and physical accessibilities of the 2 ICUs, the data on physical accessibilities were collected using the techniques of the axial map analysis (**Figure 4**); and the data on visual accessibilities were collected using the techniques of the visibility graph analysis (**Figure 5**) of Space Syntax [16-18]. These techniques and measures were described in detail by Rashid et al [1]. The *Depthmap* software [19] was used to perform both the analyses. The analyses produced the *axial connectivity*, *axial integration-R3* and *axial integration-Rn* values describing physical accessibilities; and the *visual connectivity*, *visual integration-R3* and *visual integration-Rn* values describing visual accessibilities at the local, subsystem and system levels of analysis. These measures have shown significant associations with spatial behaviors and perception in hospital units in previous studies, which were reviewed by [11, 20].

To explore how visual and physical accessibilities might affect staff perception, the data on staff perception were collected using a questionnaire survey. As described in [1], full-time and part-time ICU nurses on all shifts, physicians and intensivists who were salaried and associated with the unit, residents (where applicable), and attending physicians were invited to complete the questionnaires. Participation in the study was voluntary. Participants were recruited through emails or were approached in person. The IRB-required information and cover sheets were attached to the questionnaire to ensure that participants fully understood the intent of the study and the consequences of their participation. The questionnaire also included a floor plan of the ICU for a participant to identify the location of her primary workspace in the

unit. Later, the physical and visual accessibilities of each location were measured to explore how these measures might have affected the responses given by the participants. Altogether, 81 valid responses were received from the two units, 34 from the open unit and 47 from the racetrack unit. **Table 1** shows the distribution of survey participants based job types, indicating that the majority of participants (86.4%) were nurses.

According to the findings of the spatial analysis of the 2 ICUs using Space Syntax techniques and measures, physical and visual accessibilities were different in the 2 ICUs. Clinicians' primary workspaces were physically and visually more accessible in the open-plan ICU than they were in the racetrack ICU. Clinicians with physically and visually more accessible primary workspaces indicated more frequently than those with physically and visually less accessible primary workspaces that they knew their peers and where their peers were located in these units. The physical and visual accessibilities of clinicians' primary workplaces also affected their perception of teamwork and collaboration in both the units. In summary, the findings indicated that the open-plan ICU performed better than the racetrack ICU in terms of physical and visual accessibilities and their associations with staff perception. Yet, for various reasons the hospital decided to remodel the open-plan ICU, as described in the next section.

3. Remodeling of the Open-Plan ICU

After data collection of the first phase of the study was completed in December 2014, the open-plan ICU was completely remodeled in 2015 as a part of the modernization project involving all the old ICUs within the main hospital building built during the 1960s and 70s. However, the racetrack unit remained unchanged, since it was in a newly built wing of the hospital (**Figure 1**). In remodeling the ICUs in the main building, the design team, composed of ICU designers, ICU staff and hospital administrators, faced several problems. The first problem was that windows on the exterior walls could not bring natural light into the central parts of the main building that has very deep floor plates. Roof openings also could not be used to bring natural light into the deeper areas of the ICU floor that has several floors above it.

Therefore, all the patient rooms in the new design needed to be placed along the exterior walls of the main building to ensure direct access to natural light and outdoor views, as recommended by the *2012 ICU guidelines* and as required by the *2010 FGI guidelines* (see above).

The second problem was that, after remodeling, the new ICUs could have private patient rooms only as recommended by the *2012 ICU guidelines* and as required by the *2010 FGI guidelines*. Since the floorplates of the main hospital building are squarely shaped, the building has the least perimeter for the given area. This requirement severely restricted the number of private patient room one could place along the exterior walls of the ICU floor. The old layout had 95 patient beds. Out of which, 25 beds did not have direct access to natural light and outdoor view. Therefore, these 25 beds needed to be removed in the remodeled unit (**Figure 1**). Though having 70 beds in place of 95 beds could have been financially viable, it was not possible to place 70 new patient rooms along the exterior walls of the new ICUs for the problem explained next.

The amount of space given to each patient care space in the existing ICUs within the main building was no more than 80 to 120 sq. ft. In contrast, most patient rooms are at least twice that size, if not more, in the recently built best practice example ICUs [12, 13, 21]. This meant that there could be only 35 private patient rooms around the perimeter, if the present width of the existing patient care spaces were kept. This was not possible, because the width of the existing patient spaces was too small for a new private patient room. Nevertheless, 35 new private patient rooms in place of 95 old patient beds was not a financially viable option either.

Therefore, in remodeling the ICUs, the design team had to forgo a simple open-plan or a simple racetrack type layout. Instead, the team used a layout composed of several pods of 4 private patient rooms, each called a HYPERPOD ® by the designer. In this layout, a light well was placed along the exterior wall between every two patient rooms providing direct access to natural light and outside view for two more patient rooms that were pushed inside (**Figures 2 & 3**). Ideally, this layout would have created a service

alcove for every four private patient room if there were no preexisting structural restrictions. In reality, due to many structural limitations, a light well was not placed after every two patient rooms and the new plan became somewhat asymmetrical. As a result, although the design team was able to provide as many as 75 private patient rooms on the floor in place of the existing 95 beds, the 32-bed open-plan ICU included in the previous phase of the study was now reduced to a 15-bed ICU with private patient rooms only, with a lot of space for circulation, nurse workstations, teamwork and support functions.

It should be noted here that, though the 4-bed pods provided a financially viable solution for the remodeling of the existing ICUs while meeting several standards set by the recent best practice example ICUs, the 4-bed pod itself raises several concerns. Although the use of pods is a common strategy in ICU design for dividing a very large ICU into subunits that are more manageable, the use of 4-bed pods is rather uncommon in ICUs. Indeed, it has been suggested in the literature that a pod with less than 8 to 10 bed is too small to have an independent service core with a nursing station or substation, a medical supply room, an equipment storage area, a nourishment room, and a soil room [22, 23].

Yet, the design team might have taken the decision to use a layout composed of 4-bed pods because it would maximize the number of private patient rooms while ensuring direct natural light and visual access to outdoors for each of these rooms. They might have also taken the decision to use a layout of 4-bed pods because it would maximize the amount of support and service spaces within the unit to promote visual and physical accessibilities within the unit. Therefore, this study would like to find out if physical and visual accessibilities of the new ICU composed of 4-bed pods would be different from the open-plan ICU it replaced. The study would also like to find out if the associations of physical and visual accessibilities with staff perception would change from the old open-plan ICU to the new ICU. Additionally, the study would like to find out if any changes in the associations of visual and physical accessibilities with staff perception from the open-plan ICU to the new ICU would be similar to the changes in these associations from the racetrack unit of the first phase to the same unit of the second phase of this study.

4. The Second Phase of the Study

In August 2016, more than one and a half years after the data for the first phase of the study was collected, the authors of this study wanted to investigate if the new ICU with several 4-bed pods performed any better than the racetrack ICU or the open-plan ICU studied previously. They collected spatial and perceptual data in both the racetrack ICU and the new ICU using the tools and techniques of the first phase of the study described in the previous section.

Using the *Depthmap* software [19], the authors collected the *axial connectivity*, *axial integration-R3* and *axial integration-Rn* values describing physical accessibilities; and the *visual connectivity*, *visual integration-R3* and *visual integration-Rn* values describing visual accessibilities at the local, subsystem and system levels of analysis of the ICUs.

In the questionnaire survey, among many questions, the authors asked if clinical staff knew the names of their coworkers in the units; if they knew where their coworkers were located in the unit; and if they thought the unit provided better opportunities for teamwork and collaboration. Altogether, 50 valid responses were received from the two units, 31 from the new unit and 19 from the racetrack unit. **Table 1** shows the distribution of survey participants based job types. Like the first phase of the study, the majority of survey participants were nurses (92%).

In the analysis phase, the authors investigated the differences between the ICUs in the first and second phase of the study in terms of the overall physical and visual accessibilities of the units; the physical and visual accessibilities of clinicians' primary workspaces in the units; the associations of the physical and visual accessibilities of clinicians' primary workspaces with how well clinicians knew their coworkers, how well they knew the locations of their coworkers, and how well a unit supported teamwork and collaboration.

Using the findings of the analyses, which are described in the next section, the authors investigated *if physical and visual accessibilities and the associations between physical and visual accessibilities with staff perception would change in the racetrack ICU after one and a half years.* If no change was found, then it might be possible to argue that the critical care practice in this hospital did not change enough over the past one and a half years to have an effect on staff perception.

The authors also investigated *if physical and visual accessibilities and the associations between physical and visual accessibilities with staff perception would be different in the new ICU from the old open-plan ICU studied in the first phase.* If differences were found when the critical care practice in this hospital remained unchanged, then it might be possible to argue that the observed differences between the open-plan ICU and the new ICU regarding staff perception might have been due to the design differences of these units.

5. Differences between the ICUs in the first and second phase of the study

In reporting the differences, first, the differences between the racetrack ICU of the first and second phases are described. After this, the differences between the open-plan ICU of the first phase and the new ICU of the second phase are described.

5.1. Differences between the racetrack ICU of the first and second phases

Overall physical and visual accessibilities: Since no change was made to the layout of the racetrack ICU during the period between the first and second phase of the study, the physical and visual accessibilities of the unit did not change (**Table 2**).

Physical and visual accessibilities of ICU clinicians' primary workspaces: Though the physical and visual accessibilities of the unit did not change, the physical and visual accessibilities of clinicians'

primary workspaces in the unit improved at all the three levels– local, subsystem and system – of analysis from the first phase to the second phase of the study (**Table 3**). The findings indicate that the survey participants and/or their primary workspaces might have changed during the first and second phases of the study. It is possible that this change was a part of the ICU modernization project of this hospital during the last one and a half years that also involved making clinicians more accessible in ICUs.

Know coworkers in the unit: In the first phase, a majority of ICU clinicians (73.9%) who knew their coworkers in the racetrack ICU occupied workspaces that were physically and visually more accessible at the local, subsystem, and system levels of analysis than the workspaces of those who did not know their coworkers in the unit. In the second phase, fewer ICU clinicians (44.4%) who knew their coworkers in the racetrack ICU occupied workspaces that were physically and visually more accessible at the local, subsystem, and system levels of analysis than the workspaces of those who did not know their peers in the unit (**Table 4**). The findings indicate that while the percentage of clinicians who knew their coworkers had dropped from the first to the second phase of the study, their primary workspaces remained more accessible than those who did not know their coworkers in both phases of the study. Therefore, while any changes in the visual and physical accessibilities of clinicians' primary workspaces might have reflected a general trend of making clinicians more accessible in ICUs as a part of the ICU modernization project, they might not have worked well in this unit. That is because more clinicians indicated that they did not know their coworkers in the second phase than they did in the first phase of the study.

Know the locations of coworkers in the unit: Clinicians' awareness of where others were located in the unit remained almost unchanged in the racetrack ICU from the first to the second phase, with a majority indicating that they did not know where others were located (74.5 % in the first phase as opposed to 72.2% in the second phase) (**Table 5**). Clinicians who knew where others were located occupied visually and physically less accessible workspaces at the local, subsystem, and system levels of analysis than those who did not know where others are located in the racetrack ICU of the first and second phases (**Table 5**). The finding indicates that the associations the visual and physical accessibilities of clinicians' primary

workspaces and clinician' awareness of where others were located in the racetrack unit remained unchanged from one phase to another. The finding also confirms a view presented earlier by [1] indicating that in a visually and physically restrictive racetrack unit only nurse managers and/or charge nurses who often knew the locations of other clinicians in the unit often occupied more private workspaces than others did Therefore, clinicians who knew where others were located were not only fewer in numbers but also occupied visually and physically less accessible workspaces.

Unit provides opportunities for teamwork and collaboration: In the racetrack ICU, clinicians' view on teamwork and collaboration remained somewhat unchanged from the first to the second phase of the study, with slightly fewer clinicians supporting the view in the second phase (44.4% in the first phase as opposed to 42.11% in the second phase of the study) (**Table 6**). In the first phase, clinicians who supported and who did not support the view occupied workspaces that had almost similar visual and physical accessibilities at the local, subsystem, and system levels of analysis, as indicated by the small differences in the values of the measures [Visual connectivity: 227.42 vs 232.31, Visual integration (R3): 5.80 vs 5.78, Visual integration (Rn): 4.89 vs 4.93, Axial connectivity: 11.73 vs 12.47, Axial integration (R3): 3.05 vs 3.01, and Axial integration (Rn): 2.78 vs 2.76 (**Table 6**)]. In the second phase, clinicians who supported the view occupied more visually and physically accessible workspaces at the local, subsystem, and system levels of analysis than those who did not support the view, as indicated by the large differences in the values of the measures [Visual connectivity: 340.81 vs 235.27, Visual integration (R3): 6.28 vs 5.72, Visual integration (Rn): 5.40 vs 4.86, Axial connectivity: 17.62 vs 11.45, Axial integration (R3): 3.37 vs 2.85, and Axial integration (Rn): 3.11 vs 2.60 (**Table 6**)]. This finding may again reflect a general trend of making clinicians more accessible in ICUs through workspace changes as a part of the ICU modernization project during the one and a half years of study period.

5.2. Differences between the open-plan ICU of the first phase and the new ICU of the second phase

Overall physical and visual accessibilities: The new ICU of the second phase is visually more accessible but physically less accessible at the local, subsystem and system levels of analysis than the open-plan ICU of the first phase was (**Table 2**). This finding may be explained by the fact that, on the one hand, the layout of the new ICU with 4-bed pods provides more free spaces increasing visual accessibility. On the other hand, it creates more discontinuity and physical separation by pushing patient rooms in and out. As a result, it decreases physical accessibility within the unit (**Figures 2 & 3**).

Physical and visual accessibilities of ICU clinicians' primary workspaces: Clinicians' primary workspaces, located in the service alcove or observation area (**Figures 2 & 3**), are visually more but physically less accessible at the local, subsystem and system levels of analysis in the new ICU of the second phase than those in the open-plan ICU of the first phase (**Table 3**). The finding supports the view presented above, while the new ICU with 4-bed pods provides more free spaces increasing visual accessibility among clinicians' primary workspaces, it also creates more discontinuity and physical separation decreasing physical accessibility among the same workspaces.

Know the names of coworkers: In the first phase, a majority of ICU clinicians (73.5%) knew their coworkers in the open-plan ICU, who occupied workspaces that were physically and visually more accessible at the local, subsystem, and system levels of analysis than those who did not know their coworkers in the unit (**Table 4**). In the second phase, even more ICU clinicians (87.1%) knew their coworkers in the new ICU, but they occupied workspaces that were physically and visually less accessible at the local, subsystem, and system levels of analysis than those who did not know their coworkers in the unit (**Table 4**). One wonders if a downward change in the size of these units could be a factor in the upward change in the number of clinicians who knew their coworkers, despite the fact that their workspaces were physically and visually less accessible in the new unit. Earlier, the open-plan ICU had

32 beds, now the new ICU has 15 beds. One is likely to know a higher percentage of people in smaller units than bigger units. This can be verified by the fact that even though the new ICU has fewer beds and therefore fewer clinicians, the number of clinicians who knew their coworkers was much higher per patient bed in this unit than it was in the open-plan unit [1.8 clinicians per bed in the new ICU as opposed to 0.78 clinicians per bed in the open-plan ICU (**Table 4**)].

Concerning the accessibility of clinician's workspaces in the new ICU, it must be noted here that even though clinicians who knew their coworkers occupied visually and physically less accessible workplaces in this unit when compared with those who did not know their coworkers, the values of several accessibility measures of these workspaces were much higher in the new ICU than they were in the previous open-plan ICU (**Table 4;** also see **Table 3**). In essence, the new ICU has been able to increase visual and physical accessibilities for all clinicians' workspaces regardless of whether they knew or did not know their coworkers. This finding, again, supports a general trend of change that might have included making clinicians more accessible in ICUs of this hospital as a part of the ICU modernization project for the last one and a half years.

Know the locations of coworkers in the unit: Clinicians' awareness of where others were located in the unit improved from the open-plan ICU of the first phase to the new ICU of the second phase, with a majority indicating that they knew where others were located. Compare 67.6 % in the open-plan ICU of first phase with 74.2% in the new ICU of the second phase (**Table 5**). Put simply, a higher percentage of clinicians knew where others were located in the new ICU than the open-plan ICU. However, the associations between the visual and physical accessibilities of clinicians' primary workspaces and clinician' awareness of where others were located became complicated in the new ICU of the second phase. According the findings, workspaces of the clinicians who knew where coworkers were located in the unit were visually more accessible at the local (cell) and the global (system) level but were visually less accessible at the intermediate (subsystem) level in the new ICU than they were in the open-plan ICU of the first phase. In addition, workspaces of the clinicians who knew where others were located in the

unit were physically more accessible at the intermediate (subsystem) and the global (system) level but were physically less accessible at the local (line) level than they were in the open-plan ICU (**Table 5**). These findings help us further clarify a suggestion made earlier that while the new ICU with 4-bed pods provides more free spaces increasing visual accessibility, it also creates more discontinuity and physical separation between these open spaces decreasing physical accessibility. Based on the findings reported here, we may now suggest that while the new ICU with 4-bed pods provides more free spaces increasing the visual accessibility of clinician's workspaces at the local and global scales, it also creates more discontinuity and physical separation between these open spaces decreasing the physical accessibility of clinician's workspaces at the local level.

Unit supports teamwork and collaboration: Clinicians' view on teamwork and collaboration remained somewhat unchanged from the open-plan ICU to the new ICU, with a slightly lower percentage of clinicians supporting the view in the second phase—85.3% in the first phase as opposed to 83.33% in the second phase of the study (**Table 6**). Clinicians who supported the view occupied workspaces that had better visual and physical accessibilities at the local, subsystem, and system levels of analysis in both the open-plan ICU and the new ICU (**Table 6**). However, while the values of all the measures of visual accessibility have increased from the open-plan ICU to the new ICU, the values of all the measure of physical accessibility have decreased from the open-plan ICU to the new ICU for clinicians' primary workspaces, whether they agreed or disagreed that the unit supported teamwork and collaboration (**Table 6**). To put simply, an increase in the visual accessibility of the new ICU might have had prompted a majority of clinicians to agree that the unit supported teamwork and collaboration.

6. Summary & Conclusions

In this quasi-experimental study, the authors compared changes in staff perception and their associations with physical and visual accessibilities in adult ICUs using data collected in two phases separated by more than one and a half years. During this period, one of the ICUs with a racetrack layout did not change

physically, while the other with an open-plan layout was remodeled into a new ICU composed of 4-bed pods with separate observation areas. The purpose of the study was to see if staff perception and their associations with physical and visual accessibilities observed in the racetrack ICU during the first phase would remain unchanged during the second phase of the study in the absence of physical changes; and if staff perception and their associations with physical and visual accessibilities observed in the open-plan ICU during the first phase would change in the new ICU during the second phase of the study due to significant physical changes.

The Racetrack ICU of the First and the Second Phase

According to the findings of the study, there was no change in the overall visual and physical accessibilities in the racetrack ICU, since the unit did not change physically between the first and the second phase of the study. However, there were changes in the visual and physical accessibilities of clinician's primary workspaces, possibly following a general trend of making clinicians more accessible in ICUs of this hospital as a part its modernization project.

However, changing clinicians' primary workspaces might not have always worked well in the racetrack ICU, because the number clinicians who knew their coworkers had decreased from 1.21 persons per bed in the first phase to 0.29 persons per bed in the second phase (**Table 4**); the number clinicians who knew the locations of their coworkers had decreased from 0.43 persons per bed in the first phase to 0.18 persons per bed in the second phase (**Table 5**); and the number clinicians who agreed that the unit provided opportunities for teamwork and collaboration had decreased from 0.71 persons per bed in the first phase to 0.28 persons per bed in the second phase (**Table 6**). Even though the study did not explore if these changes affected staff performance and outcomes, it can be safely assumed that such changes might not be good for any ICU, where staff must work in teams, and collaboratively, to take care of severely ill patients.

Nevertheless, the findings of the study involving the racetrack ICU helped confirm an earlier view presented in [1] concerning the associations between the visual and physical accessibilities of clinicians' primary workspaces and clinician' awareness of where others were located in the racetrack unit. According to this view, in a visually and physically restrictive racetrack ICU only charge nurses and nurse managers might have known where others were located. As a result, the percentage of clinicians who knew where others were located remained low and somewhat unchanged from the first to the second phase (25.5% vs. 27.8%), even though they occupied workspaces that were less accessible in the second phase than the first phase of the study (**Table 5**). More important for the purpose of this quasi-experimental study were the findings that showed the visual and physical accessibilities of clinicians' primary workspaces were better for those who knew the names of coworkers and who agreed that unit provided opportunities for teamwork and collaboration than those who did not (**Tables 4 & 6**). Put simply, the study provides support for the fact that visual and physical accessibilities are important in ICU for coworker to know each other and for them to have an improved sense of teamwork and collaboration, and that the visual and physical accessibilities of clinicians' primary workspaces can be changed even in ICUs that do not undergo significant changes.

The Open-Plan ICU of the First Phase and the New ICU of the Second Phase

The overall visual and physical accessibilities changed from the open-plan ICU of the first phase to the new ICU of the second phase, and so did the visual and physical accessibilities of clinician's primary workspaces due to significant design changes (**Table 2**). In most cases, these changes have made clinicians' workspaces visually more accessible and physically less accessible in the new ICU than they were in the open-plan ICU of the first phase (**Table 3**). These changes were important, because the number clinicians who knew their coworkers had increased from 0.78 persons per bed in the first phase to 1.8 persons per bed in the second phase (**Table 4**); the number clinicians who knew the locations of their coworkers had increased from 0.72 persons per bed in the first phase to 1.53 persons per bed in the second phase (**Table 5**); and the number clinicians who agreed that the unit provided opportunities for

teamwork and collaboration had increased from 0.91 persons per bed in the first phase to 1.67 persons per bed in the second phase (**Table 6**). Again, even though the study did not explore if these changes affected staff performance and outcomes, it can be safely assumed that such changes could be good for any ICU, where staff must work in teams, and collaboratively, to take care of severely ill patients.

In addition to changes in staff perception, the findings of this study showed that the associations between the visual and physical accessibilities of clinicians' primary workspaces and clinicians' knowledge of coworkers, of coworkers' locations, and of teamwork and collaboration opportunities in the unit also changed from the open-plan ICU of the first phase to the new ICU of the second phase (**Tables 4, 5, & 6**). Concerning this, it should be noted that while the new ICU with 4-bed pods provided more free spaces increasing the visual accessibility of clinician's workspaces, it also created more discontinuity and physical separation decreasing the physical accessibility of clinician's workspaces. As a result, the associations between the visual and physical accessibilities of clinicians' primary workspaces and clinician' awareness of coworkers' locations became complicated in the new ICU, as we have noted in this paper.

Conclusions

Based on the findings of this study, it can be concluded that staff perception in ICUs are likely to change overtime even in the absence of environmental design changes (e.g., the racetrack ICU of the first and the second phase), but these changes can be made more effective when they are associated with thoughtful environmental design changes to improve visibility and accessibilities in the unit (e.g., the open-plan ICU of the first phase vs. the new ICU of the second phase). This is important because improved physical and visual accessibilities may help improve clinicians' perception in ICUs, as was shown in [1] and as has been shown in this paper. Concerning this, a few comments need to be made on the racetrack ICU, the open-plan ICU, and the ICU with 4-bed pods, which were the subject matter of this study.

It was argued in [1] and in this paper that, as privacy and direct access to natural light and outside view become important in critical care, the traditional open-plan ICU that helped maximize physical and visual access to patients from a centralized nursing station for better monitoring and care, is being phased out. In its place, the racetrack ICU is gaining popularity, because it maximizes the number of private patient rooms around the perimeter wall for direct access to natural light and outside view. However, as an ICU is designed with private patient rooms only, direct physical and visual access to individual private rooms becomes difficult from a centralized nursing station. Therefore, to make a racetrack unit work, ICU designers use decentralized nursing stations closer to private patient rooms. This creates additional problems, because an ICU with decentralized nursing stations may not provide enough opportunities for face-to-face interactions among ICU staff that are essential for teamwork and collaboration. Consequently, to mitigate the problems of patient monitoring, patient care, staff interaction, and teamwork that a racetrack ICU with private patient rooms presents, ICU designers often depend on technology, which has its own problem. As technology gets excessively complicated, it creates cognitive overload for ICU staff putting both staff and patients in harm's way. Put simply, as ICU designers solve one problem they are faced with yet another problem. Like everyone else, these designers would like to believe that technology in the end would solve all the problems.

In contrast, the studies presented here and in [1] takes a different viewpoint. Without undermining the importance of privacy, natural light, and outside view for ICU patients, and the importance of decentralized nursing stations and technology for improved patient monitoring and care, the findings of these studies suggest that ICU designers might have moved too fast from one ICU configuration to another without rigorously assessing and understanding the advantages and disadvantages of each. It is true that the open-plan ICU does not always provide privacy, natural light, and outside view for ICU patients, but it provides easy visual and physical access to patients required for better monitoring and care and for improved staff perception, as these and other studies before these studies have shown [1, 24]. In contrast, a racetrack ICU provides, privacy, natural light, and outside view for ICU patients, but it does

not provide easy visual and physical access required for better patient monitoring and care and for improved staff perception, as the study presented here and the study presented in [1] have shown. Therefore, the goal of ICU designers should be to find a configuration for ICUs that would bring together the good qualities of both the open-plan ICU and the racetrack ICU. According to this study, an unconventional ICU with 4-bed pods and generous staff and support area might have achieved this goal to some extent, indicating that ICU designers should explore the benefits of other different configurations for an ICU.

7. References

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Figure 1. A plan of the open-plan and racetrack ICUs included in Phase 1 of the study.

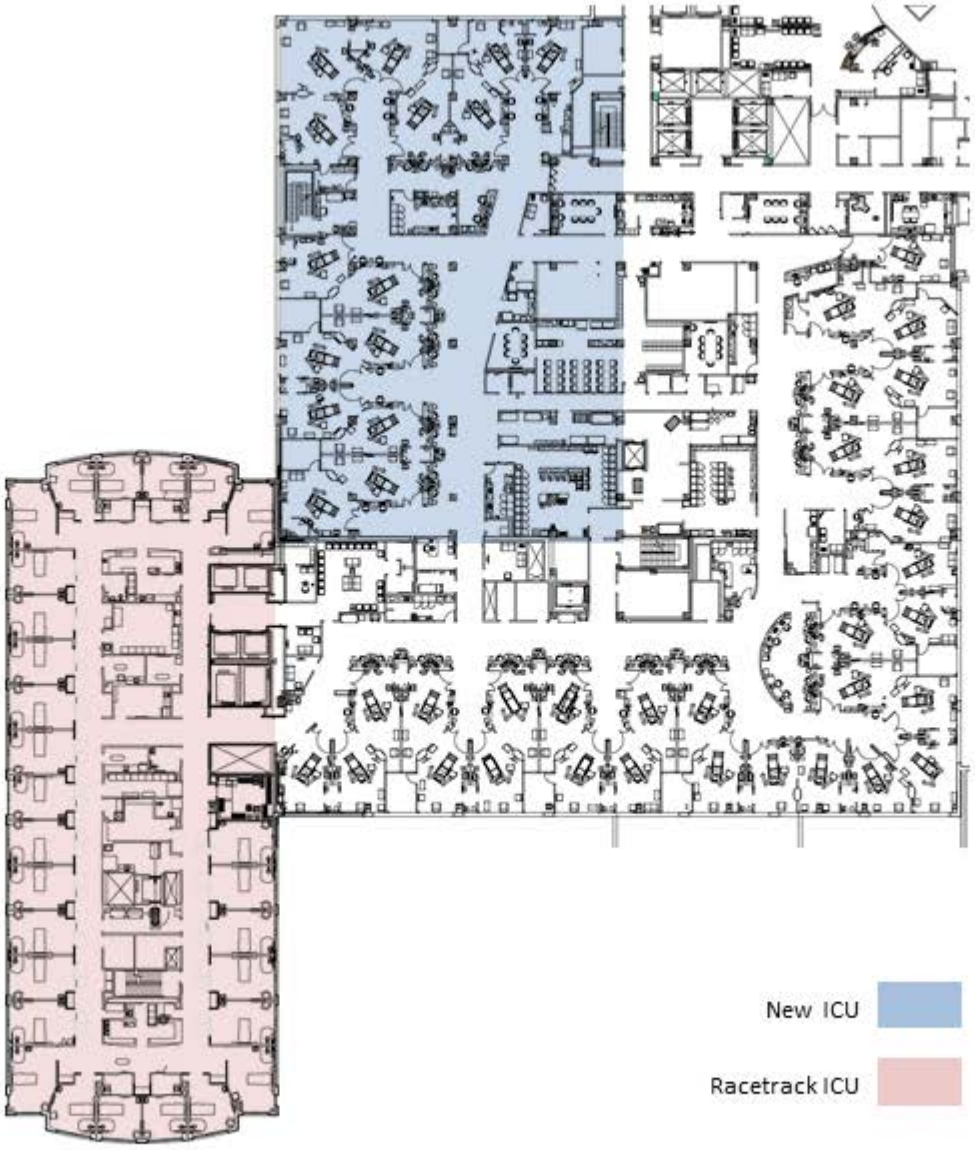

Figure 2. A plan of the new and (old) racetrack ICUs included in Phase 2 of the study.

Figure 3. Larger plans of the (old) open-plan ICU and the new ICU.

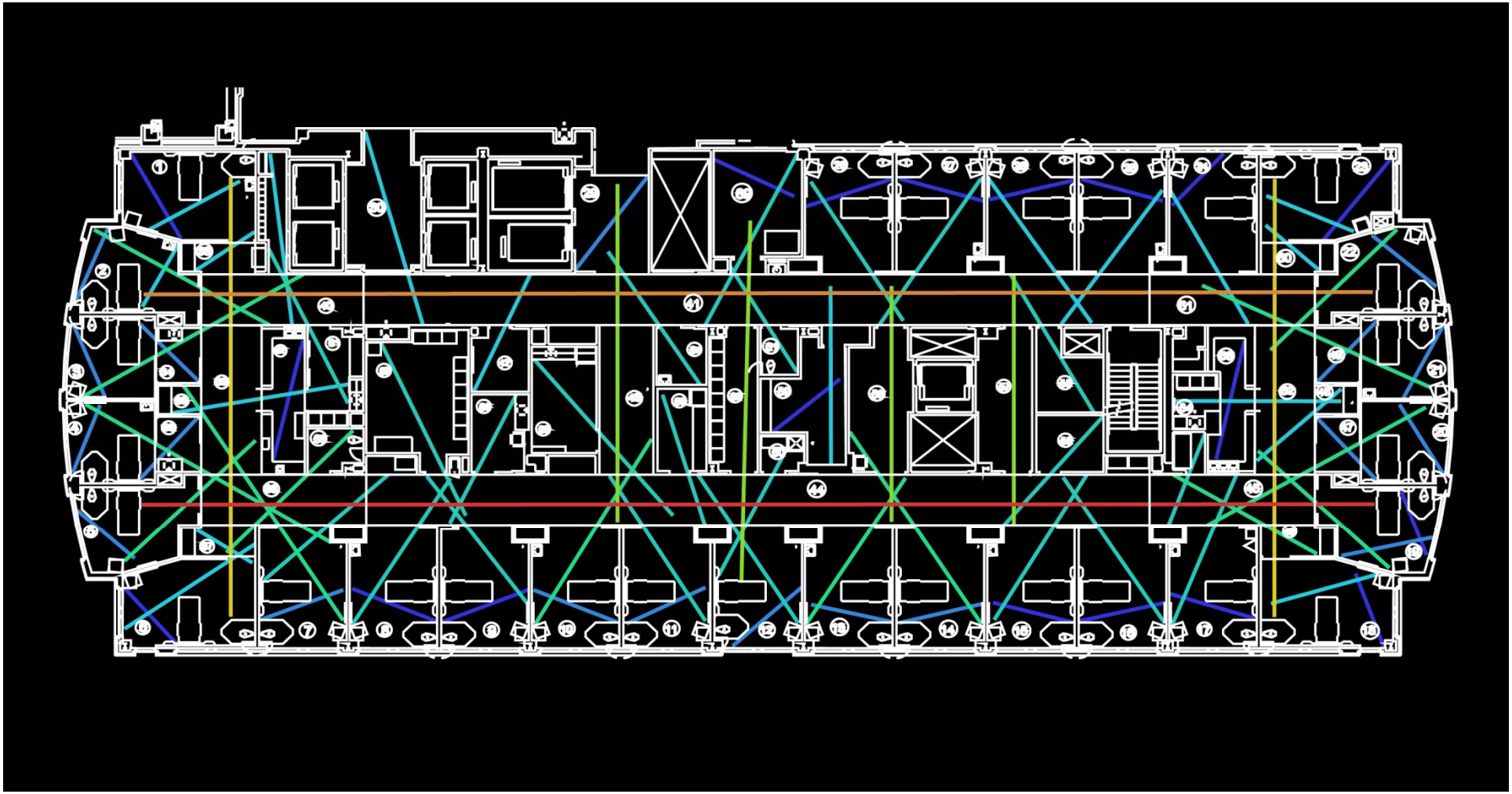

Figure 4. The axial map of the racetrack ICU colored using integration-Rn. Source: [1]

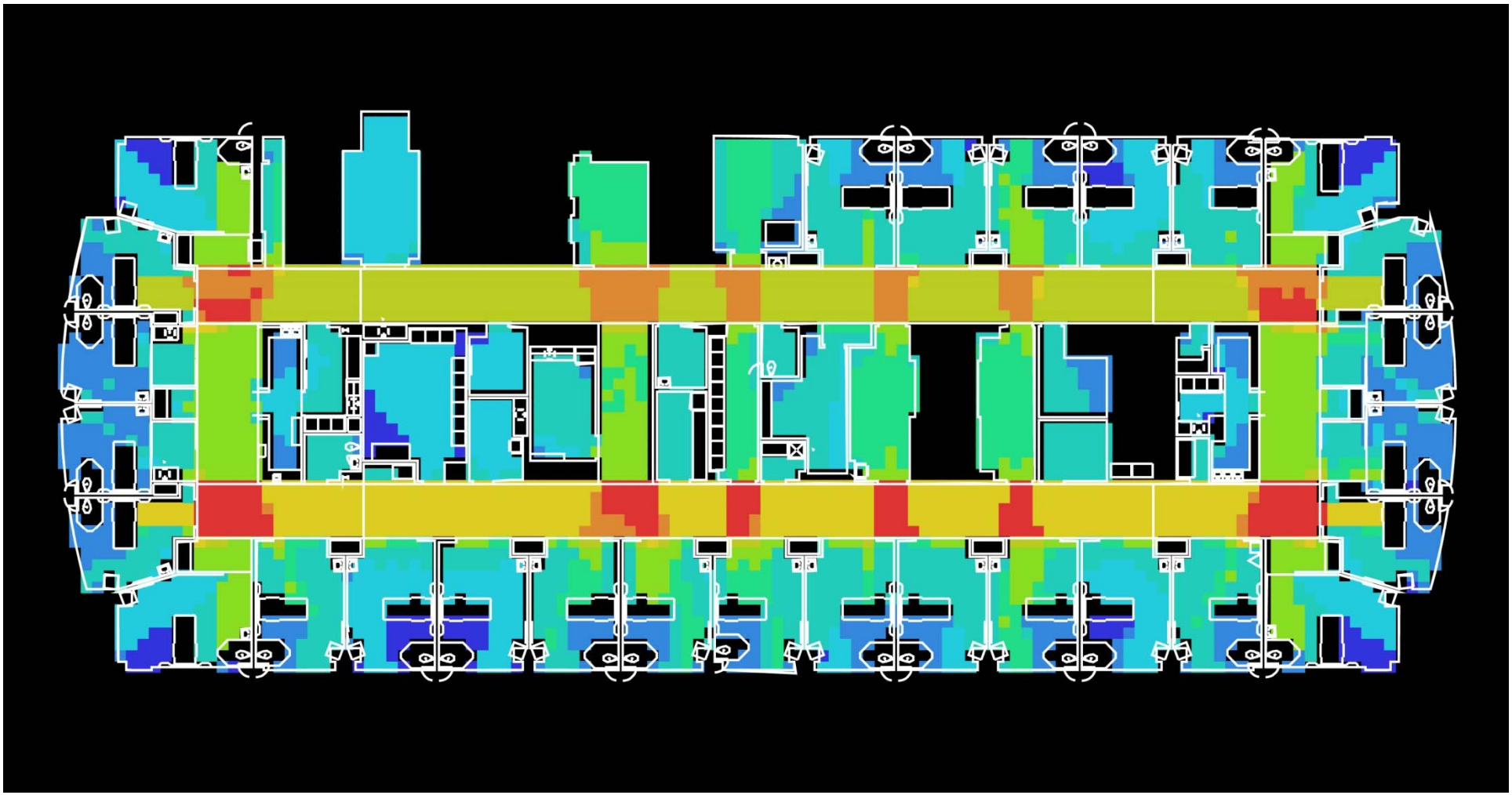

Figure 5. The visibility graph of the racetrack ICU colored using integration-Rn. Source: [1]

Participants by Job Type			
Before	Both Units	28-Bed Racetrack Unit	32-Bed Open-Plan Unit
Registered Nurse	61 (75.3%)	36 (76.6%)	25 (73.5%)
Charge Nurse	9 (11.1%)	4 (8.5%)	5 (14.7%)
Physician	2 (2.5%)	1 (2.1%)	1 (2.9%)
Others	9 (11.1%)	6 (12.8%)	3 (8.8%)
Total	81 (100.0%)	47 (100.0%)	34 (100.0%)
After	Both Units	28-Bed Racetrack Unit	15-Bed New Unit
Registered Nurse	39 (78%)	18 (94.7%)	21 (67.7%)
Charge Nurse	7 (14%)	1 (5.3%)	6 (19.3%)
Physician	1 (2%)	0 (0%)	1 (3.2%)
Others	3 (6%)	0 (0%)	3 (9.8%)
Total	50 (100%)	19 (100%)	31 (100%)

Table 1. Distribution of survey participants by job type.

		Measures of Physical and visual accessibility					
		Local (or Cell) level measure	Subsystem level measure	System level measure	Local (or Line) level measure	Subsystem level measure	System level measure
		Visual connectivity	Visual integration (R3)	Visual integration (Rn)	Axial connectivity	Axial integration (R3)	Axial integration (Rn)
1st Phase	28-Bed Racetrack Unit	236.28	5.90	5.00	3.32	2.11	1.96
2nd Phase	28-Bed Racetrack Unit	236.28	5.90	5.00	3.32	2.11	1.96
1st Phase	32-Bed Open-Plan Unit	240.81	6.00	4.51	**4.58**	**2.04**	**1.68**
2nd Phase	15-Bed New Unit	**823.30**	**7.16**	**5.58**	4.55	1.84	1.45

Table 2. Various Space Syntax measures of the Physical and visual accessibilities of the units.

		Measures of physical and visual accessibilities of the primary workplaces of survey participants					
		Local (or Cell) level measure	Subsystem level measure	System level measure	Local (or Line) level measure	Subsystem level measure	System level measure
		Visual connectivity	Visual integration (R3)	Visual integration (Rn)	Axial connectivity	Axial integration (R3)	Axial integration (Rn)
1st Phase	28-Bed Racetrack Unit	220.00	5.72	4.84	11.69	2.98	2.72
2nd Phase	28-Bed Racetrack Unit	**279.70**	**5.95**	**5.08**	**14.05**	**3.07**	**2.81**
1st Phase	32-Bed Open-Plan Unit	343.11	6.56	5.06	**16.64**	**3.21**	**2.60**
2nd Phase	15-Bed New Unit	**1330.40**	**8.20**	**6.63**	8.60	2.48	1.87

Table 3. Various Space Syntax measures of the physical and visual accessibilities of the primary workplaces of survey participants.

Know the names of other clinicians working on the unit										
					Local (or Cell) level measure	Subsystem level measure	System level measure	Local (or Line) level measure	Subsystem level measure	System level measure
			Number of participants (%)	Number of participants per bed	Visual connectivity	Visual integration (R3)	Visual integration (Rn)	Axial connectivity	Axial integration (R3)	Axial integration (Rn)
1st Phase	28-Bed Racetrack Unit	yes	34 (73.9)	1.21	**243.68**	**5.81**	**4.94**	**12.96**	**3.07**	**2.81**
		no	12 (26.1)	0.43	156.07	5.43	4.54	7.88	2.69	2.45
2nd Phase	28-Bed Racetrack Unit	yes	8 (44.4)	0.29	**425.38**	**6.79**	**5.93**	**19.13**	**3.44**	**3.15**
		no	10 (55.6)	0.38	128.45	5.08	4.21	8.30	2.65	2.42
1st Phase	32-Bed Open-Plan Unit	yes	25 (73.5)	0.78	**359.68**	**6.63**	**5.18**	**17.81**	**3.28**	**2.71**
		no	9 (26.5)	0.28	293.38	6.33	4.72	13.14	2.99	2.27
2nd Phase	15-Bed New Unit	yes	27 (87.1)	1.8	1289.33	8.12	6.57	8.40	2.44	1.85
		no	4 (12.9)	0.27	**1607.65**	**8.72**	**7.06**	**9.92**	**2.69**	**1.98**

Table 4. “Know the names of other clinicians working on the unit” in relation to the physical and visual accessibilities of the primary workplaces of respondents.

Know the locations of other clinicians working on the unit										
					Local (or Cell) level measure	Subsystem level measure	System level measure	Local (or Line) level measure	Subsystem level measure	System level measure
	Unit type		Number of participants (%)	Number of participants per bed	Visual connectivity	Visual integration (R3)	Visual integration (Rn)	Axial connectivity	Axial integration (R3)	Axial integration (Rn)
1st Phase	28-Bed Racetrack Unit	yes	12 (25.5)	0.43	146.50	5.24	4.35	8.20	2.70	2.45
		no	35 (74.5)	1.25	**248.27**	**5.90**	**5.03**	**13.04**	**3.09**	**2.83**
2nd Phase	28-Bed Racetrack Unit	yes	5 (27.8)	0.18	83.35	4.77	3.95	5.40	2.37	2.18
		no	13 (72.2)	0.46	**328.53**	**6.25**	**5.37**	**16.08**	**3.24**	**2.96**
1st Phase	32-Bed Open-Plan Unit	yes	23 (67.6)	0.72	309.18	6.42	4.79	15.00	3.04	2.43
		no	11 (32.4)	0.34	**427.94**	**6.91**	**5.74**	**20.75**	**3.63**	**3.01**
2nd Phase	15-Bed New Unit	yes	23 (74.2)	1.53	**1347.79**	8.18	**6.69**	8.57	**2.49**	**1.88**
		no	8 (25.8)	0.53	1280.38	**8.25**	6.46	**8.68**	2.44	1.81

Table 5. “Know the locations of other clinicians working on the unit” in relation to the physical and visual accessibilities of the primary workplaces of respondents.

			Unit provides opportunities for teamwork and collaboration							
					Local (or Cell) level measure	Subsystem level measure	System level measure	Local (or Line) level measure	Subsystem level measure	System level measure
	Unit type		Number of participants (%)	Number of participants per bed	Visual connectivity	Visual integration (R3)	Visual integration (Rn)	Axial connectivity	Axial integration (R3)	Axial integration (Rn)
1st Phase	28-Bed Racetrack Unit	yes	20 (44.4)	0.71	227.42	**5.80**	4.89	11.73	**3.05**	**2.78**
		no	25 (55.6)	0.89	**232.31**	5.78	**4.93**	**12.47**	3.01	2.76
2nd Phase	28-Bed Racetrack Unit	yes	8 (42.11)	0.28	**340.81**	**6.28**	**5.40**	**17.62**	**3.37**	**3.11**
		no	11 (57.89)	0.39	235.27	5.72	4.86	11.45	2.85	2.60
1st Phase	32-Bed Open-Plan Unit	yes	29 (85.3)	0.91	**357.02**	**6.62**	**5.12**	**17.31**	**3.25**	**2.64**
		no	5 (14.7)	0.16	162.20	5.73	4.27	8.00	2.67	2.01
2nd Phase	15-Bed New Unit	yes	25 (83.33)	1.67	**1386.68**	**8.31**	**6.80**	**8.83**	**2.51**	**1.89**
		no	5 (16.67)	0.33	1088.98	7.72	5.94	7.65	2.32	1.74

Table 6. “Unit provides opportunities for teamwork and collaboration” in relation to the physical and visual accessibilities of the primary workplaces of respondents.