Non-circadian Signals in the Intensive Care Unit: Point Prevalence Morning, Noon and Night

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Abstract

Background—Intensive care unit (ICU) sleep disturbance is severe and potentially related to abnormal light and sound exposure.

Objectives—To assess the prevalence of measures of light and sound disturbance in ICU patient rooms, and whether these could be modified by a sleep-promotion intervention.

Methods—This observational study with a before and after design for a quality improvement initiative surveyed environmental factors in ICU rooms at 01:00 08:00, and12:00. Surveys assessed light usage, television usage, window shade position, and room door/curtain position. Factors were compared before and after an ICU sleeppromotion intervention.

Results—990 (pre-intervention) and 819 (post-intervention) occupied rooms were surveyed. Pre-intervention, the prevalence of night-time factors included: bright lights on (21%), television on (46%), and room door open (94%). Post-intervention, more rooms had all lights off at night (41% v 50%, p=0.04), and fewer rooms had open door curtains (57% v 42%, p=0.001) and window shades (78% v 62%, p=0.002).

Conclusions—Disruptive environmental factors are common in the ICU. Some factors improve with sleep-promotion interventions.

Keywords

sleep disturbance; circadian rhythm; intensive care unit; environmental survey; quality improvement; light

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Introduction

Sleep disruption during intensive care unit (ICU) admission is severe. Patients commonly endorse that their sleep quality in the ICU is significantly worse than at home.[1–3] Studies using polysomnography (PSG) demonstrate that ICU patients experience diminished total sleep time, sleep fragmentation, decreased rapid-eye movement sleep, and increased daytime sleep.[4–6] Sleep deprivation has been linked with poor pulmonary outcomes,[7,8] abnormal immune function and inflammation,[9] and dysregulated endocrine function.[10,11] Furthermore, it is hypothesized that sleep disruption contributes to ICU delirium, which is associated with longer hospital stays, prolonged cognitive impairment, and increased mortality.[4,12–14] Sleep disruption occurring during critical illness may even persist after discharge requiring months to normalize.[15–17] Thus, it is essential to identify and target underlying causes of ICU sleep loss to help optimize outcomes of critical illness.

Sleep disruption in ICU patients likely derives from a combination of chronic sleep dysfunction, acute critical illness, medical interventions, pain, anxiety, and the ICU environment itself. The ICU environment has high sound levels, frequent care interactions, and abnormal light patterns, all of which disturb sleep.[18] With respect to sound, patients and staff commonly describe noise as one of the most disruptive factors to sleep in the ICU, [1–3,19,20] and studies have documented that background noise levels in the ICU are often significantly higher than those recommended by the U.S.

Environmental Protection Agency for hospitals.[2,21–24] A study combining PSG with sound and video recording in ICU rooms found that 20% of arousals/awakenings in ICU patients were identifiably the result of noise peaks[25]. There is also a high frequency of night-time patient care interactions occurring in the ICU, which can increase sound and light and oftentimes directly wake patients or cause them anxiety or pain. Tamburri et al retrospectively assessed the medical records of 50 critically ill patients across 4 ICUs, and found that patients experienced an average of 42.6 night-time care interactions between 19:00 and 07:00, with only 6% of the 147 patient-nights assessed having a 2hour period without interruption.[26] Notably, routine daily baths were performed between 2AM and 5AM in 61% of nights.[26] In another prospective study of 200 patients across 5 ICU types, nurses reported a mean of up to 12 nocturnal care interactions at night, with SICU and MICU nurses stating that 21% and 20% of their nighttime interactions with patients, respectively, could have been safely omitted[27]. Though light data is more limited, Elliot et al 2014 recorded ICU patient room light levels over 24-hour periods and found that daytime illuminance levels were too dim to promote proper circadian function (median 74 lux).[2] A similarly low average light intensity (79.7 lux) during daytime hours was observed in Gehlbach et al 2012 in rooms of sedated mechanically ventilated patients.[28]

Given the importance of light, sound, and night-time care interactions to sleep, clinical practice guidelines recommend that ICUs optimize light and other environmental factors to best promote patient sleep cycles and limit the risk of delirium.[13] Nonetheless, there exists a significant gap between provider awareness of these issues and actual daily clinical practice. In an international survey of 1,223 critical care providers, 75% rated their patient's sleep as "poor" or worse, and a similar majority of respondents felt that poor ICU sleep was likely

associated with worse outcomes such as delirium, longer length of stay, and prolonged mechanical ventilation.[29] Only 32% of respondents, however, reported that a sleep-promoting protocol was in place in their ICU.

Our objective was to determine how commonly our medical ICU (MICU) staff optimized the patient environment for sleep before and after a quality improvement sleep promotion intervention. To assess this, we used a survey of environmental factors influencing light, sound and other potential disturbance in patient rooms. We particularly focused on measuring simple patterns of behavior that affect environmental light exposure and sound disturbance. These include the number and types of lights kept on in patient rooms, how often the window shade is kept open, the presence of television light and sound, and how often the door and door curtains are kept open. We performed environmental surveys both before and after a unit-wide sleep promotion intervention. Overall, we hypothesize that there are highly prevalent, modifiable patterns of behaviors that could be leveraged to improve patient sleep and circadian rhythmicity in the ICU.

Methods

Study Site and Subjects

This was an observational study with a before and after design for a quality improvement initiative conducted in the MICU of a 1,500-bed academic tertiary hospital in the northeast United States. Patients are most commonly admitted for acute respiratory failure and sepsis. The unit is rectangular with 38 private patient rooms located on two adjacent floors. Each room has 3 solid walls, a clear sliding glass door with a curtain leading into the hallway, and a single exterior window. Rooms are equipped with 5 to 6 lights of varying intensity including night lights, general room lighting, and procedure lighting, as well as a television and window shade. Rooms were surveyed by direct observation from just outside the room by investigators (MA, CP, FM, MK). During a survey test period which included full surveys of more than fifty rooms, there was perfect agreement between investigators for all variables. Room surveys were conducted in two periods—August to November 2016 before, and April to May 2017 after our quality improvement intervention. This study was judged to be consistent with quality improvement and exempted from IRB oversight.

Survey Tool

Utilizing the Qualtrics (www.qualtrics.com) survey tool, investigators tallied factors at three specified times: morning (08:00), noon (12:00) and night (01:00). Surveys included observation of all patient-occupied rooms and within one hour of the designated times. Each room survey included the number and identity of lights on, whether the television picture and television sound was on, the window shade level, whether the room door was open, whether the door curtain was open, and if the patient was mechanically ventilated. No identifying patient data was collected.

Non-pharmacologic Sleep Promotion Intervention

From February to April 2017, our MICU staff implemented a non-pharmacologic, multidisciplinary, clustered care sleep promotion project, termed "Naptime." The focus of

this intervention was to promote a period of consolidated rest between 00:00 to 04:00. This protocol was developed in collaboration with a wide group of MICU stakeholders, including physicians, nurses, pharmacists, patient care assistants, and respiratory therapists. The protocol was piloted and revised with individual patients prior to unitwide implementation. The details of this protocol are published elsewhere.[30] Briefly, the goal was 1) to conduct routine care before 00:00 or after 04:00 and 2) to reduce in-room activity, noise, and light between 00:00 and 04:00. The protocol emphasized rescheduling of routine medications, labs, imaging, vital signs, invasive monitoring, and skin/wound care outside of the rest period. Bedside care that had to be delivered during the 00:00 to 04:00 rest period was clustered to keep the number of room entrances to a minimum. Relevant to our survey, the Naptime protocol includes suggestions to turn off lights and televisions and to close window shades, room curtains and room doors during the rest period. The protocol also suggests opening window shades and keeping the room light during the daytime.

Statistical Analysis

Measures of room disturbance are reported as simple proportions, based on the number of rooms demonstrating a given component of disturbance at the indicated time of day. Chi-squared analysis was used to compare proportions of disturbance measures between pre- and post-intervention periods and to determine any effects of the Naptime intervention on disturbance factors. Using ventilator status as a crude measure of illness severity, the pre- and post-intervention changes in disturbance measures were stratified by mechanical ventilation to assess for confounding or effect modification.

For these analyses, the "window shade open" disturbance was defined as the shade being at least 50% open. The "door open" disturbance was defined as the room door being open enough to allow someone to walk unimpeded into the room. The "door curtain open" disturbance was defined as the room door curtain being more than halfway open. The "bright lights on" disturbance was defined as a room having either the procedure light or headboard light on—the two objectively brightest lights in the room.

Results

Room Characteristics

There were 990 instances of room observation during the pre-intervention period, and 819 instances of room observation during the post-intervention period. In the preintervention period, 414 observations were made in the morning, 341 at noon, and 235 at night. In the post-intervention period, 257 observations were made in the morning, 308 at noon, and 254 at night. 42% of pre-intervention and 46% of post-intervention observed rooms included patients who were mechanically ventilated; this was not a statistically significant difference.

Disturbance Factors Related to Room Lighting

Disturbance factors observed in patient rooms at three different times of day are shown in Table 1 and Figure 1 (both pre- and post-intervention). With respect to room lighting, rooms were observed to have "no lights on" 45% (morning), 33% (noon) and 41% (night) of the time in the pre-intervention period. After the intervention, there was a statistically significant

increase in nighttime rooms with "no lights on" (41% vs 50%, p=0.04) (Figure 1). Meanwhile, the brightest lights (either the headboard light or procedure light) were turned "on" in the pre-intervention period 29% (morning), 41% (noon) and 21% (night) of the time. These proportions did not significantly change post-intervention.

The television picture was found to be "on" in 57%, 67%, and 46% of rooms at morning, noon, and night respectively in the pre-intervention period. The postintervention noon time-period showed a statistically significant decrease in the number of rooms with television picture "on" (67% vs. 54%, p=0.001).

Window shades were "open" in 68% of rooms in the morning, 70% of rooms at noontime, and 78% of rooms at night before the intervention. Post-intervention, there was a statistically significant increase in the proportion of rooms with window shade "open" at noon-time (70% vs. 78%, p=0.02), while night-time rooms had significantly fewer window shades "open" (78% vs. 62%, p=0.002). There was no change in the proportion of rooms with window shade "open" at the morning time-point (68% vs. 72%, p=0.26).

Factors Related to Sound and Other Disturbance

The room door was found to be "open" in 98% (morning), 96% (noon), and 94% (night) of observations pre-intervention, compared to 98%, 99%, and 91% in the postintervention period. Post-intervention, only the noon time-period showed a significant increase in the proportion of rooms with door kept "open" (p=0.045). The door curtain was "open" in the pre-intervention period at rates of 44% (morning), 48% (noon), and 57% (night). By contrast, the door curtain was "open" in the post-intervention period at rates of 46% (morning), 58% (noon), and 42% (night). The post-intervention noon timeperiod showed a significant increase in the proportion of rooms with door curtains "open" (48% vs. 58%, p=0.02), while the night time-period had significantly fewer rooms with door curtains kept "open" (57% vs. 42%, p=0.001).

Mechanical Ventilation as an Effect Modifier

Utilizing mechanical ventilation as a crude estimate of illness severity, we assessed whether illness severity could account for changes in the three environmental factors that showed differences between pre- and post-intervention periods at night— "no lights on," "door curtain open", and "window shade open" (Figure 2, Supplementary Table S1 and S2).

In the pre-intervention period, rooms with mechanically ventilated patients were significantly more likely than non-ventilated rooms to have lights on at night (19% of ventilated rooms with no lights on vs. 53% for non-ventilated rooms, p<0.001). This difference in artificial lighting was no longer seen post-intervention (40% vs 52%, p=0.09) (Figure 2A). In other words, mechanically ventilated rooms showed a statistically significant increase in the proportion of rooms with no lights on (19% preintervention and 40% post-intervention, p=0.001), whereas non-ventilated patient rooms did not show a statistically significant change (p=0.82).

With regards to door curtains, mechanically ventilated patients showed a significant decrease in the proportion of night-time rooms with door curtains open (74% pre-intervention vs.

53% post-intervention, p=0.002) (Figure 2B). Non-ventilated patients also showed a decrease in rooms with door curtain open; however, the p-value is marginal (51% pre-intervention vs. 39% post-intervention, p=0.06). For window shade open, on the other hand, only non-ventilated patient rooms showed a statistically significant change after the intervention (78% pre-intervention vs. 60% post-intervention p=0.003) (Figure 2C).

Discussion

Overall, this study observed a high prevalence of environmental disturbance factors. At baseline, during the nighttime observation period, rooms were frequently illuminated with their brightest lights, doors and door curtains were open, and television picture and sound were on. Greater than half the time rooms had some artificial lighting turned on. We also frequently observed daytime behaviors which conflict with proper circadian entrainment by limiting bright light exposure. During the morning and noon time-points, about one-third of rooms had their window shades closed and nearly onethird (noon) to one-half (morning) of rooms had no lights in use. These data suggest that there is a significant opportunity to improve the MICU environment via simple interventions which have the potential to improve patient sleep and circadian rhythms.

After implementation of a unit-wide sleep-promoting protocol in our MICU, we observed several improvements. Rooms were significantly more likely to have all lights off, door curtains closed, and window shades closed at night. We also observed some post-intervention improvement in noon-time lighting factors such as an increased opening of door curtains and window shades, although morning-time observations showed no identifiable changes. Taken together, these data suggest that a multidisciplinary intervention focused on environmental control and clustered care could indeed modify behavior to improve specific environmental parameters. Interestingly, mechanical ventilation status was found to be an effect modifier for room lighting at night. Mechanically-ventilated patient rooms showed a significant improvement in having lights turned off post-intervention, whereas non-mechanically ventilated rooms were not affected by the intervention. One hypothesis is that mechanically ventilated patients are less able to communicate and express a preference regarding their room environment, and thus at baseline are more likely to be inadvertently subjected to lighting conditions that conflict with their preference. Additionally, these patients may have greater illness severity, prompting staff to prefer "lights on" for closer monitoring. It seems plausible that non-ventilated patients, who can communicate, can express a preference over light conditions pre-intervention and thus there was relatively little change made by the intervention. Mechanically ventilated patients may, therefore, represent a particularly vulnerable ICU population for which unit interventions can improve environmental disturbances.

It is unclear to what degree patient preferences influenced environmental disturbance factors observed in our study. A qualitative study of ICU sleep disturbance found that patients and staff had contrasting beliefs. Staff commonly believed that inroom provider interruption, noise, and excessive light were the major environmental factors disrupting sleep, while patients and surrogates described emotions and anxiety as the major deterrents.[20] In fact, patients commonly described noise and in-room disturbance as expected aspects of a MICU

stay, and that they felt reassured by being closely monitored.[20] This is despite multiple studies suggesting that that subjective sleep quality in the ICU is poor and that a variety of environmental factors, including high noise levels, light exposure, and patient care interactions, are playing a role.[1–3,16,24–26] These different needs are a potential area for staff and patient education. Patients could be given information regarding the importance of a quiet and dark environment for sleep, allowed to use dim lighting options, and be reassured that there is continuous remote monitoring outside of their room.

Overall, there exists a substantial gap between provider awareness that sleep in the ICU is important to recovery and the low rate of individual or unit-wide sleep promoting practices implemented.[20,29] Quality improvement interventions and new care bundles in the ICU can be complicated to implement; they require iteration and integration across multiple stakeholders in an already high-stakes environment.[30] Barriers to ICU protocol implementation that have been identified include patient-related barriers, provider-related barriers, protocol-related barriers (such as cumbersome protocol or lack of defined role and responsibilities), and ICU contextual barriers (such as staff turnover and low prioritization of the protocol relative to patient needs).[31] Increased workload and safety concerns are common issues with implementing change in the high-acuity ICU environment.[32] Our focus herein was to demonstrate that there are simple, safe, modifiable behaviors that can be leveraged to improve the environment for sleep and circadian biology in critically ill patients.

There are several limitations of this study. First, no patient data other than mechanical ventilation was collected, limiting our ability to test for effect modification based on other patient-specific factors. For example, we did not have data on time or date of ICU admission for each patient; patients earlier in their admission may experience more in-room activity necessitating room lights kept on and doors open. Similarly, we did not collect any patient-specific subjective data, and so cannot determine to what extent environmental factors are related to patient preference. Second, several of our measures are potentially subjective with regards to data collection (degree of door curtain and window shade closure), and it is furthermore unclear to what extent these factors would affect patient sleep—nonetheless, we report them here as indicators of provider "intent" towards optimizing the patient environment. Investigators did have perfect agreement on environmental factors during a survey pilot (described above). Finally, we only collected one set of data points approximately one month after the implementation of the sleep promotion intervention, and thus cannot make inferences about the lasting effects of this intervention on behavior, or account for changes in staffing and education of providers over time.

Conclusions

Non-circadian light, sound, and patient care patterns are highly prevalent in the ICU. During the daytime periods (morning and noon, when bright light is needed), less than half of rooms had the brightest lights on, and nearly one-third had the window shade closed. Rooms at night commonly demonstrated factors such as bright lights kept on, televisions on, window shades open, room doors open, and room curtains open. After a sleep-promoting quality improvement intervention, there was a significant nighttime improvement in some measures

of disturbance, including lights turned off, door curtains closed, and window shades closed. Future work is needed to optimize ICU workflow and to reduce environmental factors that disturb patient sleep and circadian rhythmicity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

Abbreviations

ICU	intensive care unit
MICU	medical intensive care unit
PSG	polysomnography

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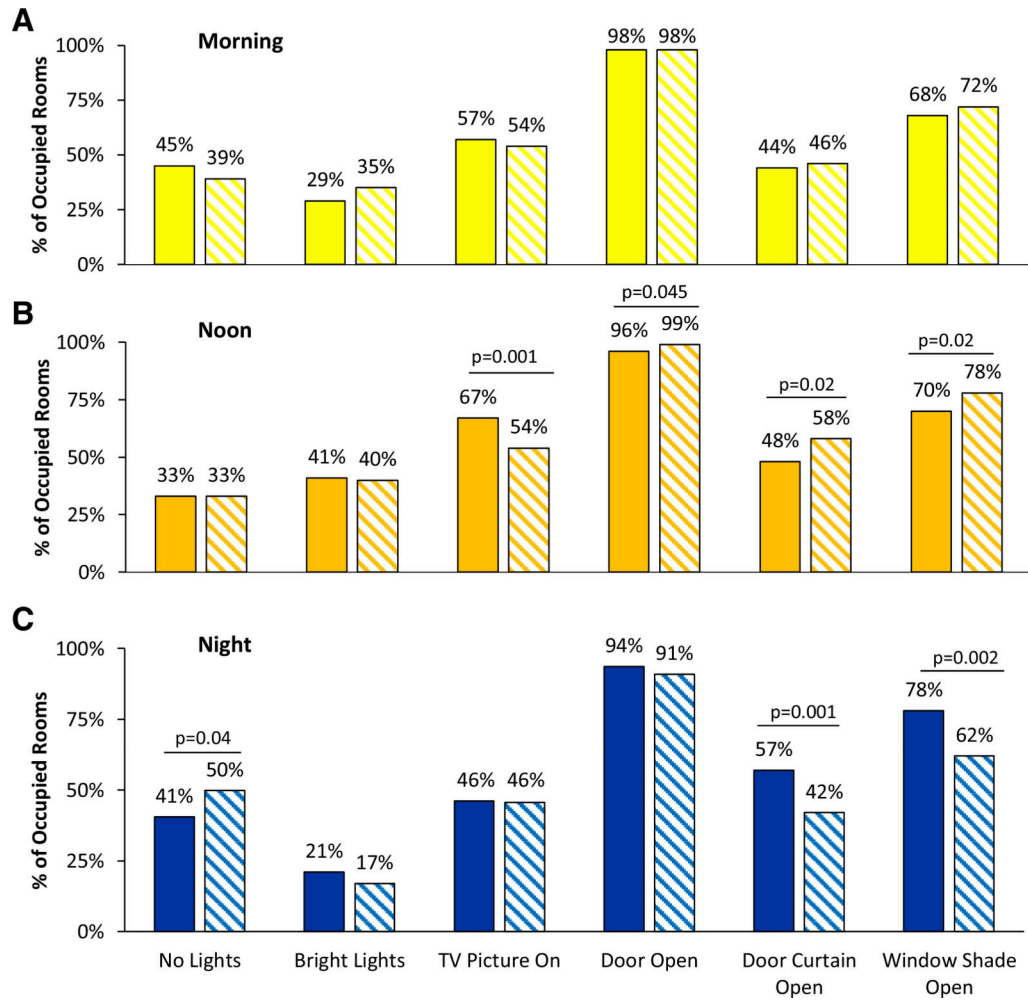**Figure 1.**

Disturbance factors before and after the sleep-promotion intervention. Solid bars are pre-intervention; hatched bars are post-intervention. "No lights" indicates that no artificial lights were on in the patient's room. "Bright lights" indicates use of either the headboard or procedure lights, which are the brightest lights in patient rooms. "Door open" indicates that the room door was open enough to allow someone to walk unimpeded into the room. "Door curtain open" indicates that a room had its curtain more than halfway open. "Window shade open" indicates that a room had its shade at least halfway open.
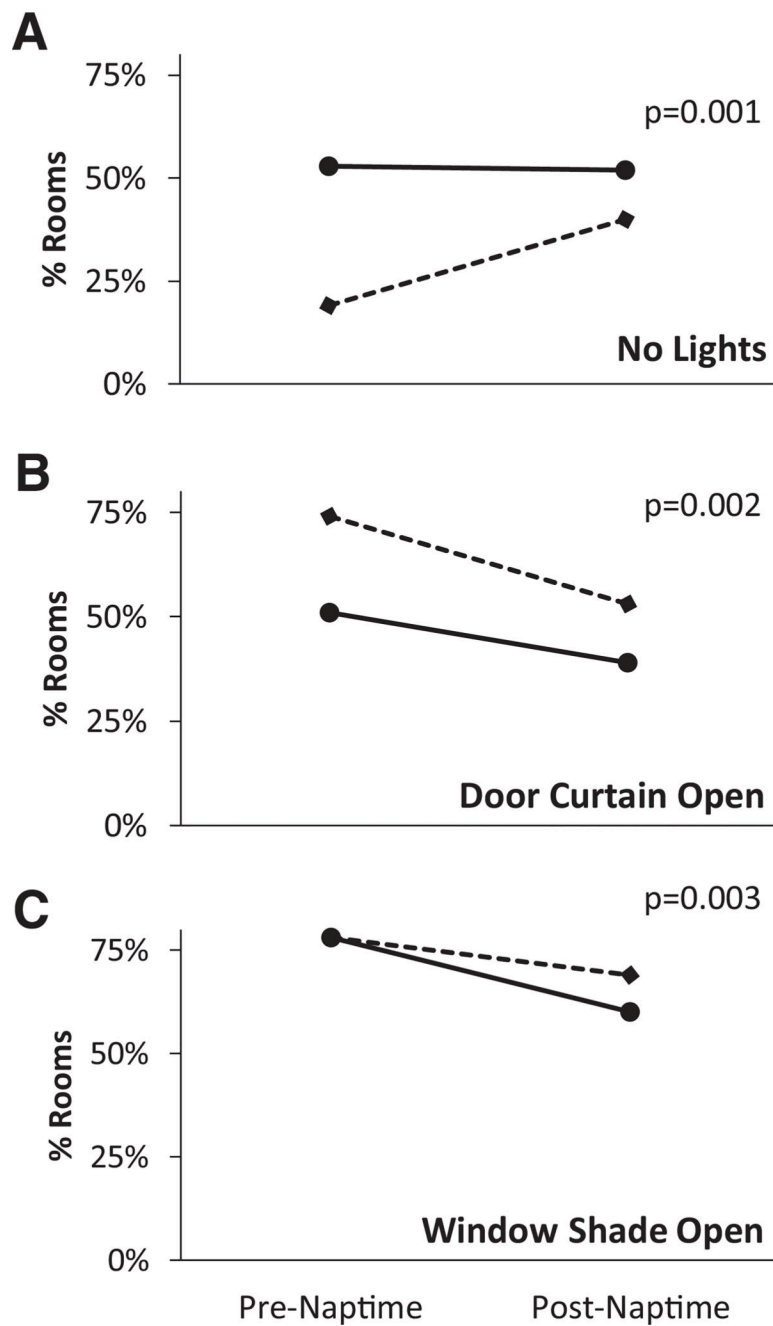
Figure 2.
Mechanical ventilation as an influence on changes in night-time disturbance factors. Solid lines indicate non-mechanically ventilated patients; dashed lines indicate mechanically ventilated patients.

Table 1.

Disturbance environmental factors before and after intervention.

Pre-implementation	Morning (n=414)	Noon (n=341)	Night (n=235)
No lights on	45%	33%	41%
Bright lights on	29%	41%	21%
Television picture on	57%	67%	46%
Television sound on	16%	26%	33%
Door open	98%	96%	94%
Door curtain open	44%	48%	57%
Window shade open	68%	70%	78%
Post-implementation	**Morning (n=257)**	**Noon (n=308)**	**Night (n=254)**
No lights on	39%	33%	50% [*]
Bright lights on	35%	40%	17%
Television picture on	54%	54% [**]	46%
Television sound on	42% [**]	44% [**]	32%
Door open	98%	99% [*]	91%
Door curtain open	46%	58% [*]	42% [**]
Window shade open	72%	78% [*]	62% [**]

[*] p<0.05 for difference in pre vs. post-intervention at the same time-point

[**] p<0.005 for difference in pre vs. post-intervention at the same time-point