The Nursing Home at Night: Effects of an Intervention on Noise, Light, and Sleep

John F. Schnelle, PhD,[*†] *Cathy A. Alessi, MD,*[†] *Nahla R. Al-Samarrai, MA,*[*] *Ronald D. Fricker, Jr., PhD,*[‡] *and Joseph G. Ouslander, MD*[§]

OBJECTIVES: The sleep of nursing home residents is fragmented by frequent awakening episodes associated, at least in part, with environmental variables, including noise and light changes. The purpose of this study was to improve sleep by reducing the frequency of nighttime noise and light changes.

PARTICIPANTS AND SETTING: Two hundred sixty-seven incontinent nursing home residents in eight nursing homes.

DESIGN: A randomized control group design with a delayed intervention for the control group.

MEASUREMENTS: Bedside noise and light monitors recorded the number of 2-minute intervals at night with peak sounds recorded above 50 dBs and the number of light changes of at least 10 lux between adjacent 2-minute intervals. Daytime behavioral observations measured sleep and in-bed time during the day, and wrist activity was used to estimate sleep at night. Awakening events associated with the environmental variables were derived from the wrist activity data.

INTERVENTION: A behavioral intervention implemented between 7:00 p.m. and 6:00 a.m. that involved feedback to nursing home staff about noise levels and implementation by research staff of procedures to both abate noise (e.g., turn off unwatched television sets) and to individualize nighttime incontinence care routines to be less disruptive to sleep.

RESULTS: Noise was reduced significantly, from an average of 83 intervals per night with peak noises recorded above 50 dBs to an average of 58 intervals per night in the group that received the initial intervention, whereas noise in the control group showed no change (MANOVA group × time $P < .001$). All 10-dB categories of noise from 50 to 90+ dBs were reduced, and light changes were reduced from an average of four per night per resident to two per night ($P < .001$). Despite these significant changes in the environmental variables, there was a significant differential improvement in the intervention group on only two night sleep measures: awakening associated with a combination of noise plus light ($P < .001$) and awakening associated with light ($P < .001$). However, there was a significant correlation between change in noise and change in percent sleep from baseline to intervention ($r = -.29$, $P < .05$), suggesting that the intervention did not reduce noise to low enough levels to produce a significant improvement in sleep. The intervention effects on all environmental variables were replicated in the delayed intervention group, who again showed significant improvement on the same sleep measures. Observations of day sleep and in-bed time did not change over the phases of the trial for either group.

CONCLUSION: The significant reductions in noise and light events resulting from the intervention did not lead to significant improvements in the day sleep and most night sleep measures. An intervention that combines both behavioral and environmental strategies and that addresses daytime behavioral factors associated with poor sleep (e.g., excessive time in bed) would potentially be more effective in improving the night sleep and quality of life of nursing home residents. J Am Geriatr Soc 47:430–438, 1999.

Key words: night incontinence care; nursing home; awakenings; sleep; noise

Sleep fragmentation among nursing home (NH) residents has been associated with a variety of medical, environmental, and behavioral factors. Sleep-related respiratory disturbance, periodic limb movements, depression, and circadian rhythm abnormalities are only some of the medical conditions that are both prevalent among NH residents and known to affect sleep adversely.[1–4] Behavioral factors potentially associated with poor nighttime sleep include low levels of daytime physical activity, excessive daytime napping, and long periods of time spent in bed.[4] In a previous study, we found that incontinent residents in eight NHs spent an average of 18 hours per day in bed.[5] Moreover, during 36 observations completed between 8 a.m. and 5 p.m., these residents were found to be sleeping, on average, 23% of the time.

With respect to environmental factors, both acute and long-term institutional settings are characterized by high levels of noise and care patterns that are disruptive to sleep.[6,7] In a recent study conducted in ten NHs, we recorded peak sound levels at residents' bedsides every two minutes for 10 hours at night. For each resident, between 19 and 33 peak

From the *Borun Center for Gerontological Research and UCLA School of Medicine, Los Angeles, California; the †Multicampus Program in Geriatric Medicine and Gerontology, UCLA School of Medicine, and the Sepulveda VA Geriatric Research, Education and Clinical Center; the ‡Rand Corporation, Los Angeles, California; and §Atlanta VA Rehabilitation Research and Development Center and Wesley Woods Geriatric Center at Emory University, Atlanta, Georgia.
Research was supported by NINR Grant No. 5R01NR02795 and NIA Pepper Center Grant Number 1P60-AG10415.
Address correspondence to John F. Schnelle, PhD, UCLA-Borun Center, 7150 Tampa Ave., Reseda, CA 91335.

0002-8614/99/$3.50

sound measurements reached 60 dBs or louder. Furthermore, 42% of the awakenings from sleep, as documented by residents' wrist activity, were associated with either noise (22%) or light and noise-plus-light combinations (20%), which generally are indicative of nursing care routines.[8] The most common sources of noise that could be identified were staff vocalizations (26%), television sets (19%), other residents (21%), and equipment such as linen carts, intercoms, and telephones (21%).[5]

These data support the wisdom of NH regulatory guidelines, which recommend that environmental causes of sleep disruption be identified and eliminated before implementing other interventions (such as psychotropic medications). There are, however, relatively few data documenting the effectiveness of environmental interventions. In a previous study, we documented that it is possible to individualize nighttime incontinence care routines so that associated noise and light are less disruptive to sleep.[9] No study, however, has documented the degree to which generalized noise, unrelated to specific care routines, can be reduced.

In this study, we report the effects of an intervention that combined the individualized nighttime incontinence care routines with other procedures designed to reduce nighttime noise generally. We address two questions: (1) Can an intervention that does not involve physical modifications to the NH environment reduce nighttime noise and light changes? (2) What is the effect of the intervention on awakenings and other sleep measures?

METHODS

Two NHs were recruited in each of 4 years and assigned to either an immediate or a delayed intervention group. Each pair of NHs underwent three phases of study. In Phase 1, baseline measurements were collected under usual care conditions in both NHs. During Phase 2, the immediate intervention NH received the intervention while the delayed intervention NH continued with usual care conditions. Thus, in Phase 2, the delayed intervention NH served as a control comparison for the immediate intervention NH. During Phase 3, the intervention was performed in the delayed intervention NH. During the 4-year study period, four delayed intervention NHs served as controls for four immediate intervention NHs, and all eight NHs eventually received the intervention.

Subjects and Setting

The subjects were residents in these eight NHs, six of which were proprietary, which ranged in size from 120 to 220 beds. One home served a predominantly black population. The staff-to-resident ratios of all homes were similar, ranging from a ratio of one nursing assistant per eight residents on the 7:00 a.m. to 3:00 p.m. shift to one nursing assistant per 20 residents on the 11:00 p.m. to 7:00 a.m. shift. All residents documented by physical checks for wetness to be incontinent were eligible to participate in the study unless they were expected to be short-stay residents (e.g., they resided on Medicare transitional care units) or had a chronic indwelling urinary catheter. Incontinent residents were targeted because of published data indicating that incontinence care routines were conducted in nursing homes in a manner that disrupted sleep.[8] One major component of the intervention involved in this trial was to individualize these routines to make them less disruptive to sleep. According to the facilities' medical records, the percentage of incontinent residents in each facility ranged from 65 to 80%. All residents identified by the facility as incontinent were confirmed to be so when research staff completed physical checks over a 2-day period. A total of 577 incontinent residents in the eight NHs met the inclusion criteria, and consent to participate in the trial was obtained for 267 (46%) of these residents. Thirty-seven (14%) of these 267 residents were eventually dropped from the study because of subsequent refusal to participate or behavioral problems that precluded their further participation. Nighttime sleep, light, and noise data were collected for the remaining 230 subjects during the baseline Phase 1. Ninety subjects in the immediate intervention group and 94 subjects in the delayed intervention group subsequently completed the intervention phase of the trial. Five subjects withdrew consent, and the remainder either died or were hospitalized for sufficiently long periods of time to preclude their participation in the trial. Medical record information was retrieved for the purpose of describing the subjects, and research staff assessed the cognitive and mobility status of the subjects directly using the Folstein Mini-Mental State Exam (MMSE) and the Functional Incidental Training Protocol, respectively.[10,11] Daytime behavior was monitored with an observational protocol that measured the subjects' location (in or out of bed) and their sleep-awake status. Observations were completed for 5 days for each subject by locating each one every 15 minutes between 8:00 a.m. and 4:00 p.m. and observing them for 1 minute to determine if they appeared to be sleeping. Sleep was defined as a 1-minute interval with no purposeful movement and with eyes closed. Observations for symptoms of sleep-disordered breathing (sleep apnea) were conducted for 1 night on each resident according to a standardized protocol validated in a NH population.[12] Research staff were trained in all behavioral observations (sleep-wake, subject location, sleep apnea) until interobserver agreement above Kappa = .80 was obtained. Periodic interobserver agreement was calculated throughout the study to prevent observer drift.

NIGHTTIME NOISE, LIGHT, AND SLEEP MONITORING

Measurements during the nighttime period were conducted between 7:00 p.m. and 5:00 a.m. Our objective was to collect data on each resident for a minimum of 5 nights; the average number of nights monitored per subject was 5.3.

At 7:00 p.m., each subject's location (in bed vs out of bed) was noted. When the subject was in bed, a bedside monitor and a wrist activity monitor were activated. The bedside monitor contained a cadmium sulfide photocell that monitored the maximum light level in the room at 2-minute intervals and an electric microphone that monitored peak sound levels (defined as sound levels between 50 and 90+ dBs) at 2-minute intervals. In this paper, we report the frequency of peak sound per each 2-minute interval as well as changes in peak light intensity between consecutive 2-minute intervals. Sound levels were subdivided into all 2-minute intervals, with peak sounds recorded above the following decibel category levels: 50–59 dBs, 60–69 dBs, 70–79 dBs, 80–89 dBs, and 90+ dBs. To put these numbers in perspective, a person talking in a normal tone of voice at the resident's bedside would typically produce a peak sound of approximately 60 dBs.

The photocell measured light in the range of 0 to 60 foot candles, and a light change was recorded whenever the light

level changed by approximately 1 foot candle (10.8 lux) To put these numbers in perspective, light at a resident's bedside measured approximately 1 foot candle at night with the door open, the hall light on, but all room lights off. If ceiling lights were on, the light meter reading was between 6 and 8 foot candles. With all room lights on (i.e., both ceiling lights and over-the-bed lights), the light meter reading was between 10 and 12 foot candles.

The wrist monitor, built specifically for this project by Augmentech, Inc. (Pittsburgh, PA), was integrated with the bedside monitor. Wrist activity measurement has been used extensively to estimate sleep versus wakefulness in various populations, including nursing home residents.[13] The device, a lightweight "bracelet" that is strapped snugly but not uncomfortably to the resident's wrist," was based on an IC sensor accelerometer (model 3031–002). The accelerometer output was AC-coupled and high-pass filtered with a time constant of 250 ms. The signal was sampled four times per second. With these continuous recordings of wrist activity, two summary values were calculated for each 2-minute interval. First, the lowest reading was subtracted from the highest reading for each 2-minute period to measure the peak wrist activity during the interval. Second, all wrist activity measures were averaged over each 2-minute period. Using these summary values, we developed an algorithm to detect sleep and validated it against 240 intervals of behavioral observations.[6] The most specific and sensitive decision rule involved a combination of the peak and average wrist activity variables. Peak activity less than 40, as recorded by the device, and average activity less than 15, as recorded by the device, were together considered sleep; if either or both values were higher, subjects were considered awake. It should be noted that with this algorithm, a subject could be asleep, have little wrist activity for 1 minute and 15 seconds, then awake and still be recorded for the entire 2-minute interval as awake. Previous studies have validated wrist activity data against polysomnography and behavioral observations of sleep.[13,14] We did not validate the equipment used in this study against polysomnography. We did, however, validate data from the wrist activity monitor against behavioral observations of sleep in both this study and a previously reported study.[6] For this study, research staff observed eight subjects continuously for 60 minutes. For each resident, the behavioral observations for 30 separate 2-minute intervals were then compared with the wrist actigraph notation of sleep. Results from the wrist activity monitor agreed with the behavioral observations on 94 to 98% of separate 2-minute observations during which the subjects were awake and on 90% of the 142 observations during which the subjects were asleep for a significant Kappa agreement of .79 ($P < .01$).

Software designed for this study analyzed the wrist activity data for successive 2-minute intervals concurrently with all data collected by the bedside monitor. The following four values were calculated: (1) average duration of a sleep episode; (2) peak sleep duration; (3) percentage of time spent in bed asleep; and (4) number of awakenings. The average duration of a sleep episode was calculated by averaging the duration of all sleep episodes that occurred throughout the night for each resident. Peak sleep duration was defined for each resident as the longest period of sleep each night. The percentage of time spent in bed asleep each night was calculated by dividing the total number of minutes asleep, as indicated by wrist activity, by the total recording time for each night. An awakening was defined as two consecutive 2-minute intervals with wrist activity characteristic of wakefulness following at least 10 minutes of uninterrupted sleep (i.e., at least five consecutive 2-minute intervals during which wrist activity indicated sleep). The software program identified awakenings associated with changes in both light and sound by calculating how many awakenings occurred during or immediately after a 2-minute interval with an increase in light and/or sound levels. An increase in sound level was defined as a change of 10dBs or more between successive 2-minute intervals. A change in light was defined as a change of 1 foot candle or more between successive 2-minute intervals. We also analyzed all awakening events with a more liberal definition of sleep, which was 6 consecutive minutes of wrist activity indicative of sleep followed by 4 minutes of activity indicative of wakefulness. This definition increased the number of waking events by 83% but did not change the proportion of waking events associated with each environmental variable, nor did it change the outcome of other analyses reported in this paper. We will report in this paper only the awakening events associated with the more conservative 10-minute sleep definition.

Baseline Phase 1: Usual Care

Baseline data were collected during a usual care period for all residents on five separate nights. During this phase, research staff provided incontinence care in a manner that reflected the usual care patterns of indigenous staff, although simulating usual care proved difficult. In each of the eight NHs, the administrator and director of nursing reported that it was facility policy for staff to provide nighttime incontinence care on a 2-hour turning and changing schedule. All floor supervisors reported the same. During a three- to six-night period before implementing Phase 1, however, research staff observed that none of the NHs provided nighttime incontinence care on a regular 2-hour schedule. Moreover, the frequency with which NH staff changed incontinent residents varied from night to night in these facilities. In all cases, however, incontinence care was accomplished by turning on room lights and talking in a normal conversational tone. As a result of these observations, the following protocol was used during the usual care, baseline phase. The monitoring equipment was placed on all residents between 7:00 p.m. and 8:00 p.m. and removed at 5:00 a.m.; an average of 9.9 hours per night was recorded for each resident. Research staff made hourly rounds, with an average of 10 rounds per night, making written notes regarding sources of noise, indigenous staff behavior, and resident sleep status upon entering and leaving the room. Sleep status was determined by 1-minute observations, with sleep defined as eyes closed and no purposeful movement. Whenever indigenous NH staff were observed providing incontinence care to residents who were not participating in our study, research staff also checked and changed the participating residents in an effort to simulate usual care. Research staff provided the incontinence care because urination episodes were monitored with wired pads that had to be changed and reconnected to monitoring equipment after each incontinence episode. These data have been reported in another paper.[15] Research staff talked in normal conversational tones, used the same lighting as indigenous staff, and checked and changed residents even if they were sleeping during these rounds. Based on indigenous staff practices, changing rounds in two of the NHs were conducted

between 8:30 p.m. and 10:00 p.m., 11:30 p.m. and 12:30 p.m., 2:00 a.m. and 3:30 a.m., and 4:30 a.m. and 6:00 a.m. Changing rounds in the other six homes were more unpredictable but typically occurred between 7:30 p.m. and 9:30 p.m., 11:30 p.m. and 1:00 a.m., and 3:30 a.m. and 5:00 a.m.; thus, research staff followed this schedule in these facilities.

Intervention Procedures

During the intervention phase, all noise, light, and sleep measures were collected using the same procedures used in the baseline phase. In addition, research staff implemented an intervention with four major components: (1) in-service education; (2) verbal and visual feedback; (3) noise abatement; and (4) individualized incontinence care.

In-Service Education

The educational component featured one 30-minute session on both the 3:00 p.m.- 11:00 p.m. and 11:00 a.m. to 7:00 a.m. shifts, which took place before implementing the intervention but after the baseline data collection was completed. General issues concerning sleep and the outline of the intervention protocol were discussed. The noise levels recorded in the nursing home during baseline conditions were presented with simple graphics. This session was followed by brief nightly sessions (5–10 minutes), which were held at the nurses' station immediately before each shift change. These follow-up sessions were designed to provide feedback about noise and light data as well as to reinforce the basic principles of the intervention. Spanish and English written materials were provided to staff, and a Spanish interpreter was available on most nights.

Verbal and Visual Feedback

During each nightly session, staff were given verbal feedback about noise levels and sources of noise (e.g., 80 loud noises were recorded in resident X's room). Bar graphs contrasting noise levels during the baseline phase to each intervention night were presented during the nightly sessions as well as posted on the doors of residents' rooms.

Noise Abatement

On each night of the intervention phase, research staff asked residents during the first hourly round if they would like their doors closed. This procedure was based on preliminary evidence that closed doors significantly reduced bedside noise levels.[16] If both the resident and the roommate agreed, the door was closed. Approximately 20 to 30% of the time, however, the resident and roommate could not agree on shutting the door, and the door remained open. Study subjects who were watching television or listening to the radio were asked to lower the volume after 9:00 p.m. Other residents were asked to do the same if their radio or television could be heard in the rooms of participating residents. These requests were made only if the research staff judged that the TVs or radios were loud enough to disrupt sleep. Research staff turned off television sets that were not being watched. In addition, after 9:00 p.m., NH staff were asked to not use the intercom and to talk in a low tone of voice while in the hall or in residents' rooms. Earphones for television use were encouraged but seldom observed. We did not provide earphones but plan to do so in future noise abatement efforts, although earphones may be unacceptable to many of the residents.

All of these intervention components engendered considerable controversy. Some NH staff believed that it was against regulatory policy to shut residents' doors and others believed it was against fire code policy to leave doors open. Many staff protested that it violated residents' rights to turn down TV volumes, whereas others thought there was a written policy that television sets could be turned off between 9:00 p.m. and midnight. Similarly, staff held conflicting beliefs about when to use or not use the intercoms, and staff in many facilities reacted negatively to being asked by research staff to talk in a low tone of voice. No written policies pertaining to these matters could be found, so it was necessary to negotiate agreements about the noise abatement procedures in each NH. In the last two facilities, 18 nurses aides and four supervisory staffs (2 LVNs, 2 RNs) were asked to respond anonymously to questions about noise and sleep. These questions were added in an attempt to understand why some staff at all facilities cooperated only reluctantly with the noise abatement procedures.

Individualized Incontinence Care

During the intervention phase, research staff provided incontinence care during hourly rounds whenever participating residents were observed to be awake. Residents who had been assessed as being at low risk for skin problems were allowed to sleep for as many as four consecutive hourly checks but were awakened on the fifth if still asleep. Residents who were assessed as high risk for skin problems were allowed to sleep for two consecutive hours before being awakened, if necessary, on the third hour. Whenever a resident was changed, efforts were made to reduce noise and light levels (e.g., research staff talked in low tones of voice and moved bedside curtains slowly). Preliminary data showed that talking in a normal tone of voice produced a 60-dB sound and moving a bedside curtain with metal rings rapidly produced a 75-dB sound.[16] The entire individualized care intervention has been described in other studies and has been documented to reduce the number of awakenings caused by incontinence care.[9]

RESULTS

Description of Subjects

Table 1 illustrates descriptive data for the two groups of subjects who participated in this trial. There were no significant differences between the two groups on any of the variables with the exception of ethnicity. The larger proportion of black subjects in the immediate treatment homes was attributable to one home in that group that housed a predominately black population. Correlations were calculated between all three night sleep outcome measures and all descriptive variables listed in Table 1 as well as the sound and light variables recorded during baseline, which are seen in Table 2. Gender was the only subject-specific variable associated with the night sleep measures. In this case, males showed poorer peak sleep ($r = .15$, $P < .05$) and average sleep duration ($r = .13$, $P < .05$). Because of the absence of differences between immediate intervention or control groups on any variable known to be associated with the major sleep outcome measures, we did not consider covariant analysis strategies in our between group comparisons. Covariates evaluated included individual demographics such as ethnicity, sex, and age, medical conditions, medications, and the effects of the facil-

Table 1. Subject Characteristics

	Immediate Group (n = 90)	Delayed Group (n = 94)	*P* Value
Age	82.6 (7.4)	85.3 (11.9)	.57
Length of Residency in years	3.7 (4.0)	3.2 (3.2)	.36
Ethnicity			
White	72%	91%	.05
Black	17%	1%	
Hispanic	6%	8%	
Female	85%	79%	.23
Body mass index	21.8 (4.7)	22.8 (5.2)	.21
Independent ambulation	28.9%	27.7%	.85
MMSE Score	11.1 (9.4)	10.7 (9.1)	.74
No. of medications (routine and PRN)	8.1 (4.4)	7.8 (4.3)	.790
% daytime observations in bed (baseline)	40.0 (26.5)	34.5 (26.1)	.22
% daytime observations asleep (baseline)	23.6 (17.8)	24.1 (14.6)	.85
% of nightime observations snoring	20.1 (31.8)	16.2 (27.6)	.47
Average loudness of breathing at night (scale 1–3)	1.3 (.43)	1.4 (.46)	.12
% of nightime observations with leg movement	.93 (.93)	.92 (.92)	.98

(Numbers in parentheses ( ) are standard deviations. Statistical test either *t* test or chi-square as appropriate).

Table 2. Noise and Light over Three Phases of Trial

	Phase 1			Phase 2			Phase 3	
Noise and Light Variables	Baseline 1 Immed. Homes n = 90 Mean (±SD)	Baseline 1 Delayed Homes n = 94 Mean (±SD)	T Value Paired Sample	Intervention 1 Immed. Homes n = 90 Mean (±SD)	Baseline 2 Delayed Homes n = 94 Mean (±SD)	F Ratio Group × Time MANOVA	Intervention 2 Delayed Homes Mean (±SD)	T Value Paired Sample
Total noise	82.9 (43.6)	72.4 (40.6)	1.69	58.3 (37.7)	65.4 (36.3)	9.87**	52.6 (33.1)	4.4**
90+ dBs	11.6 (12.8)	9.9 (10.5)	.99	7.7 (7.7)	8.5 (8.5)	2.45	5.7 (6.5)	3.9**
80–89	9.5 (8.0)	7.9 (6.2)	1.55	5.9 (5.1)	7.5 (6.6)	10.9**	5.8 (6.4)	2.9*
70–79	9.6 (6.4)	8.1 (5.1)	1.71	6.4 (5.4)	7.5 (6.3)	9.7**	6.3 (5.8)	1.8
60–69	17.8 (11.5)	15.8 (12.3)	1.6	12.5 (9.5)	14.0 (8.8)	4.5**	11.4 (7.3)	3.2**
50–59	34.7 (18.7)	30.7 (16.0)	1.49	25.8 (15.9)	27.8 (14.5)	5.99**	23.4 (12.6)	3.6**
Total light changes	4.1 (3.2)	6.6 (3.7)	4.76**	2.1 (1.9)	6.7 (4.1)	30.7**	2.5 (1.8)	10.5**

Phase 1 = Baseline; Phase 2 = Immediate intervention only; Phase 3 = Delayed intervention.
Phase 3 analyses compared Baseline 2 and Intervention 2 for delayed group using paired *t* tests.
Phase 2 was compared with Phase 1 using MANOVA.
*Significant at .05 level.
**Significant at .001 level.

ity. None were found to be significantly related to any of the outcome measures.

Noise and Light Changes

Table 2 presents the noise and light data over the three major phases of the trial. During Phase 1, *t* tests for independent samples were used to assess differences between the subjects assigned to the immediate versus those assigned to the delayed intervention control group. There were no significant differences between groups on any noise variable recorded during baseline Phase 1, when all residents were receiving usual care. There was, however, a significant difference in the number of light changes, with the delayed intervention homes showing a higher rate of such changes than the immediate homes. During Phase 2, the differential effects of the intervention on the environmental variables for the immediate intervention subjects who were in treatment were compared with the delayed intervention subjects who continued in the baseline condition. There was a significant interaction between group and time as detected by MANOVA. This interaction indicates that the immediate intervention subjects in Phase 2 showed a significant change from baseline whereas the delayed intervention subjects, who continued in usual care conditions, showed no significant changes. Finally, when the intervention was implemented in the delayed homes during Phase 3, there were statistically significant reductions in both noise and light for the delayed intervention subjects who were compared across time between Phase 2 and Phase 3. If intervention Period 1 data for the immediate intervention group is compared with intervention Period 2 data for

the delayed group, there were no significant differences on any of the noise or light measures.

We noted that it was very difficult to implement noise abatement procedures in most nursing homes and that some staff actively or passively expressed resistance to our requests to talk in a reduced tone of voice or to otherwise comply with our noise abatement requests. In an effort to better understand this resistance, we asked questions of staff in the last two homes to determine their perceptions of how residents sleep and the effects of noise on sleeping. The questions were:

1. Do you believe that NH residents sleep poorly? Yes/No
2. Do you think that noise contributes to sleep disturbance in NHs? Yes/No
3. Who makes most of the noise in the NH? (Choose one): (a) Staff, (b) Residents, and (c) Both staff and residents equally

Ninety percent of the staff responded "yes" to Question 1, and 80% responded "yes" to Question 2. Twenty percent believed that most of the noise that disturbed sleep came from residents, 22% believed it came from staff, and 56% answered both residents and staff.

Awakenings

Table 3 presents the number and percentage of awakenings that were associated with noise, noise plus light, light changes only, or unknown/other causes. There was a significant difference detected by independent sample *t* tests between the immediate and delayed intervention groups on awakenings caused by light during baseline Phase 1. However, the *P* value for this difference was .049, and this difference is not considered important when adjustments for multiple comparisons are made. During Phase 2, there was a significant group-by-time MANOVA interaction on the proportion of awakenings associated with the light-plus-noise combination and awakenings associated with light only. This interaction indicates that the four immediate intervention NHs, which received the intervention in this phase, showed a significant change from baseline whereas the four delayed intervention homes, which continued to receive usual care, showed no significant change. During Phase 3, the effects of the intervention on awakening events associated with light-plus-noise and the light alone variable were replicated in the delayed intervention group relative to Phase 2 baseline measures. These latter analyses were completed with paired *t* test procedures in which only the delayed intervention subjects were compared over time between Phase 2 and Phase 3. In addition, paired *t* tests also indicated that between baseline (Phase 2) and intervention (Phase 3) for the delayed intervention home group, there were significant increases across time in the proportion of awakenings attributable to noise and a reduction in total awakes. However the reduction in awakes during this phase only brought the total frequency of awakenings back to the level observed for the delayed intervention group in their first Baseline (Phase 1). These changes in awakes caused by noise are similar in direction to that which occurred for the immediate treatment group between baseline (Phase 1) and intervention (Phase 2). In both groups, the reduction in the number of awakenings caused by noise-plus-light or light only were offset by increases in the number of awakenings caused by noise only. This increase in the number of awakenings attributable to noise occurred despite statistically significant reductions in the number of 2-minute intervals with peak sounds recorded at all loudness levels (see Table 2). The variation between phases in the total number of awakenings analyzed, as presented in the last row of Table 3, is due primarily to slight differences in the number of nights

Table 3. Awakenings over Three Phases of Trial

	Phase 1			Phase 2			Phase 3	
Wake Events	Baseline 1 Immed. Homes n = 96	Baseline 1 Delayed Homes n = 94	T Value Indepen. Sample	Intervention 1 Immed. Homes n = 90	Baseline 2 Delayed Homes n = 94	F Ratio Group × Time MANOVA	Intervention 2 Delayed Homes	T Value Paired Sample
Wakes associated with noise only	1.3 (.77)	1.00 (.75)	1.52	1.23 (.79)	.93 (.64)	1.28	1.12 (.73)	2.67**
	28%	23%		3%	22%		28%	
Wakes associated with light only	.09 (.14)	.14 (.19)	1.9	.04 (.10)	.16 (.26)	3.97	.09 (.15)	2.86**
	2%	6%		1%	3%		2%	
Wakes associated with noise + light	.38 (.43)	.44 (.42)	1	.13 (.16)	.60 (.55)	38.74**	.12 (.21)	8.19**
	9%	11%		3%	13%		3%	
Wakes (other)	2.5 (1.0)	2.6 (1.2)		2.7 (1.3)	2.6 (1.3)		2.8 (1.2)	.43
	61%	60%	0.33	66%	62%	0.55	67%	2.65**
No. of wakes analyzed	4.2 (1.4)	4.2 (1.6)	0.05	4.2 (1.7)	4.5 (1.5)	1.1	4.2 (1.5)	2.17*
	1891	2045		2069	2489		1997	

Phase 1 = Baseline; Phase 2 = Immediate intervention only; Phase 3 = Delayed intervention.

All analyses completed with frequency data (SD), and percentages in each cell indicate the proportion of all wakening events within the column. Phase 3 analyses compared Baseline 2 and Intervention 2 for Delayed intervention group.

In the first six nursing homes that participated in this trial, we have reported that incontinence episodes accounted for 3% of waking events in the "other" category. All other awakenings events in this category were not associated with any variable that we measured.

*Significant at .05 level; **Significant at .001 level.

that data was successfully obtained. The average number of awakening events analyzed per subject varied little between conditions, as is also indicated in Table 3.

Sleep Outcomes

Table 4 illustrates the changes in the three sleep variables (i.e., percent sleep, average peak sleep, average sleep duration) that occurred between the three phases of the trial for both the immediate and delayed intervention groups. There were no significant group by time MANOVA interactions for any of the sleep outcome variables, indicating that the means for the subjects in the immediate group did not change between Phase 1 and Phase 2 in a manner significantly different from the delayed intervention group. There are two basic types of comparisons that can be made in this table to further understand these results.

The first is to compare means between the two groups for each of the three outcome variables within Phase 1 and then within Phase 2. The second is to compare the change in sleep variables across phases by intervention groups.

Beginning with the latter, using percent sleep as an example, Table 4 shows that the change in mean percent sleep for the immediate intervention group was an increase of 3.3% (60.8 minus 57.5), which was significant using a one-sided paired t test ($P = .020$). The paired t test was used because it is appropriate to examine the change in sleep by individual, and a one-sided test was used because it was reasonable to expect that a decrease in noise and light could only cause an increase in the amount of sleep. Table 5 presents the P values for the three comparisons for the immediate intervention group and the six comparisons for the delayed intervention group. The table shows that there is a significant increase in sleep for all three sleep variables for the immediate intervention group, yet there was also a significant increase in sleep between the two baselines for the delayed intervention group for percent sleep and average peak sleep. Further, there was no significant sleep change for the delayed intervention group from the second baseline to intervention. Table 6 presents the results for two-sample t tests for the comparison between the means for each group for each of the three sleep variables within Phase 1 and Phase 2. The question of interest here is whether the mean result for each sleep variable is significantly different between the immediate and delayed groups. The table shows that there was no significant difference between the initial baseline results for both groups, as desired. There is also no significant difference between the improvement in sleep from intervention for the immediate intervention group and the second baseline measurement for the delayed intervention group. Further tests also show that there is no significant difference between the two groups' intervention means.

These results show that the intervention did not have a statistically significant effect over and above a measurement effect. Note that the trends in Table 4 suggest that the intervention did have a small but statistically indistinguishable effect. This judgment is based on the fact that for all three sleep variables, the delayed intervention group's second baseline values all lie at or below the immediate intervention group's intervention values, whereas the delayed intervention group's intervention Phase 3 values all lie above their baseline Phase 2 values. Furthermore, if only the Phase 1 and Phase 2 results are considered, there is a significant change in all three sleep variables for the immediate intervention group and a significant change in only two of the three sleep variables for the delayed group (see Table 5).

Finally, there was no significant change in the percentage of observations in which subjects were observed either in bed or sleeping during the day between Phase 1 and Phase 2 for either the immediate or delayed intervention groups. The immediate group was observed in bed and sleeping on 40% and 23.6% of the observations, respectively, during baseline (see Table 1). The numbers during the intervention period for this group were 38.8% for in bed and 22.1% for sleep. The delayed intervention group's baseline in bed and sleep time were 34.5% and 24.1% of the observations, respectively, during Phase 1 (see Table 1) and 37.6% in-bed and 24% sleep observations during Phase 2 while this group continued in baseline.

A series of correlational analyses were performed in an effort to better understand why the significant reduction in noise events did not result in significant sleep improvement or a reduction in the percentage of awakenings associated with noise. First, the correlation between the absolute change in noise for each hour of the night and the change in percent sleep for that hour was calculated, and the change in percent sleep for each resident was calculated with both measures averaged across all hours and across all homes. We included only the percent sleep outcome measure in these correlational analyses because it was problematic to calculate either peak

Table 4. Sleep Outcomes over Three Phases of Trial

	Phase 1		Phase 2		Phase 3	
Sleep Variables	Baseline 1 Immed. Homes n = 90 Mean (± SD)	Baseline 1 Delayed Homes n = 94 Mean (± SD)	Intervention 1 Immed. Homes n = 90 Mean (±SD)	Baseline 2 Delayed Homes n = 94 Mean (±SD)	F Ratio Group × Time MANOVA	Intervention 2 Delayed Homes n = 86 Mean (±SD)
Sleep %	57.5 (14.9)	55.9 (16.5)	60.8 (16.2)	60.8 (15.7)	0.82	61.1 (18.1)
Peak sleep	54.2 (26.3)	54.2 (25.2)	63.5 (36.4)	60.2 (30.6)	1.2	61.7 (34.0)
Average sleep duration	11.9 (7.6)	11.6 (6.5)	13.8 (9.0)	12.7 (8.8)	0.54	13.9 (9.6)

Phase 1 = Baseline; Phase 2 = Immediate intervention only; Phase 3 = Delayed intervention.
See Tables 5 and 6 for statistical comparisons of these data.

Table 5. Changes in Sleep Outcome

	Immediate Intervention Group Intervention 1 minus Baseline 1	Delayed Intervention Group Baseline 2 minus Baseline 1	Intervention 2 minus Baseline 2
Percent sleep	0.020	<0.001	0.644
Average peak sleep	0.001	0.015	0.404
Average sleep duration	0.014	0.150	0.143

Values are *P* values for one-sided paired *t* tests; data are shown in Table 4.

Table 6. Comparisons of Mean Values for Sleep Outcomes

	Phase 1	Phase 2
Percent sleep	0.620	0.656
Average peak sleep	0.872	0.495
Average sleep duration	0.639	0.513

Values are *P* values independent of sample *t* tests. Data are shown in Table 4. All comparisons are between intervention and control groups within each phase for each of the three sleep outcome measures. Phase 1 is Baseline and Phase 2 is immediate intervention.

sleep or average duration of sleep for any 1 hour. Using discrete 60-minute intervals meant that both of these latter sleep outcome measures would be arbitrarily truncated by cutting off the analysis at 60 minutes. For example, if a resident was asleep from 8:50 p.m. to 9:00 p.m., peak sleep might be counted as 10 minutes even though that resident might have continued to sleep into the next hourly period.

There was a correlation ($r = .29$, $P < .001$) across all homes between absolute change in noise and change in percent sleep from baseline (Phase 1) to intervention (Phase 2). When these data are considered on an hourly basis, there are significant negative correlations between noise reduction and changes in sleep for all hours except 7:00 p.m. ($r = -.14$), 8:00 p.m. ($r = -.08$), and 4:00 a.m. ($r = -.11$). The correlations for the remaining hours were as follows: 9:00 p.m. ($r = -.19$ $P < .01$), 10:00 p.m. ($r = -.31$ $P < .001$), 11:00 p.m. ($r = -.23$ $P < .01$), 12:00 a.m. ($r = -.31$ $P < .01$), 1:00 a.m. ($r = -.33$ $P < .001$), 2:00 a.m. ($r = -.24$ $P < .001$), and 3:00 a.m. ($r = -.26$ $P < .001$).

DISCUSSION

Our intervention resulted in statistically significant changes in two environmental variables known to be associated with awakening events (e.g., noise and light). However, these changes did not result in significant improvements in night or day sleep measures. We believe that a combination of factors explains these results.

First, the intervention probably did not reduce noise to sufficiently low levels. Noise levels above 50 dBs were reduced during the intervention phase by an average of approximately 18 2-minute intervals per night per resident. However, even during the intervention phase, an average of 54 2-minute intervals with peak sounds above 50 dBs were recorded, and there were no hours during the night in any NH that were characterized by zero noises recorded above 50 dBs. In short, no NH in this study could be characterized as "quiet" during any phase of the study despite our best efforts with a behaviorally focused intervention. Perhaps this is the reason that the analysis of the waking events revealed that awakenings associated with noise did not decrease during the intervention period, but awakenings associated with incontinence care (noise plus light and light changes) did decrease significantly during this period for both groups. Since research staff implemented the individualized incontinence care routines, we had more control over these noise plus light and light variables than general noise levels. The noise and light combinations associated with nursing care patterns explain only 11 to 16% of the baseline awakening events for the immediate and delayed intervention groups, respectively. For this reason, the very large reductions in these environmental causes of sleep disruption were not sufficient to improve overall sleep measures. Inasmuch as there were significant correlations between noise/light changes and awakening events, as well as noise reduction and sleep improvement percentages, it is difficult to believe on either an intuitive or an empirical basis that noise reduction is not related causally to sleep outcomes. The more compelling argument is that noise must be reduced even further than those levels produced by our intervention. It is also possible that we did not significantly reduce the sources of noise that are known to be particularly disruptive to sleep. There is evidence that noise parameters other than those measured and assessed in this trial are associated with sleep disturbance.[17]

Supplementing our behavioral intervention with environmental interventions that reduce noise further and improving the sensitivity of noise and sleep measurement will further explicate the relationship between noise and sleep. In this regard, we have collected preliminary data that suggest that the physical environment of the NH can be retrofitted cost effectively to reduce the intensity of noises transmitted throughout the NH. As a result of these data, we believe it is possible, using a combined behavioral/environmental intervention, to reduce noise below the levels reported in this study.[16]

A second factor affecting our results is that our intervention did not address all behaviors known to be associated with poor night sleep. A high frequency of napping, low physical activity, low exposure to bright light, and long periods of time in bed are associated with poor night sleep.[4] We reported in this study that residents spent long periods of time in bed and were observed sleeping frequently during the day. We have reported in other studies that residents show extremely low physical activity levels during the day, and others have reported that NH residents are not adequately exposed to bright light.[18,19] In consideration of all these behavioral and environmental factors, we believe that it may be necessary to implement a combined behavioral/environ-

mental intervention over the entire 24-hour period. This intervention should be designed to address both nighttime noise and the behavioral factors listed above in order to improve NH residents' sleep. Such an intervention should also be designed to be consistent with residents' preferences for daily care.[5]

The third factor influencing our results is that we may not have measured sleep with sufficient precision to detect intervention effects, nor did we control for medical factors that might limit the effectiveness of our intervention. Polysomnography is regarded as a gold standard measure of sleep even though its validity and usefulness in a demented NH population has been questioned.[13] Despite technical problems that will certainly limit its general applicability for NH residents, polysomnography, combined with technology to measure respiratory disturbance and periodic leg movements, could provide important information that we did not obtain in the current study. For example, one would expect that the significant reductions in noise produced in this study might have reduced transient arousals in at least that subgroup of residents who did not have frequent apnea episodes. Our behavioral observations of sleep and apnea, as well as the wrist activity measures of sleep, did not permit measurement of sleep stages or transient arousals and, very likely, underestimated the severity of respiratory-caused sleep disturbance. We very likely also underestimated awakenings since studies using polysomnography have reported 20 to 31 awakenings per night in similar subjects.[20,21] We did not covary our analyses on apnea data because the behavioral observations of apnea that we collected did not correlate significantly with any sleep outcome measure. Using more invasive but precise technologies to measure sleep and apnea for at least that portion of residents who will tolerate such measurement may provide important information about the effects of behavioral and environmental interventions. Similarly, it is known that there are age-associated changes in sleep as well as changes produced by dementia, and it is unknown if these changes are reversible. It is very possible that behavioral and environmental interventions will have a very limited impact on sleep in many extremely old and/or demented nursing home residents.

Despite our inability to document clinically significant improvements in sleep in this trial, we believe that NH providers should educate their staff about the importance of sleep and noise for health and quality of life outcomes among NH residents and consider implementing noise abatement protocols. There is evidence that high levels of noise has generalized, deleterious effects on health, and it is intuitively obvious that residents would have better life quality if they were not awakened frequently by care practices and high noise levels, even if their sleep does not objectively improve.[7] The fact that most of the noises identified in this trial are under the control of the staff (i.e., an estimated 58%) makes it even more compelling to implement staff educational programs.[5] We were very surprised in this study to find how difficult it was to solicit cooperation from staff with relatively minor requests to be quiet. We can only assume that NH staff did not fully appreciate the impact of noise on residents' sleep. The interview data that we report suggest that staff believe, or at least acquiesce to, the concept that sleep is important to residents and that noise disrupts sleep. However, the connection between this belief and staff behavior is tenuous, and we believe that more intensive staff training and feedback models than those tested in this study will have to be developed. One improvement might be to identify what noise abatement protocols nursing staff would find acceptable before implementing interventions. A second would be to illustrate noise episodes to staff more concretely. In this project, noise frequency was illustrated graphically, and it is our impression that nursing home staff disassociated their own behavior from these abstract data. Playing taped sounds of noise experienced by residents, including those noises generated by nursing home staff, might be a more effective educational procedure. However, a prerequisite to making any noise abatement intervention successful will have to involve increasing awareness among NH leadership of the need for noise abatement and sleep enhancement policies. The absence of such written policies in all eight of the NHs involved in this trial reflects the fact that this awareness does not currently exist. Future efforts to improve the results reported in this study should start with the articulation of noise abatement and sleep enhancement policies to which all levels of NH staff contribute.

REFERENCES

1. Ancoli-Israel S, Parker L, Sinaee R et al. Sleep fragmentation in residents from a nursing home. J Gerontol 1989;44:M18–21.
2. Bliwise DL, Bevier WC, Bliwise NG et al. Systematic 24-hour behavioral observations of sleep and wakefulness in a skilled-care nursing facility. Psychol Aging 1990;5:16–24.
3. Bliwise DL, Carroll JS, Dement WC. Predictors of observed sleep/wakefulness in residents in long-term care. J Gerontol Med Sci 1990;45:M126–130.
4. National Institutes of Health Consensus Development Conference Statement. The treatment of sleep disorders of older people. Assoc Prof Sleep Soc 1990; 5:16–24.
5. Schnelle JF, Cruise PA, Alessi CA et al. Sleep hygiene in physically dependent nursing home residents: Behavioral and environmental intervention implications. Sleep 1998;21:515–523.
6. Schnelle JF, Ouslander JG, Simmons SF et al. The nighttime environment, incontinence care, and sleep disruption in nursing homes. J Am Geriatr Soc 1993;41:910–914.
7. Grumet GW. Pandemonium in the modern hospital. N Engl J Med 1993; 328:433–437.
8. Cruise PA, Schnelle JF, Alessi CA, Ouslander JG. The nighttime environment and incontinence care practices in nursing homes. J Am Geriatr Soc 1998;46: 181–186.
9. Schnelle JW, Cruise PA, Alessi CA et al. Individualizing nighttime incontinence care in nursing home residents. Nurs Res 1998;47:1–8.
10. Folstein MF, Folstein SE, McHugh PR. "Mini-Mental State": A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198.
11. Schnelle JF, MacRae PG, Ouslander JG et al. Functional incidental training, mobility performance, and incontinence care with nursing home residents. J Am Geriatr Soc 1995;43:1356–1362.
12. Cohen-Mansfield S, Waldhorn R, Werner P, Billig N. Validation of sleep observations in a nursing home. Sleep 1990;13:512–525.
13. Ancoli-Israel S, Clopton P, Klauber MR et al. Use of wrist activity for monitoring sleep/wake in demented nursing-home patients. Sleep 1997;20:24–27.
14. Mullaney DJ, Kripke DF, Messin S. Wrist-actigraph estimation of sleep time. Sleep 1980;3:83–92.
15. Ouslander JG, Buxton WG, Al-Samarrai NR et al. Nighttime urinary incontinence and sleep disruption among nursing home residents. J Am Geriatr Soc 1998;46:563–566.
16. Ahuja K, Funk R, Hso J et al. Noise in nursing homes: A pilot study presented at the annual meeting of the American Medical Directors Association, San Antonio, TX, March 1998.
17. Pearsons KS, Barber DS, Tabachnick BG, Fidell S. Predicting noise induced sleep disturbance. J Acoust Soc Am 1995;87:331–338.
18. Alessi CA, Schnelle JF, MacRae PG et al. Does physical activity improve sleep in impaired nursing home residents? J Am Geriatr Soc 1995;43:1098–1102.
19. Ancoli-Israel S, Clopton P, Klauber MR et al. Variations in circadian rhythms of activity, sleep and light exposure related to dementia in nursing home patients. Sleep 1997;20:18–23.
20. Prinz PN, Vitaliano P, Vitiello MN et al. Sleep, EEG and mental function changes in senile dementia of the Alzheimer type. Neurobiol Aging 1982;3: 361–370.
21. Allen SR, Seiler WO, Stahelin HB, Spiegel R. Seventy-two hour polygraphic and behavioral recordings of wakefulness and sleep in a hospital geriatric unit: Comparison between demented and non-demented patients. Sleep 1987;10:143–159.