Eskaton Circadian Lighting Project

Sacramento Municipal Utility District

SMUD™

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1. Executive Summary

1.1 Introduction

During the last ten years, the lighting industry has undergone tremendous changes. LEDs and wireless controls have completely disrupted the industry and have opened up exciting new opportunities for energy savings, data collection and even possible health benefits.

Research conducted by the Lighting Research Center (LRC), part of the Rensselaer Polytechnic Institute, DOE and others has shown that lighting affects our circadian rhythms, and consequently may have significant impacts upon our health. Specifically the spectrum and the intensity of the light source, as well was the duration and timing of the exposure affect our sleep patterns.

It is also a well-established fact that seniors have special lighting requirements. For example: a healthy, 70 year old person needs up to 80% more light than a healthy 20 year old, yet they are much more sensitive to glare—especially at night. These requirements pose quite a challenge for creating high quality lighting systems for seniors. It's also no secret that the population in the United States is rapidly growing older:

> *The US Census Bureau estimates that 46 million people living in the US in 2014 were age 65 or older; that number is projected to increase to 98 million by 2060, representing 24% of the US population at that time. This aging population almost certainly will require more healthcare facilities, with an expected corresponding increase in electricity use for lighting these facilities.*
>
> Dr. Robert Davis
> Pacific Northwest National Laboratory

In response to this growth, many corporations are planning to build new care facilities or expand their existing ones. The good news is that circadian lighting research is picking up considerable momentum. Efforts by the Lighting Research Center and tremendous advances in LED and controls technology promise exciting new opportunities to improve the quality of life for seniors.

Recently, several manufacturers introduced tunable-white LED screw-in lamps (aka light bulbs) with wireless communication. During 2016, SMUD worked with Eskaton to test tunable-white LED lighting for seniors who reside at Monroe Lodge, one of Eskaton's independent living facilities. The main objective of this project was to gain a better understanding of how these products work and identify potential benefits for Eskaton's residents.

Eskaton chose to use Stack Lighting's LED light bulbs. These light bulbs offer several interesting features and communicate via a wireless network.

About Eskaton

Founded in 1968, Eskaton is now the largest nonprofit community-based organization serving seniors in the Greater Sacramento area. Eskaton's dedicated team members provide services and support for nearly 12,000 individuals annually who live in our communities or participate in their comprehensive Home Support Services. Eskaton's difference lies in their broad array of choices and affordable options to engage and support people living in their own homes, as well as those who choose to live in one of our communities.

Eskaton's primary mission is to enhance the quality of life of seniors through innovative health, housing and social services.

1.2 Project Objectives

The primary purpose of this project was to assess the potential benefits and challenges for using tunable-white LED lighting for seniors living at Eskaton's Monroe Lodge. Specific objectives for this project included answering the following research questions:

1. What are the performance characteristics of Stack's technology? What are the potential energy savings?

2. How well does Stack's technology integrate with current infrastructure? How easy is it to install the lamps, wireless switches and the hub? What are some potential obstacles? What problems need to be resolved?

3. How easy are the controls to use? What information do the residents need to fully use the technology? How well do they understand the technology?

4. How satisfied are the residents with the Stack bulbs and controls? What are the potential non-energy benefits associated with using this technology? For example, did the residents experience any improvements in their sleep patterns? Did the Stack system help reduce the number of falls?

5. What are the market barriers to the use of this technology?

1.3 Project Results

This project included lighting upgrades for 13 apartments and was organized into three major phases:

1. Original lighting system
2. New floor lamps, table lamps and lighting fixtures with standard LED bulbs
3. New floor lamps, table lamps and lighting fixtures with Stack LED bulbs

During each phase, the project team visited the apartments to obtain illumination measurements and interview the residents. The project team also recorded the number, types and wattages of the light bulbs for each of the three scenarios. Although the overall results of this project were favorable, the team encountered several significant challenges. Below is a high-level summary of the project results.

Energy Savings

Unfortunately, the sheer number of LED light bulbs, the configuration of the electrical wiring for the apartments, and frequent programming changes for the Stack lighting system made monitoring actual energy consumption extremely problematic. Consequently, the team chose to compare the total connected load (i.e. total Watts) for the three different scenarios. The results are shown in Figure 1 below.

Connected Lighting Load	Total W	Ave./Apt	Savings
Scenario			
Original Lighting	4,978	383	n/a
New Fixtures + LED Light Bulbs	3,110	239	38%
New Fixtures + Stack Light Bulbs	3,976	306	20%

Figure 1: Connected lighting load for the three different lighting systems.

Observations

- The average connected lighting load (i.e. Watts) for the Stack system was around 20% lower than the original lighting system. This is impressive since the project team had to add so many additional floor and table lamps to provide adequate illumination levels.

- The average connected lighting load (i.e. Watts) for the Stack system was around 28% higher than the LED baseline. This is primarily due to Stack's embedded wireless communication capabilities. The Stack A19 bulbs consume

11 Watts and the BR30 bulbs consume 13 Watts, compared to 9.5 Watts per bulb for the standard LEDs.

- The calculated connected lighting load for the Stack bulbs shown above does not account for Stack's ambient light sensing feature. When enabled, this feature automatically dims the bulbs when daylight is present. However, the project team chose to disable this feature because some of the residents complained about their bulbs not reaching full brightness and the project team wanted to maximize circadian stimulus.

SMUD Surveys

Residents who participated in this study were interviewed and asked to answer eleven questions about their lighting and sleep habits. They were asked the same questions for all three lighting scenarios. Overall, the residents were very pleased with their new lighting and the standard LED light bulbs. The results were also favorable for the Stack system, but some programming issues adversely affected the results. For more detailed information, please refer to the Project Results section of this report.

Eskaton Surveys

In addition to the SMUD Surveys, the participating residents were asked ten questions regarding their sleeping habits, history of falls, perceived energy levels and overall quality of life. These surveys provided a lot of valuable insights regarding the behavioral effects of Stack's lighting system.

Sleep Patterns and Nighttime Safety Observations

The data for this study shows mixed results. On one hand, the residents reported the following improvements[1]:

- 22% reduction in the amount of time needed to fall asleep
- 27% reduction in daytime drowsiness
- 45% improvement in perceived energy levels
- 72% improvement in daytime activity levels

"These new lights make me feel so much happier—this has been a great opportunity for the residents." Project Participant

[1] For more detailed information, please refer to the Project Results section of this report.

On the other hand, there were no overall reported changes in the number of times that the residents woke up each night, or the number of reported falls during this study. Most of the residents who participated in the project routinely wake up several times at night to visit the bathroom due to medical reasons. Because of this, it is uncertain if changes in lighting would affect their sleeping habits. However, the fact that 93% of the residents reported getting out of bed at least once per night (Figure 2), underscores the need to provide adequate lighting for nighttime navigation.

Although almost all of the surveyed residents expressed concerns about falling, there were no reported falls at any time during this study. Since Monroe Lodge is designed to be an independent living facility, residents who are identified as high-risk for falling usually move to a facility that offers higher levels of care.

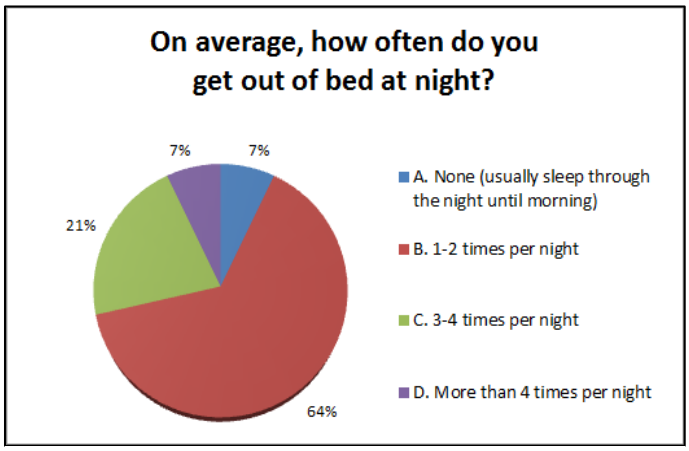


Figure 2: 93% of the residents reported getting out of bed at least once per night. This underscores the need to provide adequate lighting for nighttime navigation.

1.4 Acknowledgements

While many people contributed to the success of this project, we particularly appreciate the cooperation and help from the following individuals:

- Tristin Benjamin (Eskaton)
- Therese ten Brinke (Eskaton)
- Sara Montgomery (Eskaton)
- Scott Okamoto (Eskaton)
- Mike Spitale (Eskaton)
- Participating residents at Eskaton Monroe Lodge
- Neil Joseph (Stack Lighting)
- Chris Leader (Stack Lighting)
- Kassandra Gonzales (Lighting Research Center)
- Desiree Burk (SMUD)
- Michael Burns (SMUD)
- Mary Clement (SMUD)
- Jennifer Garcia (SMUD)
- Connie Samla (SMUD)

2. Project Description

2.1 Background

Lighting Challenges for Senior Care Environments

Providing proper lighting for senior care environments can be very challenging. As we grow older, we need a lot more light, yet are much more sensitive to glare (Figure 3). It also takes much longer for our eyes to adapt from bright to dark environments[2]. Consequently, many falls occur while returning to bed after using restrooms at night. And, if all of these factors were not enough of a challenge, seniors often suffer from eye diseases such as cataracts, glaucoma, age-related macular degeneration and diabetic retinopathy.

Lighting and Health: The Basics

Studies conducted by the Lighting Research Center (LRC) of the Rensselaer Polytechnic Institute (Troy, New York) and others indicate that different spectrums (i.e. wavelengths) of light can affect production of certain chemicals such as melatonin. Since melatonin causes us to feel drowsy, it is important to produce adequate levels for maintaining healthy sleep cycles.

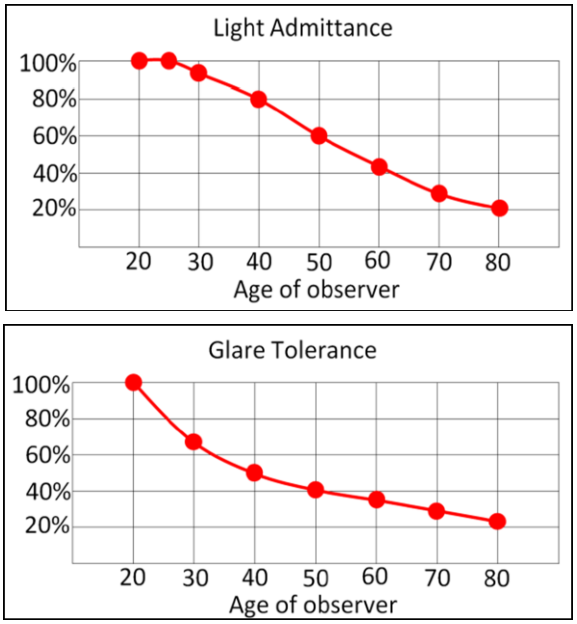


Figure 3: Providing proper lighting for seniors can be very challenging. Seniors need much more light (top graph) yet are much more sensitive to glare (bottom graph).

Many factors can affect sleep and much more research needs to be done to fully understand how lighting affects our health. However, at least four important factors have been identified:

1. Spectral content of the light source
2. Intensity level of the light source
3. Duration of exposure
4. Timing of the exposure

[2] ANSI/IESNA RP-28-16

Although the actual science is rather complicated and filled with important details, the Lighting Research Center currently recommends using lighting with more blue content at higher levels during waking hours and warmer sources at lower illumination levels during the evening hours. The LRC has developed a tool to help quantify the Circadian Stimulus (CS) for lighting applications[3]. The tool is based upon extensive testing and requires the following inputs:

- Illumination levels: the amount of light on various surfaces, typically measured in footcandles or lux. Since the CS tool is based upon the amount of lux entering the eye, vertical illumination measurements (or calculations) must be used.

- Correlated Color Temperature (CCT): basically the appearance (i.e. warmth or coolness) of the light source measured in Kelvin. Although CCT may be used to provide a rough calculation, more accurate calculations require obtaining the spectral power distribution for the light source being used.

- Spectral Power Distribution (SPD): light sources produce different wavelengths within the visible light spectrum. It is common practice in the lighting industry to measure and display these characteristics in a SPD graph (Figure 4). It is important to know the SPD since specific wavelengths of light can trigger different chemical responses within people and other living organisms.

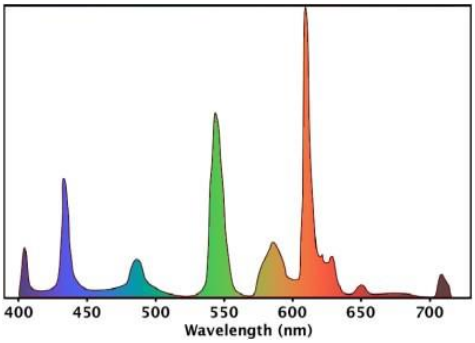


Figure 4: Light sources produce varying amounts of light in different wavelengths. Labs often measure and describe these traits by using Spectral Power Distribution (SPD) graphs.

LRC's tool assumes one hour of exposure time. LRC's Health Institute recommends the following for seniors:

- Circadian Stimulus (CS) values of at least 0.3-0.4 for at least two hours from 8:00 a.m. to 12 noon. (Figure 5)

- CS values of 0.2 to 0.15 between the hours of 12 noon and 6 p.m.

- At night, CS values of less than 0.06 (while awake)

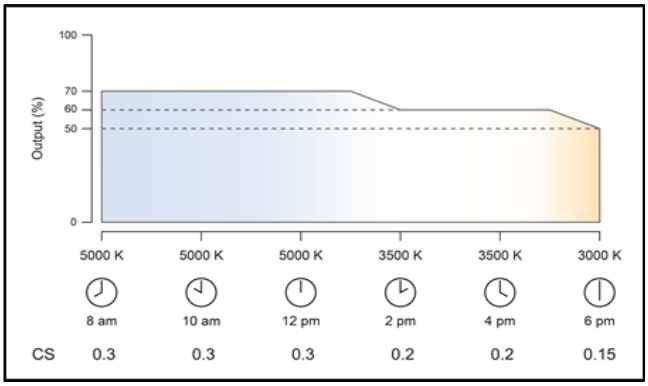


Figure 5: The Lighting Research Center (LRC) recommends varying the amount of circadian stimulus (CS) for seniors during different times of the day.

[3] For more information, please visit the Lighting Research Center website: http://www.lrc.rpi.edu/

In residential applications, CS values are often affected by the color of walls, the size and color of lamp shades and many other factors. The CS values for this project were calculated and adjusted based upon site measurements. For more information, please refer to the Project Results section of this report.

2.2 Project Overview

This project included thirteen apartments and was organized into three phases that included a total of six steps:

Phase 1: Original Lighting

1. Lighting Design. During this step, the project team reviewed various options including different types of floor lamps, table lamps, vanity fixtures, dining room fixtures and night lighting options. The team obtained samples and scheduled a presentation for Eskaton's residents.

2. Recruitment. Once the samples were obtained, the project team provided a presentation to the residents which included an overview of circadian principles and information about the project itself. Immediately following the presentation, 15 residents (13 apartments) signed up to participate in the project.

3. Lighting Audits. During this step, the project team visited each apartment to assess the lighting and interview the residents. The team obtained illumination measurements and recorded the location, number, type and wattage of the light bulbs that were being used. The team discovered numerous lighting problems including low illumination levels, damaged cords, exposed light bulbs and a computer screen in a bedroom that was left on all night (Figure 6). The team also worked with residents to:

    - Identify areas where more light was needed
    - Select new floor and table lamps
    - Choose locations for the new wireless switches
    - Identify the number of bed lights needed
    - Determine which dining area fixtures needed to be replaced

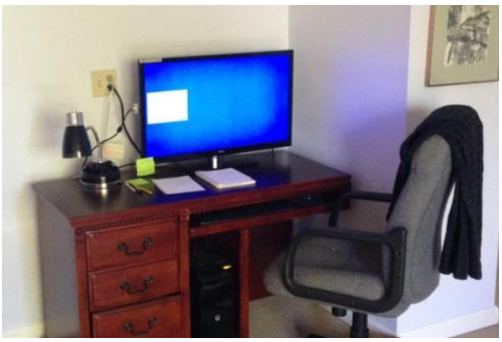


Figure 6: During this step, the project team discovered numerous lighting problems including low illumination levels, damaged cords, exposed light bulbs and this computer screen in a bedroom that was left on all night.

Phase 2: New Lamps and Fixtures with Standard LED Light Bulbs

4. New Lighting Installation. Providing proper lighting for the residents required adding new floor lamps, table lamps, and replacing the fixtures in the dining rooms, bathrooms, and some kitchens (Figure 7). This step also included installing motion-activated LED lights under the beds (Figure 8).

   In order to establish a clean baseline for the next phase (circadian lighting), the team installed standard (i.e. non-tunable) LED light bulbs in all of the fixtures. The lumen output of these LED light bulbs was comparable to the rated output of the Stack bulbs.

   The residents agreed to have Eskaton store their original floor and table lamps until the end of the study period. Residents were given the option to keep the new lights or have their old ones returned to them at the end of the project.

Figure 7: Providing proper lighting for the residents required adding new floor lamps, table lamps, and replacing the fixtures in the dining rooms, bathrooms, and some kitchens.

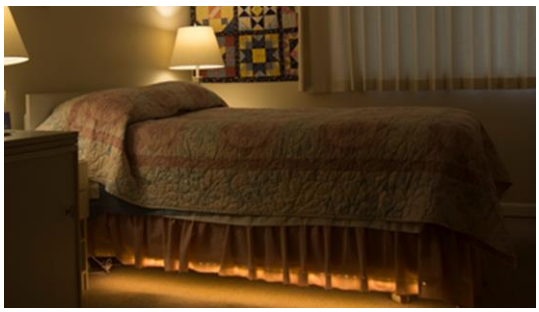


Figure 8: The project team installed motion activated LED lights under each of the beds included in the study.

Phase 3: New Lamps and Fixtures with Stack LED Bulbs and Wireless Controls

5. Circadian Lighting. Around thirty days after the new lights were installed, the team obtained illumination measurements and surveyed the residents once again. After the surveys were completed, the standard LED bulbs were replaced with Stack's tunable-white LED light bulbs (Figure 9). The project team also installed several wall-mounted wireless switches.

Figure 9: Tunable-white LED light bulbs from Stack Lighting.

During waking hours, the Stack bulbs were programmed to automatically change the kelvin temperatures from 5000K to 2200K as shown in Figure 10.

The Stack bulbs were programmed with smartphones using Stack's free software app. The current version of the Stack system requires using a wireless hub with a hard-wired connection to a router. Overall the system was easy to use, although there were some connectivity issues during the early stages of the project. Fortunately, these problems were solved by changing some of the programming.

The team also developed a very innovative night-time navigation mode (aka Nightlight feature). When residents push the "sleep" button (Figure 11), all of the lights in their apartment turn off. When they get out of bed, the Stack light bulbs sense their movements and automatically turn on at very low levels (around 5% of maximum). The Nightlight feature may be overridden by using wireless wall switches like the one shown in Figure 12. When the residents hit the "wake button" in the morning, the Stack bulbs resume operation in the circadian lighting mode.

Figure 10: During waking hours, the Stack lamps were programmed to automatically change kelvin temperatures from 5000K to 2200K as shown above.

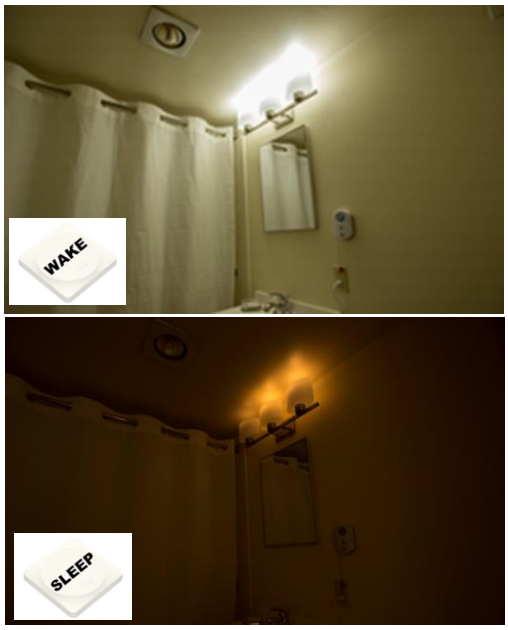


Figure 11: The project team developed a very innovative night-time navigation mode (aka Nightlight feature). When residents push the "sleep" button, all of the lights in their apartment turn off. If they get out of bed, the Stack lamps sense their movements and automatically turn on at very low levels.

6. Final Visits. After the residents had used the Stack light bulbs and wireless controls for 30 days, the project team once again visited the apartments to conduct the final surveys and obtain illumination measurements. Measurements for all three CCT settings were obtained for some, but not all, of the apartments.

Figure 12: The Nightlight feature may be overridden by using wireless wall switches like this one shown above.

3. Project Results

This was the first time that SMUD has undertaken a project of this kind. Although the overall results of this project were favorable, it required a considerable amount of time and effort. Working with so many participants and cutting edge technologies required the team to make several adjustments "on the fly". The project team and participants did a remarkable job of staying flexible along the way.

The following sections include the project results and some key lessons learned. It is our hope that sharing this information will help others interested in conducting similar projects in the future.

3.1 Energy Savings

Unfortunately, the sheer number of LED light bulbs, the configuration of the electrical wiring for the apartments, and frequent programming changes to the Stack lighting system made monitoring actual energy consumption extremely problematic.

Consequently, the information shown below in Figure 13 and subsequent observations based solely upon the total connected load (i.e. total Watts) for the three different lighting scenarios.

Connected Lighting Load	Total W	Ave./Apt	Savings
Scenario			
Original Lighting	4,978	383	n/a
New Fixtures + LED Light Bulbs	3,110	239	38%
New Fixtures + Stack Light Bulbs	3,976	306	20%

Figure 13: Connected lighting load for the three different lighting systems.

Observations

- The average connected lighting load (i.e. Watts) for the Stack system was around 20% lower than the original lighting system. This is impressive since the project team had to add so many additional lamps to provide adequate illumination levels. A total of 23 floor lamps, 12 table lamps, 22 floor can lights and 347 Stack LED light bulbs were purchased for just 13 apartments! Although Stack's A19 bulbs are a good replacement option for 60 Watt incandescent bulbs, seniors need a lot more light. Fortunately, Stack plans to offer bulbs with higher lumen output in the near future.

- The average connected lighting load (i.e. Watts) for the Stack system was around 28% higher than the LED baseline. This is primarily due to Stack's embedded wireless communication capabilities. The Stack A19 bulbs consume 11 Watts and the BR30 bulbs consume 13 Watts, compared to 9.5 Watts per bulb for the standard LEDs.

- The calculated connected lighting load for the Stack bulbs shown above does not account for Stack's ambient light sensing feature. When enabled, this feature automatically dims the bulbs when daylight is present. However, the project team chose to disable this feature because some of the residents complained about their bulbs not reaching full brightness and the project team wanted to maximize circadian stimulus.

- Since the Stack light bulbs include motion detectors and wireless communication, they require power at all times. Although the residents could turn the lights "off" by using their phones or wireless switches, the lamps consumed approximately 0.4 Watts each in the "standby" mode.

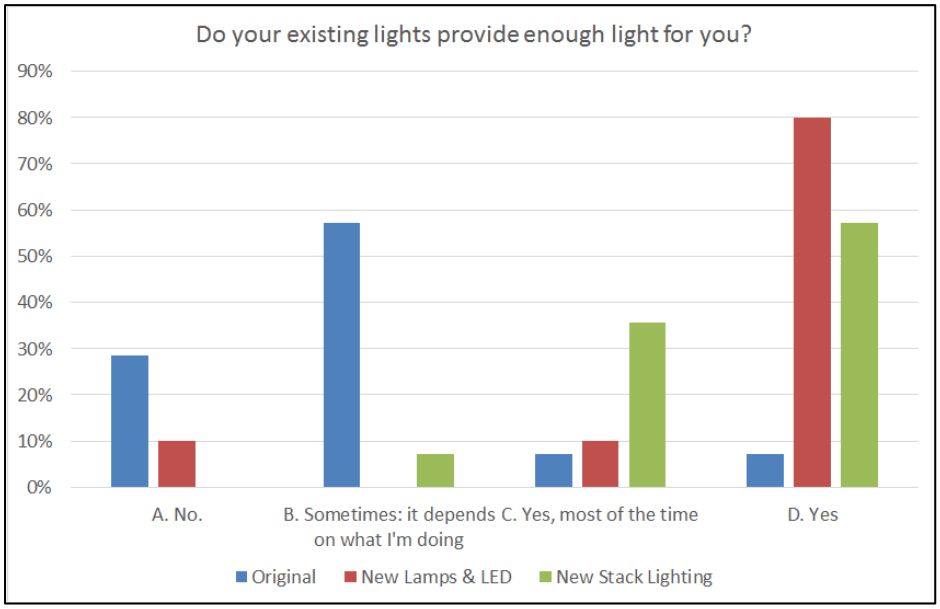
3.2 SMUD Survey Results

Residents who participated in this study were interviewed and asked to answer eleven questions about their lighting and sleep habits[4]. The residents were asked the same questions for three scenarios (1) Their original lighting system; (2) New lamps and fixtures with standard LED bulbs; (3) new lamps and fixtures with Stack LED bulbs.

[4] The survey questions are included in Appendix A of this report.

In addition to the multiple choice questions, residents were encouraged to provide candid feedback about all aspects of the project. Key findings from the surveys are presented below.

- Question: Do your lights provide enough light for you?



- Observations

  - Only 14% of the respondents said that their original lighting was adequate most or all of the time (categories C and D).

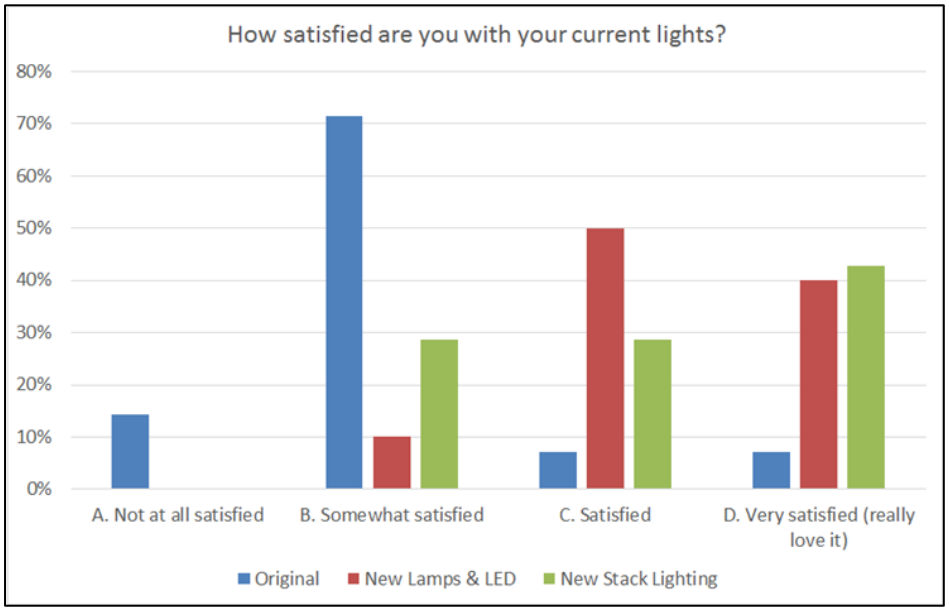
  - 90% of the respondents said that the new fixtures with the standard LED bulbs provided adequate light most or all of the time.

  - 93% of the respondents said that the new fixtures with the Stack LED bulbs provided adequate light most or all of the time. However, the numbers were sharply lower for all of the time (category D). The project team believes this reduction was because the Stack bulbs were originally programmed to automatically dim during the evening hours. Once the team learned that residents preferred higher levels at night, the programming was changed. Since then, no further complaints have been received. However, this change was made after the surveys were completed.

- Generally speaking, illumination levels for the original lighting system were lower than recommended by the Illuminating Engineering Society (IES). In fact, one resident only had 1 foot-candle of illumination at her night stand because her existing table lamp was so inefficient.

- The original light bulbs were a mix of compact fluorescents, incandescent, and a few LEDs. Most of the CFLs had a CCT of 2700K, but some were as high as 5000K.

- Question: How satisfied are you with your current lights?



- Observations

  - Only 14% of the respondents said they were satisfied or very satisfied with their original lighting (categories C and D).

  - 90% of the respondents said they were satisfied or very satisfied with the new fixtures with standard LED bulbs (categories C and D).

  - 71% of the respondents said they were satisfied or very satisfied with the new fixtures with Stack LED bulbs (categories C and D). The project team believes this reduction was due primarily to the Stack bulbs automatically dimming during the evening hours. When the team found out the residents needed more light, the Stack bulbs were reprogrammed. No further complaints were received after this change was made.

- Feedback regarding original lighting:

    - Very dark in this apartment at night”
    - “Not enough light”
    - “I put up with it”
    - “Lights do not provide enough light and are glary. Please help”
    - “Uses parking lot lights and SMUD nightlights”

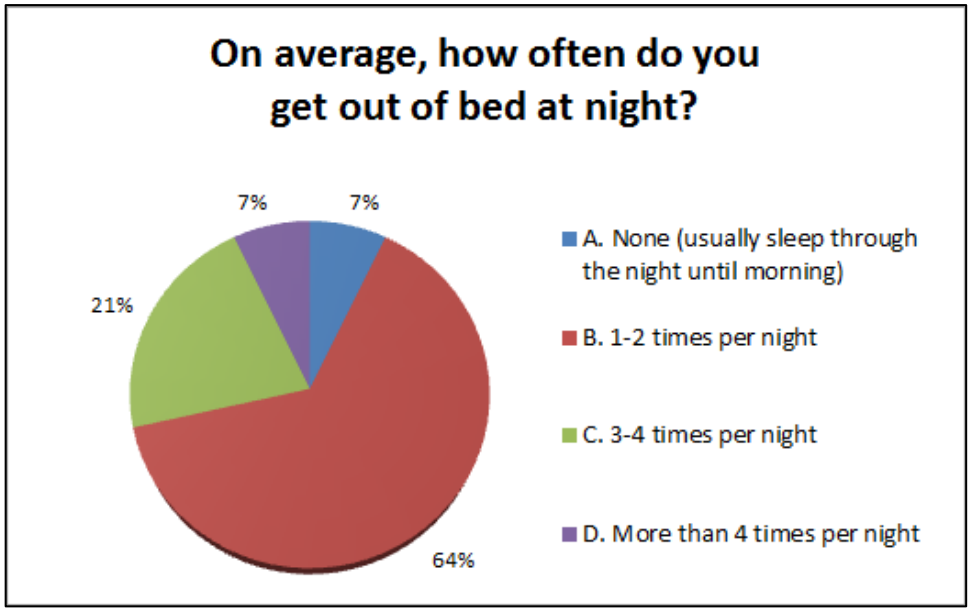
- Feedback regarding new fixtures with standard LED bulbs:

    - “Didn’t have much light before –read easier now”
    - “Lighting before was terrible, I love it and have envious friends”
    - “Don’t need to turn the light on with the bed lights”
    - “Do not turn lights on at night due to the under bed lights, but I didn’t before either”

- Feedback regarding new fixtures with Stack LED bulbs and wireless controls:

    - “Dim in evening, not enough light”
    - “Color tone ok but dims too early”
    - “Significantly better than before”
    - “Makes me happy”
    - “Bulbs too heavy, made the floor lamp tip over”
    - “Good features”
    - “Not sure when we press awake they come on”
    - “Reads on couch but needs new eye glasses”

- Question: On average, how often do you get out of bed at night? Do you typically turn on a light to see where you are going?



- Observations:
    - 93% of the residents get out of bed at least once per night. Almost all of them cited medical conditions. This underscores the importance of providing safe lighting for nighttime navigation to and from the bathroom!
    - Several of the residents said they use amber LED night lights. Most of these lights were given to the residents during a presentation (by SMUD) one year before the study.
    - Overall, there were no discernible changes in the number of times residents woke up during the night.
    - There were no reported falls at any time during this study.

3.3 Eskaton Survey Results

During the project Eskaton developed an additional set of ten survey questions designed to learn more about their residents' sleeping habits, history of falls, perceived energy levels and overall quality of life. These surveys were administered after the new fixtures with standard LED bulbs were installed, and once again after the Stack system was installed. These surveys provided a lot of valuable insights regarding the behavioral effects of Stack's lighting system. The survey questions are included in Appendix B of this report. The residents reported the following improvements:

- 22% reduction in the amount of time needed to fall asleep
- 27% reduction in daytime drowsiness
- 45% improvement in perceived energy levels
- 72% improvement in daytime activity levels

Several residents said they were very excited and thankful for the new lighting. One of them said she "felt so much happier" after the new lights were installed.

3.4 Circadian Stimulus (CS) Values at Eskaton

The project team provided illumination level measurements, information regarding the original lighting and Stack light bulbs to the LRC. Based upon this information, the LRC calculated CS values for the three locations where the residents said they spent most of their time: (1) Favorite sitting place (chair or sofa); (2) Dining area (eating and reading); (3) Bathroom vanity.

Original Lighting (2700K)

Location	Light level	CS value
Sitting place	9 fc	0.09
Dining area	15 fc	0.14
Vanity	95 fc	0.46

Figure 14: Lighting Research Center (LRC) circadian stimulus (CS) calculations for the three areas where the residents said they spent most of their time.

Observations:

- The illumination levels and CS values for the original lighting (Figure 14) were very low except for the bathroom vanity. However, most of the residents in this study spent minimal time in those areas.

The predicted CS values verses the actual conditions for the Stack light bulbs were significantly different (Figure 15). This was because the light reaching the residents was affected by the color of the walls, the type and color of the lamp shades as other factors. The CS values for the areas where the residents spent most of their time (sitting place) were much lower than anticipated.

Predicted New Conditions (with Stack System)

Location	Light level	CS value (average)
Sitting place	36 fc	0.31
Dining area	65 fc	0.41
Vanity	55 fc	0.37

Actual New Conditions (with Stack System)

Location	Light level	CS value (average)
Sitting place	36 fc	0.08
Dining area	65 fc	0.36
Vanity	55 fc	0.38

Figure 15: The predicted CS values verses the actual conditions for the Stack light bulbs were significantly different.

3.5 Sleep Pattern and Safety Observations

Sleep Patterns

The survey data for this project show mixed results. On one hand, some residents reported that it was easier to fall asleep at night, they were less drowsy during the day and they had higher levels of energy. On the other hand, there were no overall reported changes in the number of times that the residents woke up each night. Most of the residents who participated in the project said they routinely wake up several times at night to visit the bathroom due to medical reasons.

Many of the residents at Eskaton's Monroe Lodge are very active: they spend time outdoors walking their dogs, running errands and engaging in other activities. They also spend a considerable amount of time in Eskaton's common areas (e.g. dining room, game room, exercise room). All of these factors make it less likely that changes in lighting would produce radical changes in their sleeping habits.

However, the fact that 93% of the residents reported getting out of bed at least once per night, underscores the need to provide adequate lighting for nighttime navigation.

Falls

Although almost all of the surveyed residents expressed concerns about falling, there were no reported falls anytime during this study. Since Monroe Lodge is designed to be an independent living facility, residents who are identified as high-risk for falling usually move to a facility that offers higher levels of care.

3.6 Lessons Learned

Although this was a very rewarding project, the project team encountered several significant challenges. Fortunately, all of the team members did an outstanding job overcoming these obstacles and making this project successful.

Lighting Challenges

The bedrooms and living room areas were lit by a combination of floor and table lamps which were owned by the residents. Some of these lamps were quite old and in poor condition. During the surveys the project team discovered a few safety hazards including frayed electrical cords, shorted switches, empty sockets, broken CFLs and lamps without shades (Figure 16). The team immediately repaired or removed many of these lights from service. It is important to note that the residents bring their own floor and table lamps when they move in. One of the team members commented that a few residents had "30 year-old lamps with 30-year old bulbs in them."

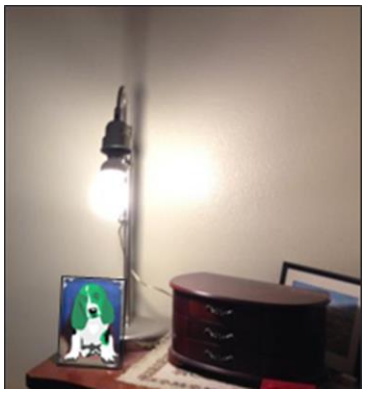


Figure 16: During the surveys the project team discovered (and immediately corrected) a few safety hazards.

Eskaton provides compact fluorescent lamps but some residents chose to buy their own light bulbs, mostly higher wattage incandescents. The CFLs provided by Eskaton had the following characteristics:

- 2700K
- 13 to 19 Watts
- 800 to 1200 lumens

The original lighting presented some significant challenges. First, there were not enough floor and table lamps to provide adequate illumination. Secondly, seniors need a lot of light and most of these fixtures had only one socket. Consequently, most of the residents used higher output bulbs, instead of the 60 Watt incandescent bulbs common to so many other residential applications.

Because the original fixtures only had one socket and Stack's A19 bulbs were only rated for 800 lumens, the team had to purchase several new floor and table lamps with multiple sockets in order to provide adequate illumination. All in all, the team purchased and installed a total of 23 floor lamps, 12 table lamps, 22 floor can lights and 347 Stack LED light bulbs for just 13 apartments! Fortunately, Stack is currently developing a higher lumen variant in order to provide improved lighting for the aging population while reducing implementation costs.

The kitchen, dining area and bathrooms were illuminated by ceiling and wall–mounted light fixtures. Although the Illumination levels in most of these areas were adequate,

some of the original fixtures produced a significant amount of glare. Because of this, the team chose to replace all of the bathroom fixtures and most of the dining area fixtures.

This project provided a valuable lesson: although the Stack LED light bulbs are designed to be used in any fixture with a standard screw-in socket, the original lighting was so inadequate it needed to be replaced. Consequently, engaging in these types of projects requires a considerable amount of time and money. The average cost for the lighting upgrades was $2,500 per apartment (not including labor for the team members). Fortunately, these costs are expected to be much lower in the future.

Bed Lights

The project team chose to use e3Light Group's motion-activated LED lights to provide nighttime navigation (Figure 17). On the positive side, all of the residents said that they really liked the bed lights and that the lights helped them find their way around at night (Figure 18). Furthermore, e3 will soon be launching a Stack Enabled version of their bed light product. Overall, the service provided by the e3Light Group was excellent, but the installer made the following comments about the bed lights:

Figure 17: The project team chose to use e3Light Group's motion-activated LED lights to provide nighttime navigation (http://en.mylight.me/products/).

- Multiple bed styles made installation very time consuming (30 – 45 minutes per bed).

- Better mounting options for the motion sensors and shorter wires are needed. Since most of the beds had metal frames with curved legs, the installer had to use a lot of gorilla tape and zip ties to secure the sensors and manage the cords (Figure 19).

- Sensitivity adjustments and graduations for the timer settings on the sensor housings would make set-up and commissioning much easier.

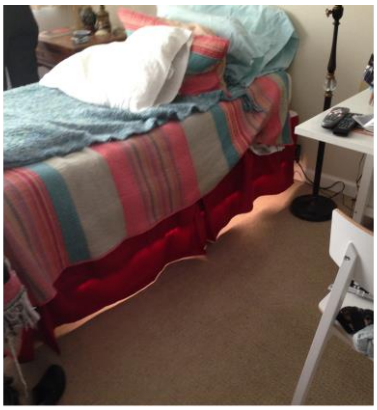


Figure 18: All of the residents said that they really liked e3Llght's LED bed lights.

- Initially many of the residents felt the lights were too bright. Fortunately, the lights had an easy-to-use dimming feature.

- The residents' pets presented an unforeseen challenge: cats and dogs often triggered lights and became tangled in the cords!

The good news is that e3light is working on a commercial grade system that will make installation easier, better secure the sensors and reduce the amount of cables.

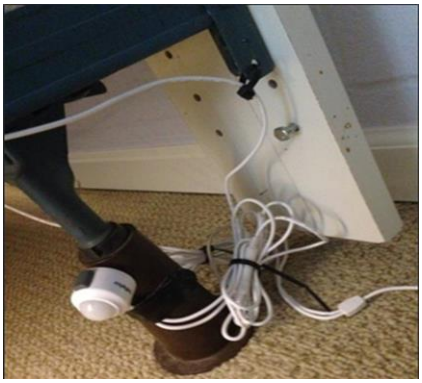


Figure 19: The wires were much too long. The installer had to use multiple zip ties and gorilla tape to manage the cords.

Stack Lighting System

Stack's LED light bulbs are available in both BR30 Downlight and A19 Classic formats (Figure 20), and include a variety of innovative features:

- Tunable-white light (for circadian lighting options)
  - BR Downlight: 2700K to 6500K
  - A19 Classic: 2200K to 5000K

- Rated life of 30,000 hours (L^{70})

- Power consumption:
  - BR Downlight: 13W
  - A19 Classic: 11W

- Efficacy
  - BR Downlight: 57.6 lumens per watt
  - A19 Classic: 72.7 lumens per watt

Figure 20: Stack's LED light bulbs include a variety of innovative features and are available in both BR30 (left side) and A19 (right side) formats.

- Color rendering: 80 CRI

- Dimmable down to less than 1% of maximum

- Wireless communication and easy-to-use programming apps

- Embedded motion sensors turn off the lights when no one is around.

- Embedded ambient light sensors dim the lights when daylight is present.

Providing tunable-white lighting is only part of the story. Since the Stack bulbs include embedded sensors and wireless communication, they may be used to enhance security systems, wellness detection systems and other building management applications. However, there are some downsides to this technology:

- Some residents were surprisingly tech savvy while others were not at all. Consequently, some of them needed a lot of coaching regarding how to use the controls. While some of the residents were comfortable using their smart phones to operate the lights, most wanted physical switches. To address this need, the project team included several wireless switches like the one shown in Figure 21. The tech-savvy residents said the Stack phone app was easy to use.

Figure 21: Since some of the residents wanted physical switches to control the lights the project team included several wireless switches like this one shown above.

- Cost: like most other "smart-light bulbs," the Stack bulbs cost significantly more than standard LED bulbs.

- Light distribution of the A19 Classic bulbs is not truly omnidirectional. This can cause uneven light distribution in fixtures designed for use with omnidirectional bulbs (Figure 22).

Figure 22: As shown above, Stack's A19 Classic LED light bulbs are not truly omnidirectional. This can cause uneven light distribution in lamps designed for use with omnidirectional bulbs.

- Current versions of the Stack A19 Classic bulbs only produce 800 lumens (roughly the equivalent of a 60-Watt incandescent). Although this would be adequate for many residential applications, seniors need more light.

  Consequently, the team had to buy new floor and table lamps with multiple sockets and use multiple Stack bulbs. This significantly increased the cost of the lighting upgrades. Fortunately, Stack is working on a higher lumen version for aging-population applications.

4. Observations and Next Steps

4.1 Observations

The primary purpose of this project was to assess the potential benefits and challenges for using tunable-white LED lighting for seniors living at Eskaton's Monroe Lodge. Overall, the project was a success: the new lighting system provided better lighting, boosted morale and is expected to reduce energy consumption by at least 20%. Additionally, feedback from the participants will help Stack and e3Light improve upon their products.

As discussed earlier, the circadian lighting results for this project were mixed. Although several residents reported less daytime drowsiness and higher energy levels, there were no discernible changes in the number of times the residents reported waking up at night. Since most of them wake up for medical reasons, it is uncertain that changes in lighting would have any positive impact.

There are several key takeaways from this project:

- Since 93% of the residents in this study reported routinely getting out of bed 1-4 times per night, providing adequate lighting for nighttime navigation for all residents should be a high priority. Mounting motion-activated LED lights under the beds and Stack's Nightlight feature proved to be very effective ways to accomplish this task.

- When seniors move into independent living facilities, they usually bring their old table and floor lamps with them. Unfortunately this often results in poor quality lighting. Furthermore, some of these lamps may pose safety hazards from shorted switches, frayed cords etc. As one of the project team members said some residents had "30 year old lamps with 30 year old light bulbs in them." Because of this, SMUD highly recommends that all providers of senior housing conduct lighting audits soon after new residents move in or change apartments. The inspection should check for:

    - Frayed electrical cords
    - Shorted switches or sockets
    - Lamp cords that present tripping hazards
    - Exposed light bulbs (source of glare and possible burn hazard)
    - Floor lamps that tend to tip over too easily
    - Adequate night time lighting for navigating to and from the bathroom
    - Lamps or fixtures that produce glare
    - Areas that are dark or under lit—especially at night
    - Computer screens left on during the night
    - Circadian friendly software such as Apple's Night Shift for iPads and F.lux for personal computers.

4.2 Next Steps

Utility providers (such as SMUD) should continue to provide lighting education and resources for the senior housing industry. Based upon our findings, we believe that significant opportunities exist to improve the safety of seniors while meeting our energy efficiency goals.

SMUD and Eskaton are currently engaged in additional research at Monroe Lodge. The 2017 project will include lighting upgrades for 10 more apartments and many of the common areas used by the residents. Project objectives include:

- Providing feedback to Stack regarding their circadian lighting programming defaults. This includes adjusting the CCT and brightness levels to maximize circadian stimulus and meet the preferences of the residents
- Testing the new Stack Care Analytics platform
- Reducing implementation costs for the apartments. This will include using a higher lumen variant of Stack's bulbs once they have been released.
- Quantifying energy savings for the common areas
- Developing new strategies for assessing the lighting and surveying the residents.

SMUD wishes to thank Eskaton and their residents for participating in the 2016 study. We are looking forward to our 2017 project!

5. Appendix A: SMUD Survey Questions

Survey Questions

Section 1: Lighting

1. Do your existing lights provide enough light for you? What is your typical task at this location?
   a. No
   b. Sometimes: it depends on what I'm doing
   c. Yes, most of the time
   d. Yes

   Comments: _____

2. Do your existing lights produce uncomfortable glare? Which ones?
   a. No
   b. Sometimes: it depends on what I'm doing
   c. Yes, most of the time
   d. Yes

   Comments: _____

3. How satisfied are you with your current lights?
   a. Not at all satisfied
   b. Somewhat satisfied
   c. Satisfied
   d. Very satisfied (really love it)

   Please explain the reason for your answer: _____

4. When you choose light bulbs, what is most important to you?
   a. Price
   b. Light output
   c. Color of light (rendering)
   d. Energy efficiency
   e. Appearance of the bulb (color, shape)
   f. Other (please explain)

   Comments: _____

Section 2: Sleep habits

1. How often do you watch TV, use a computer, an I-pad or tablet just before bedtime?
   a. Never
   b. Hardly ever
   c. Often (2-3 times per week)
   d. Almost every night
   e. Other

   Comments: _____

2. How often do you read just before bedtime?
   a. Never
   b. Hardly ever
   c. Often (2-3 times per week)
   d. Almost every night
   e. Other

   If you read, where do you sit while reading? _____

   Comments: _____

3. On average, how often do you usually wake up at night?
   a. None (usually sleep through the night until morning)
   b. 1-2 times per night
   c. 3-4 times per night
   d. More than 4 times per night

   Comments: _____

4. On average, how often do you get out of bed at night? Do you typically turn a light on to see where you are going?
   a. None (usually sleep through the night until morning)
   b. 1-2 times per night
   c. 3-4 times per night
   d. More than 4 times per night

   Comments: _____

Thank you for participating in this project!

6. Appendix B: Eskaton Survey Questions

Please complete the following questionnaire:

Sleep Scale Modified:

1. Approximately how long does it usually take you to fall asleep?
   a.) 0-15 minutes
   b.) 16-30 minutes
   c.) 31-45 minutes
   d.) 46-60 minutes
   e.) More than 60 minutes

2. What time do you typically wake up?

   Write in the time: _____

3. What time do you typically go to bed?

   Write in the time: _____

4. On average, how many hours did you sleep each night?

   Write in the number: _____

5. How often during the PAST 5 weeks did you…

Question	All the Time-1	Often-2	Sometimes-3	Seldom-4	Never-5
Feel that your sleep was restless					
Get enough sleep to feel rested upon waking up in the morning					
Feel drowsy or sleepy during the day					
Have trouble staying awake during the day					

Functional/Fall Assessment

6. What is your history of falling?
    a. One or more falls within 6 months that resulted in either an injury or doctor visit
    b. One or more falls within 6 months that did not result in injury
    c. One or more slips/trips in the home no injury
    d. None

7. If a fall/slip or trip has occurred what was the reason or reasons for the fall?
    a. Medication
    b. Fatigue
    c. Environment (uneven surface, poor lighting, clutter)
    d. Medical condition (arthritis, muscle weakness, chronic pain, Parkinson's disease)
    e. Other _____

8. Are you concerned about the possibility of falling?
    a. Not at all
    b. Somewhat concerned
    c. Fairly concerned
    d. Very concerned

9. Does your concern about the possibility of falling limit your activities?
    a. Yes
    b. No
    c. Not applicable

Quality of Life Assessment (Modified)

10. Please select the respond that best describes you/your views:

Question	Strongly Agree-1	Agree -2	Neither Agree or Disagree -3	Disagree-4	Strongly Disagree-5
I have a lot of physical energy during the day					
I feel safe where I live					
I get pleasure from my home					
I am healthy enough to have my independence					