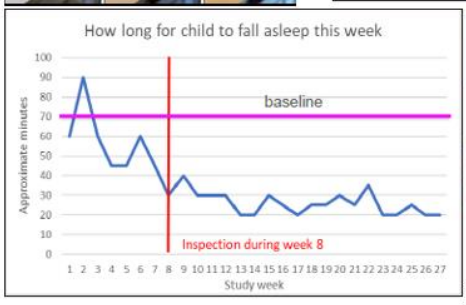
Lighting for the Spectrum

Project Report

Sacramento Municipal Utility District

SMUD™

December 30, 2019



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1. Executive Summary

1.1 Introduction

Sally let out a deep sigh. "Here we go again!" she thought. Last night had been a nightmare: it took over an hour of arguing to get her daughter to finally go to sleep. And, as if that was not enough, her daughter also woke up the entire family twice in the middle of the night. "Is there any hope?" she wondered as she headed down the hallway to her daughter's room. As a parent of a child with Autism Spectrum Disorder (ASD), Sally was definitely not the only one struggling with these issues.

As you can tell, this is not a typical emerging technology report. The focus is not about saving energy, reducing electrical demand or carbon emissions. Instead, it is an account of how circadian lighting techniques have dramatically improved the lives of over two dozen families.

During this past year, SMUD worked to implement lighting improvements for 36 families who have children between the ages of 5-10 years old with ASD. These families installed programmable lighting systems (aka connected lighting) in their homes. The main objective of this project was to determine if circadian lighting could provide tangible benefits by reinforcing daily routines and easing transitions from one activity to another. One of the primary goals was to help children and their parents sleep better. This project was based upon implementing three main principles:

- Use the lighting system to develop and reinforce routines/transitions
- Avoid exposure to blue-white light at night
- Provide lighting for safe nighttime navigation

1.2 Background

Research conducted by the Lighting Research Center[1], the United States Department of Energy (DOE) and others has shown that lighting affects our circadian rhythms, and consequently may have significant impacts upon our health. Specifically, the color spectrum and the intensity of the light source, as well as the duration and timing of the exposure affect our sleep patterns. Studies have also shown that prolonged sleep deprivation can lead to memory deficits, limited attention spans, poorer balance and higher rates of depression and anxiety.

During the past five years, SMUD has worked with our customers to implement five circadian lighting projects[2]:

- ACC Care Center (2015 & 2017)
- Eskaton Monroe Lodge (2017 & 2018)
- Gold Ridge Elementary School (2018)

[1] For more information, please visit the Lighting Research Center website: http://www.lrc.rpi.edu/
[2] To access and download the full reports, please visit: www.smud.org/Circadianlighting

The results of these projects were compelling. Dementia patients experienced less falls and a reduction in nighttime anxiety (ACC). Seniors at an independent living center reported higher daytime energy levels (Eskaton). The teachers at Gold Ridge Elementary School said that it was easier to teach their special education students, and both families who participated in the home lighting improvements experienced very positive results.

While reflecting upon the results of these studies, SMUD researchers noticed a common denominator—the power of routine! Simply stated, the lighting systems provided proper circadian lighting (the right color of light at the right time of day) as well as visual cues that helped people transition from one activity to another. This was especially powerful during the evening hours. Encouraged by these results, SMUD launched the Lighting for the Spectrum project in 2019.

1.3 Project Objectives

The main objective for this project was to answer the following research questions:

- Did the new lighting systems produce any observable behavioral changes in the children with ASD? If so, what?
- Did the new lighting systems help the children sleep better?
- Did the new lighting systems help the parents/guardians sleep better?
- What are the performance characteristics of the technology? How easy was it to install the technology? What obstacles are likely to be encountered? What problems need to be solved?
- How easy is the technology to operate for the customer? What information is necessary for customers to fully use it? How well do customers understand the technology?
- How satisfied are customers with the technology?
- Should SMUD promote the technology on a broader basis? If so, through what programs or channels? Does SMUD need to develop a new program? Should SMUD consider partnering with one or more LED fixture or lamp manufacturers?

These questions were addressed through on-site lighting assessments, baseline questionnaires, 29 weeks of online surveys and face-to-face interviews.

1.4 Results

At the beginning of the study, we asked the participants to complete a baseline survey. We asked them to rank their child for the four categories shown below (Figure 1) and to tell us how long it took (on average) for their child to fall asleep after being put to bed. We also asked them to identify problem areas such as anxiety and meltdowns.

Baseline Ratings	5 (best)	4	3	2	1 (worst)
Child's emotional state		X			
How difficult to get child to bed					X
How difficult to get child out of bed			X		
Ease of activity transitions			X		

Figure 1: All of the families who ranked their children at a 3 or lower for the categories shown above and successfully met the project requirements benefitted significantly from this project.

For the 33 out of 36 families who successfully met the project requirements, the results were fantastic!

- All of the children with ratings of 3 or lower saw improvements in their respective categories.
- 100% of the 8 children with baseline "Emotional State" ratings of 3 or lower saw statistically significant improvements[3].
- 95% of the 19 children with baseline ratings of 3 or lower for the "How difficult to get child to bed" question experienced statistically significant improvements[3].
- 97% of the 30 children with baseline ratings of 3 or lower for the "ease of activity transitions" question saw statistically significant improvements[3].
- 33% of the 33 participants reported dramatic reductions (50% or more) in the amount of time required for their child to fall asleep. 67% of the 33 participants showed a statistically significant decrease[3] from their baseline.
- Several families reported it is now easier to get their child to wake up in the morning and get them ready for school.
- Some families reported reductions in challenging behaviors such as meltdowns, biting and bedwetting.

[3] Based on a statistical confidence level of 90%

- When asked what impact the lighting system had made upon their family, participants provided the responses shown in Figure 2 below.

Answer Given	Meaning	Total
No significant changes	No impact	0
I enjoy the lights, but they are a luxury that I could live without	Low impact	3%
The lights have helped my family somewhat	Moderate impact	20%
The lights have really helped my family	High impact	37%
The lights have changed our lives	Life-changing	40%

77%

Figure 2: When the 33 participants were asked what impact the lighting system had made upon their family, they provided the responses shown above.

At the beginning of this project, SMUD assembled a Steering Committee that included the UC Davis Mind Institute, the Fly Brave Foundation, a special education high school teacher and a wildlife biologist who is on the autism spectrum. These thoughtful individuals provided tremendous insights and gave this project credibility. Here is a quote from the Director of the UC Davis MIND Institute:

> *"I have been very impressed by the commitment of SMUD to helping families who have children with autism. The care with which the study was designed and conducted was exemplary. The findings are very interesting and show the importance of lighting not only to the circadian rhythms of the children but also helping them understand patterns and expectations. The bottom line is that the children are sleeping better, which is likely to lead to fewer behavioral challenges and less stress for all family members!"*
>
> *Leonard Abbeduto, Ph.D.*
> *Director, UC Davis MIND Institute*

1.5 Next steps

It is very important to note that simply delivering lights to these families would not have produced the same results. The success of this project was largely due to the active participation of the parents. Under the guidance of the project team, the parents used the lighting system to develop and encourage new routines and discourage unwanted behaviors.

Our next steps will be focused on education and outreach. We will be working with the UC Davis Mind Institute and others to share the results of this project. We are currently in discussions with Philips regarding ideas for rolling out these solutions to the ASD and Special Needs communities. Ultimately our goal is to provide a helpful tool to families who have children with ASD. Although we believe these techniques could provide benefits to almost everyone, helping families who have children with special needs is a great place to start.

1.6 Acknowledgements

Although many people contributed to this project, we particularly appreciate the cooperation and efforts of:

The families who participated in this study

Project Steering Committee Members

- Dr. Leonard Abbeduto (UC Davis MIND Institute)
- Vanessa Bieker (FlyBrave Foundation)
- Sarah Foster (Wildlife Biologist, ASD Advocate)
- Elizabeth McBride (UC Davis MIND Institute)
- Aaron McClatchy (Luther Burbank High School)

Cadmus (SMUD Consultant)

- David Ladd
- Sepideh Shahinfard

SMUD Staff

- Dave Bisbee
- Susan Corbelli
- Zoey Giammona (Intern)
- Connie Samla
- Tommy Turk
- Lynne Valdez

2. Project Description

2.1 Project Scope

This project explored the potential benefits (i.e. improved sleep cycles) for installing circadian lighting systems in the homes of 36 families who have children with ASD. Ultimately, 33 of the 36 families successfully met the project requirements. To maximize our effectiveness, SMUD worked with the UC Davis Mind Institute and local ASD support agencies to obtain participants and conduct outreach. Each of the participating families received:

- Lighting education (i.e. workshop, consultations)
- In-home lighting assessments
- Energy audits
- Philips Hue lighting systems worth up to $1,500
- Technical support from SMUD

Project participants were required to complete a baseline questionnaire, 29 online weekly surveys and an interview with SMUD staff at the end of the project. The survey and interview questions have been included in the appendix section of this report. Participants were also responsible for installing and programming the lights. The major project milestones and schedule are shown in Figure 3 below.

Project Milestone	Time Frame	
	Start	End
1. Project Development & Approval	6/1/18	7/16/18
2. Assemble Project Team & Steering Committee	7/16/18	9/14/18
3. Develop Evaluation Strategies	9/14/18	12/3/18
4. Recruit Participants (SMUD Workshop)	12/3/18	2/1/19
5. Select participants	2/4/19	2/4/19
6. Execute contracts	2/4/19	3/1/19
7. Complete baseline surveys	3/1/19	3/15/19
8. Complete weekly surveys (evaluation period)	3/3/19	9/29/19
9. Complete In-Home Assessments	3/4/19	4/5/19
10. Lighting Systems Installed & Inspected	4/5/19	5/15/19
11.Complete Final Interviews	9/30/19	10/31/19
12. Complete Draft Report	11/1/19	12/16/19
13. Complete & Publish Final Report	12/16/19	12/30/19
14. Project Closeout	12/30/19	1/15/20

Figure 3: Major milestones for the Lighting for the Spectrum Project

2.2 Baseline Conditions

Lighting Systems

The project team conducted on-site lighting assessments for each of the participating families. During these site visits the team worked with the parents to develop tailored lighting strategies. The project included a variety of single-family homes and two apartments. The original lighting systems (Figure 4) varied widely and included:

- Daylight color (5000K) light bulbs in children's bedrooms and bathrooms
- Homes with lots of windows and abundant daylighting
- Homes with few windows and low illumination levels
- Many ceiling fans with light kits
- A lot of exposed lamps (glare problem)
- Pin-based compact fluorescent lamps (CFLs) with magnetic ballasts
- Various types of dimmers

Figure 4: The original lighting systems varied widely and presented some technical challenges for the project team.

Since the Hue system is primarily based upon light bulbs with screw-in sockets, we were unable to install it in fixtures that had sockets designed for pin-base CFLs. The fact that the Hue system is not compatible with wall dimmers also created some challenges.

Observed Behaviors

Before the lighting systems were installed, the parents reported a variety of issues and challenging behaviors (Figure 5) including:

- Excessive use of iPads, tablets and smart phones
- Fear of the dark
- Anxiety
- Bedwetting

- Sleeping with parents
- Nightly battles about going to bed
- Difficulty getting out of bed
- Difficulty transitioning between activities
- Sensitivity to glare
- Audible outbursts
- Meltdowns and physical outbursts

Figure 5: Nightly battles about bedtime, fear of the dark, sensitivity to glare and difficulty transitioning between activities were commonly reported challenges before the new lighting systems were installed.

2.3 New Lighting System

Although SMUD does not endorse specific products or manufacturers, the project team chose to use the Philips Hue system (Figure 6) based upon its options and capabilities. Specific products used included:

- White Ambiance light bulbs
- White Ambiance + Color light bulbs
- Wireless Smart dimmer switches
- Hue Tap switches
- Motion sensors
- Flexible LED light strips
- Smart Table Lamps (not shown)

These hardware options enabled the project team to develop solutions for almost every situation.

Another key aspect of the Hue system is the software. The participants were able to use their phones, tablets and or computers to program and control their new lighting system.

Figure 6: The project team chose to use Philips Hue because it offers a variety of bulbs and controls. Image credit: Amazon.com

Philips offers a variety of prepackaged software formulas that help users maximize the features of the Hue system (Figure 7). Participants in this project used several of these formulas to implement a wide variety of strategies.

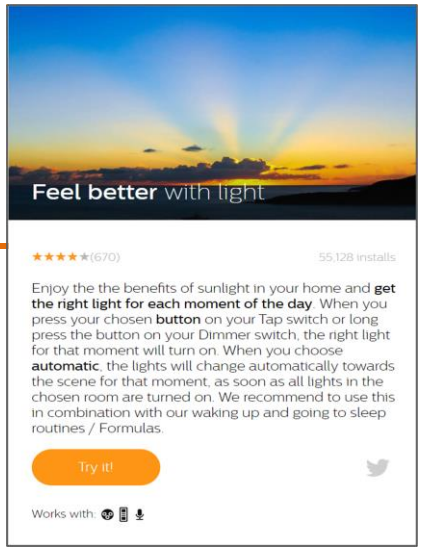


Figure 7: Philips offers a variety of prepackaged software formulas that help users maximize features of the Hue system. Image credit: https://labs.meethue.com/formulas

3. Strategies & Results

As stated earlier, this project was based upon implementing three main principles:

- Use the lighting system to develop and reinforce routines/transitions
- Avoid exposure to blue-white light at night
- Provide lighting for safe nighttime navigation

The following sections describe the specific strategies used to meet these objectives.

3.1 Circadian Lighting Strategy (Feel Better with Light)

Research conducted by the Lighting Research Center, DOE and others has shown that lighting affects our circadian rhythms, and consequently may have significant impacts upon our health. Specifically, the color spectrum and the intensity of the light source, as well as the duration and timing of the exposure affect our sleep patterns. Because of this, SMUD currently recommends limiting exposure of blue-white light sources at night.

The appearance of light sources is measured and described using a metric called Correlated Color Temperature or CCT. This system uses degrees in Kelvin as the units of measure. Lights that appear warm have lower CCTs (e.g. 2700K) while lights that appear to be cooler have high CCTs (e.g. 6000K). Ideally, people should use lights with higher color-temperatures in the morning and warmer tones (lower CCT) in the evening (Figure 8).

Figure 8: Ideally, people should use lights with cooler color-temperatures (5000K) in the morning and warmer tones (2700K) in the evening. For more information on this topic download our Circadian Lighting Guide via smud.org/CircadianLighting. Photo credit: Energy Star

Fortunately, the Hue Lighting app offers an easy way to program the lights to change color-temperature throughout the day through a formula called “Feel Better with Light”[4]. Project participants used this feature to vary the lights

[4] Philips changed the name of this formula to “Time-based light”. This and other Hue formulas may be accessed via: https://labs.meethue.com/formulas

from blue-white (high CCT) in the morning to warmer tones (low CCT) in the evening (Figure 9). According to our research, the Circadian Lighting strategy helped the children in this study be more willing to go to bed and fall asleep faster.

The Hue app enables users to select preset "scenes" for different times of the day. As part of our project, we measured the color temperature for each of the scenes commonly used for circadian lighting. The results of our measurements and recommended settings are shown in Figure 10.

Because children on the autism spectrum tend to have issues with sleeping, one of our weekly survey questions was "How long does it take for your child to fall asleep after you have put them to bed?" As shown by the following charts and comments, many of our participants experienced dramatic improvements in this area. Please note that the lines shown as the "baseline" on these charts are from the baseline surveys. As you review these charts and comments, please remember that before the study started, many of these parents experienced what they described as "nightly battles" over bedtime.

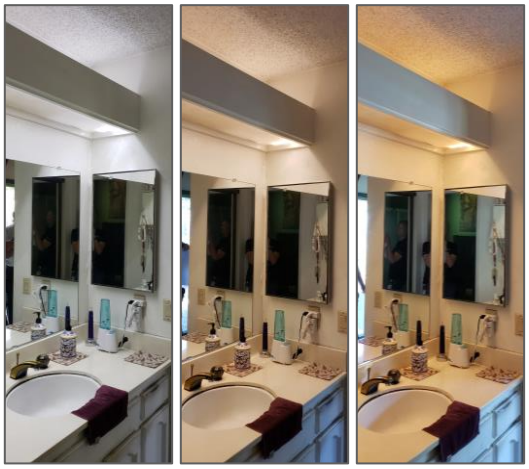
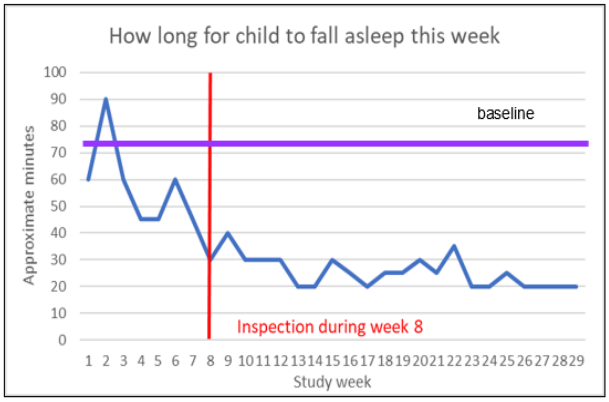


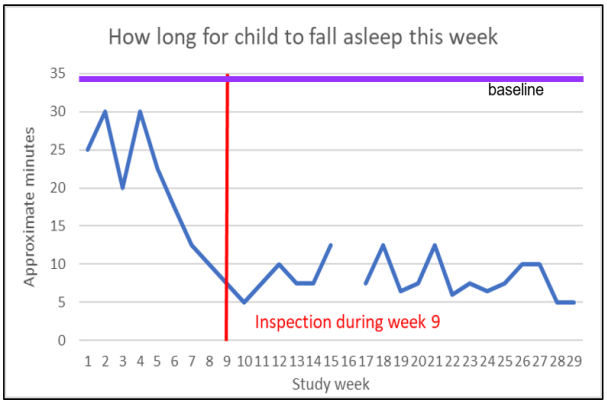
Figure 9: Project participants programmed the lights in their homes to vary from blue-white tones in the morning to warmer tones in the evening. This strategy provided visual cues to the children and made it easier for their parents to get them to go to bed.

Time of Day	HUE App Setting	Color Temperature
Wake up – 1:00 p.m.	Energize	6500 – 6600K
1:00 p.m. – 4:00 p.m.	Concentrate	4400K
4:00 p.m. – 7:00 p.m.	Read	2900K
7:00 p.m. – Bed time	Relax	2200 – 2300K
Nighttime Navigation	Nightlight	2200K

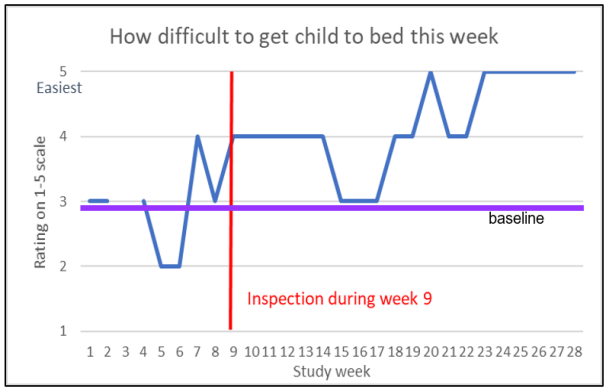
Figure 10: CCT measurements and recommended settings for the Feel Better with Light (Time-Based Lighting) routine used during this project. Photo credit for Hue icons: Philips



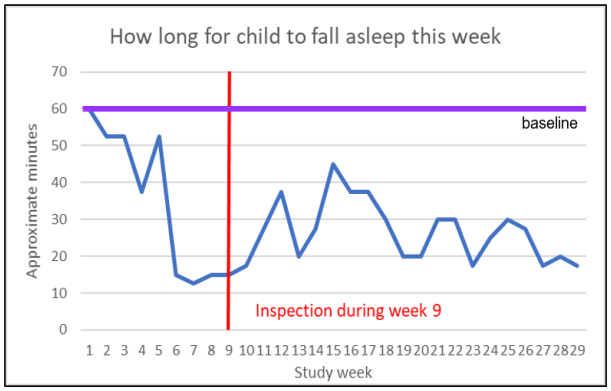
"It used to take our daughter more than one hour to fall asleep. It is so much easier now!"



"The lights are helping my son go to bed and fall asleep faster. Evenings are so much easier for me now!"



"These lights have changed our lives! Not having to argue over bedtime has made it so much easier. I have not slept so well in a long time. This system has helped our whole family!"



"This really works well in the common areas of our home (e.g. family room). It provides cues for bed time."

3.2 Go to Sleep Strategy

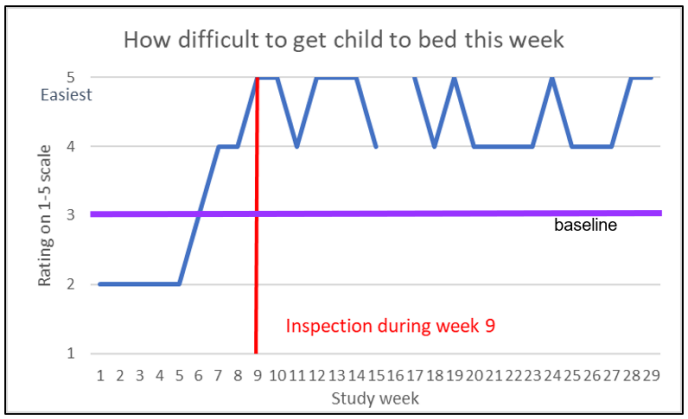
As the name implies, the Go to Sleep strategy is designed to help people fall asleep. The project team discovered the best way to implement this strategy was to use table lamps and flexible light strips mounted underneath the beds instead of the overhead lights (Figure 11). Parents programmed the lights to gradually fade and turn off after bedtime. The Go to Sleep strategy helped children who were afraid of the dark.

Figure 11: Parents often used table lamps and strip lights under the bed for the "Go to Sleep" strategy.

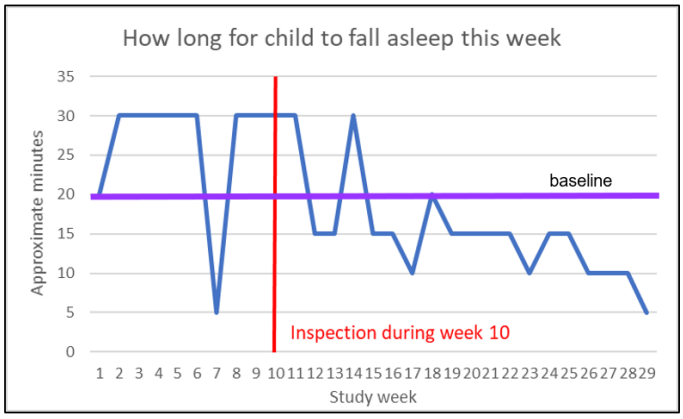
As before, we saw impressive results with this strategy (see the following charts and comments). However, since parents who used this strategy also used the Circadian Lighting strategy, it was very difficult to separate the effects of each strategy.

The charts and comments shown below are based upon the baseline questionnaires, weekly surveys and personal interviews with the parents.

"Easier to go to bed, he also has not been wanting me to stay in his bed with him anymore."



"We had a good week. He went to bed right away when it was time and fell right to sleep."



3.3 Morning Wake Up Strategy

The Morning Wake Up strategy scheduled overhead lights (Figure 12) to automatically turn on in the morning using the Concentrate or Energize settings. Some parents set the lights to gradually ramp up over 10-15 minutes while others used the "power wake-up" (instant on) setting.

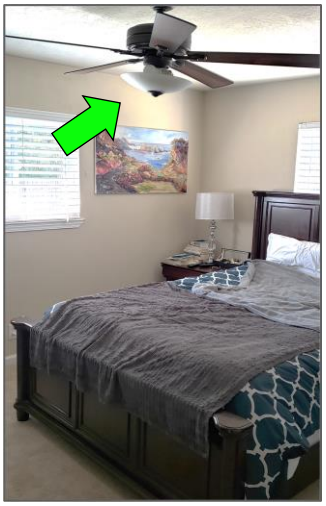
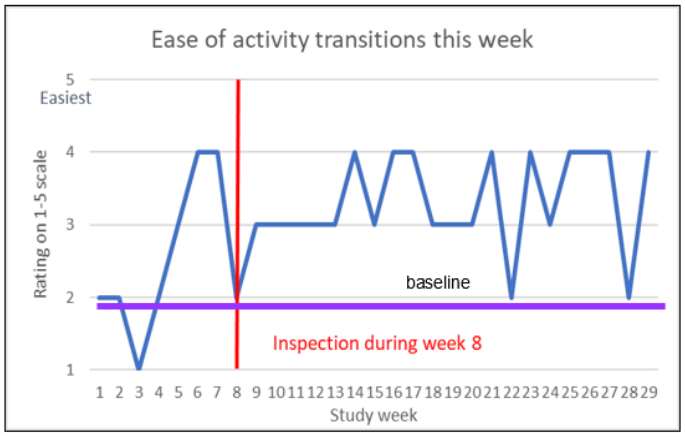


Figure 12: Parents often used overhead lights for the "Morning Wake Up" strategy.

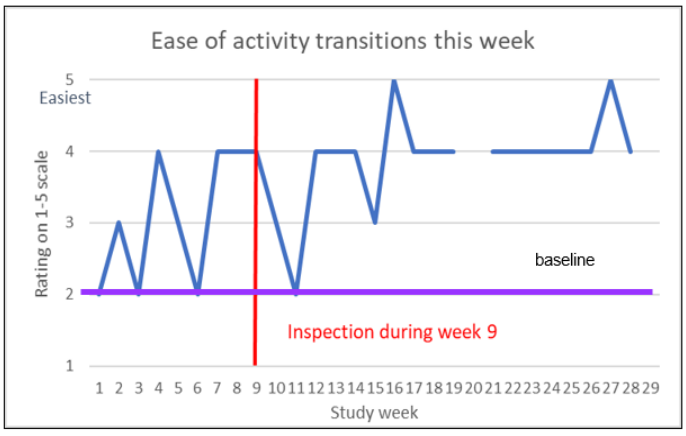
According to the baseline surveys, several parents found it very challenging to get their children out of bed in the mornings. Although this is common for most children, it can be much more so for children on the autism spectrum. Before the new lighting systems were installed, some parents reported that mornings were very challenging—meltdowns and aggressive behavior were common.

The charts and comments below are based upon the baseline questionnaires and weekly survey data that was collected over a period of 29 weeks. Several of the participating families reported dramatic improvements.

"Before this project began, our daughter would react very aggressively when awakened. This routine has changed that dramatically!"



"Our son is dyslexic and very visual. The lighting cues really help him know what is coming up next. It took him about a week to catch on to the new routine…he learns from watching which is his superpower."



3.4 Nighttime Navigation

One of the primary strategies of this project was to provide adequate lighting whenever anyone in the family got up in the middle of the night. This was accomplished primarily by using LED light strips mounted under the beds, Smart Table Lamps and lights in the bathroom set for nightlight mode. These lights were usually controlled by motion sensors placed under the bed and in the bathrooms. This combination provided enough light to visit the bathroom with minimal disruption. For children who were extremely afraid of the dark, the LED strip lights under the beds were left on during the night and set at minimal brightness.

"Sometimes our son needs help going to the bathroom in the middle of the night. The nighttime navigation lights have really helped these occurrences be less disruptive. It is now easier for our son and his father to go back to sleep."

During the initial lighting assessments, we learned that most (if not all) of these children were afraid of the dark. This caused a lot of them to jump into their parent's beds and or yell out at night. It also caused some of them to wet their beds on a frequent basis (because they were afraid to get up). The comments below were made at the beginning and end of the study.

Before: *"She would wake in the darkness, shrieking out for her Grandma."*

> **After:** *"She winds down with the lights set at the relaxed mode. When she wakes up, she runs quietly to Grandma's room and sleeps peacefully until we wake her for school."*

Before: *"She wakes up in the middle of the night and tries to sleep in our room because her room is dark and scary."*

> **After:** *"Good week for bedtime, she went down without a fight. Generally speaking, we are leaps and bounds better than when all of this started. She did not wake up in the middle of the night to sleep with us."*

Before: *"My son sleeps with either me or my husband and falls asleep about 45-60 minutes after going to bed."*

> **After:** *"I never want to go back to those days!"*

Before: *"It would take my son about 30-45 minutes to fall asleep and I would lie with him."*

> **After:** *"He basically is going to bed on his own which he hadn't done prior to this study and without me staying with him."*

3.5 Calm Down

During this project, one of the parents developed a very innovative procedure to help her six-year-old daughter calm down faster during meltdowns. When her daughter had a meltdown at home, her mother brought her into her bedroom and had her sit in a comfortable chair. While sitting in the chair, her daughter hugged a teddy bear and did deep breathing exercises. While this was happening, her mother turned the lights in the room to the “Relax” setting. Since the windows in this room are covered by blackout curtains, this technique worked exceptionally well. The little girl’s mother made the following comments during our final interview:

> *“The circadian lighting routine has been very helpful. The biggest impact however has been an amazing reduction in the frequency and duration of her meltdowns. We use the lights as part of a routine to calm our daughter down. The length of the tantrums has decreased from over one hour to less than 15 minutes! Also, I have not been bitten by my daughter in over three months. Less anxiety too.”*

3.6 Bedtime Cuing

Many children love to play video games, watch TV or movies on their iPad. During this project several parents told us that one of their biggest challenges was getting their children to transition from these activities to bedtime. Although the Circadian Lighting strategy was very helpful, some children needed something more obvious to alert them. This was especially true during the summer months for homes with many windows. Fortunately, some parents created very innovative strategies that really seemed to help. For example, they used color changing light bulbs to signal their children. The key element for this strategy was consistency: parents had to teach their children the new routine and then enforce it. One mother reinforced the new routine by teaching her son that “red means bed” (Figure 13).

Figure 13: Some parents used color changing light bulbs to signal their children. One mother reinforced the new bedtime routine by teaching her son that “red means bed”.

3.7 Colors as a Reward

The final technique used in this study was to use "Colors as a Reward." The basic idea was to make the children's bedrooms a fun place to be at night. To accomplish this, the project team used color-changing LED light strips and/or light bulbs (Figure 14). For example, if the child did a good job getting ready for bed, the parents would let them choose colors for the night.

Here are some of the comments:

"She asked a couple nights to go to bed early so she could be with her pink lights."

"During our vacation he did mention that he couldn't wait to get home to his special lights."

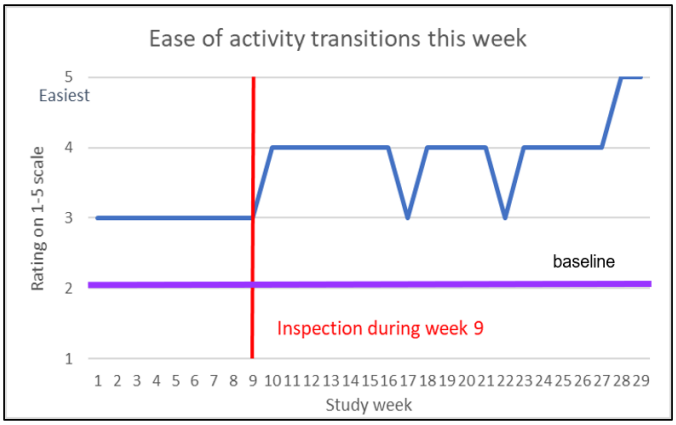
"He really likes his desk lamp on a red color as he goes to sleep. He said it sooths him."

Figure 14: The project team used color-changing LED strip lights and or light bulbs to make the child's room and fun and inviting place to be.

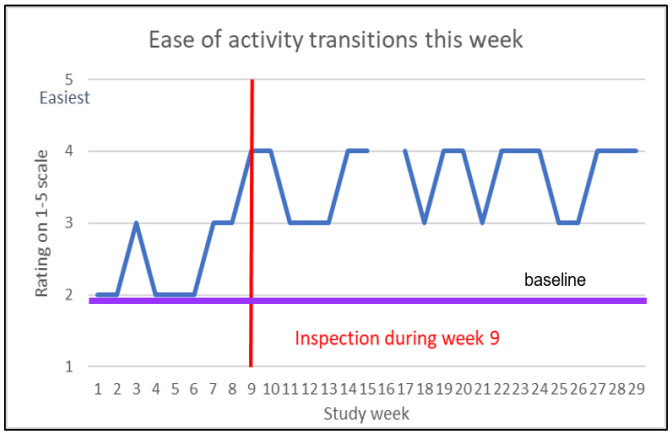
3.8 Transitions

One of the goals of this project was to help the children transition from one activity to another. Common examples of transitions are doing homework, getting ready for bed, waking up, and getting ready for school. The combination of the lighting strategies described above produced very positive results for several of the families in this study. The following charts and comments are based upon the baseline questionnaires, weekly survey data and interviews with the parents.

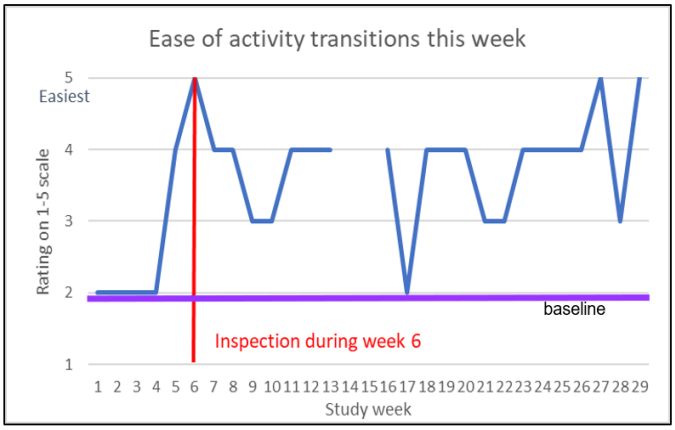
"Even with new goals introduced in her daily therapy, she is doing well with them and has responded well to the changes in routine."



"He just seemed more flexible and mellow this week, easier to transition between activities."



"I am not entirely sure if it has been the lighting or maturity that has helped him make so much progress, but I would say it is probably a combination of both. He thrives when he is in control. Having a sense of ownership with the lights has increased his confidence. I do know that the lighting has helped at night with the bed time routine and in the morning, getting him up and ready for the day."



3.9 Overall Results

At the beginning of the study, we asked the participants to complete a baseline survey. We asked them to rank their child in the four categories shown below (Figure 15) and to tell us how long it took (on average) for their child to fall asleep after being put to bed. All of the families who ranked their children at a 3 or lower for these categories and successfully met the project requirements benefitted from this project.

Baseline Ratings	5 (best)	4	3	2	1 (worst)
Child's emotional state		X			
How difficult to get child to bed					X
How difficult to get child out of bed			X		
Ease of activity transitions			X		

Figure 15: All of the families who ranked their children at a 3 or lower for the categories shown above and successfully met the project requirements benefitted significantly from this project.

We also asked the parents to identify problem areas such as anxiety, meltdowns and tantrums. For the 33 families who successfully met the project requirements, the results were fantastic!

- 100% of the 8 children with baseline "Emotional State" ratings of 3 or lower saw statistically significant improvements[5] compared to the period before the lighting was installed.

- 95% of the 19 children with baseline ratings of 3 or lower for the "How difficult to get child to bed" question experienced statistically significant improvements[5].

- 97% of the 30 children with baseline ratings of 3 or lower for the "Ease of Activity Transitions" question saw statistically significant improvements[5] (Figure 16).

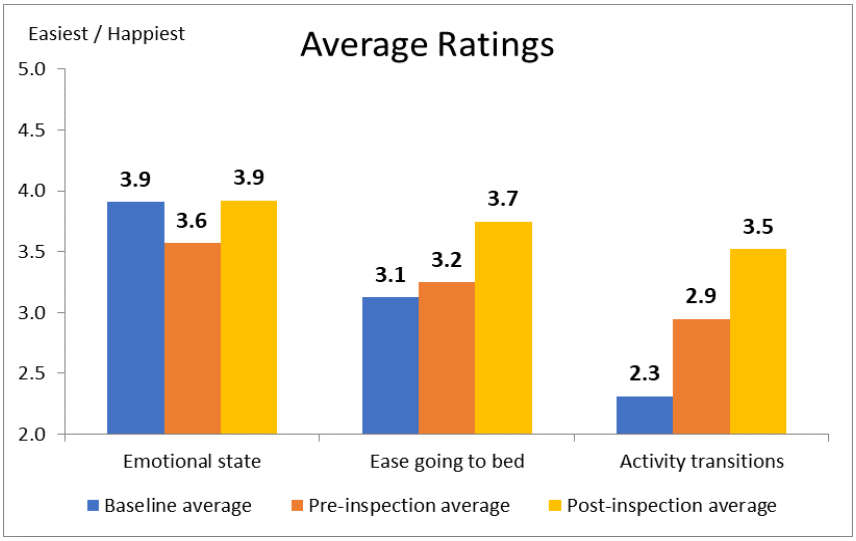


Figure 16: Project participants experienced significant improvements in several categories—especially in activity transitions.

- Several families reported it is easier to wake up their child in the morning and get them ready for school (compared to the time period before the lights were installed).

- 33% of the 33 participants reported dramatic reductions (50% or more) in the amount of time required for their child to fall asleep. 67% of the 33 participants showed a statistically significant decrease[5] in the time for their child to fall asleep compared to their baseline (Figure 17).

[5] Based upon a statistical confidence level of 90%

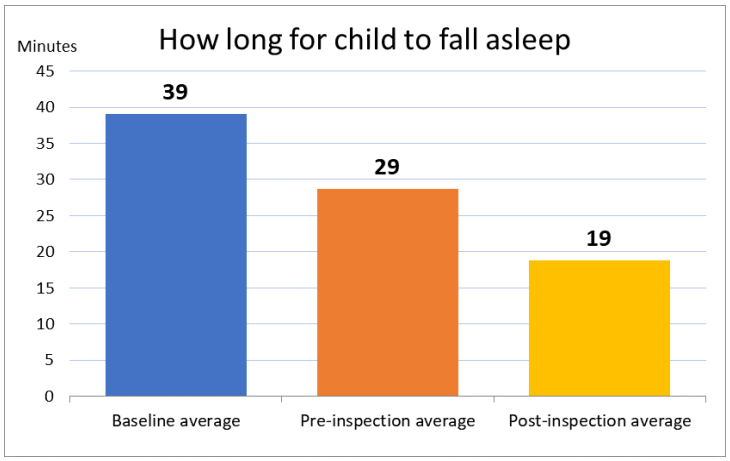


Figure 17: Many participants in this project experienced significant reductions in the amount of time required to go to sleep.

- Some families reported reductions in challenging behaviors such as meltdowns, biting and bedwetting.

- When asked what impact the lighting system has made upon their family, participants provided the responses shown in Figure 18 below.

Answer Given	Meaning	Total
No significant changes	No impact	0
I enjoy the lights, but they are a luxury that I could live without	Low impact	3%
The lights have helped my family somewhat	Moderate impact	20%
The lights have really helped my family	High impact	37%
The lights have changed our lives	Life-changing	40%

77%

Figure 18: When the 33 participants were asked what impact the lighting system had made upon their family, they provided the responses shown above.

- One parent who described the lighting as “Life-changing” reported that their child experienced significant reductions in the length and severity of her meltdowns. As mentioned previously in this report, this parent used the lights as part of an overall routine to help calm her daughter down. However, most of the reasons given by those in the “High impact” or “Life-changing” categories fell into one of three areas.

1. Many parents experienced a significant reduction in arguments over bedtime (Figure 19).

2. Several parents reported a significant reduction in the amount of time for their children to fall asleep after being put to bed (Figure 20). Some of these parents used to have to lay in bed with their children every night until they fell asleep—a process that often took an hour or longer.

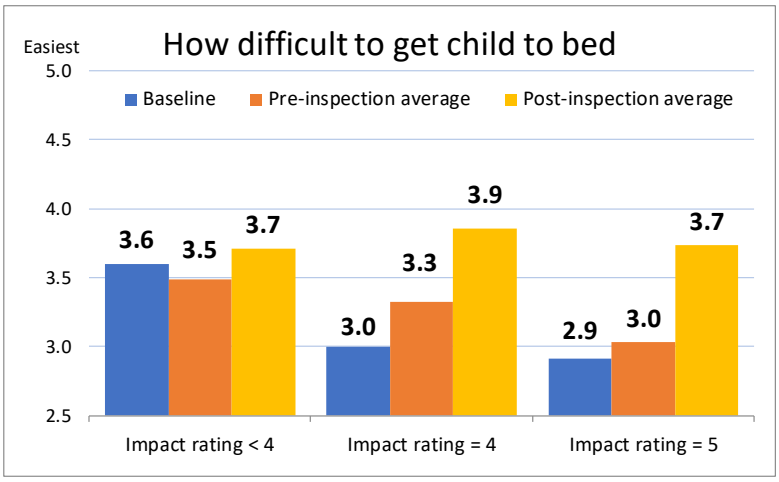


Figure 19: Many of the parents who described the lights as "Life-changing" experienced a significant reduction in arguments over bedtime.

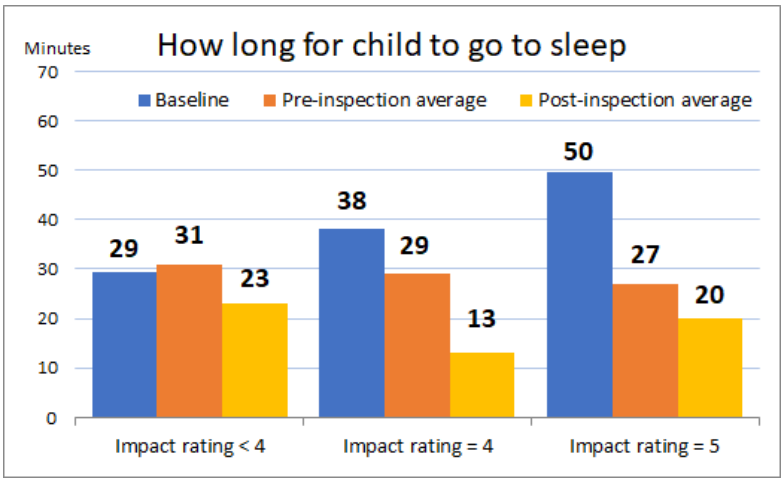


Figure 20: Several parents who described the lights as "Life-changing" reported a significant reduction in the amount of time for their children to fall asleep after being put to bed.

3. Another key area was "Ease of Activity Transitions". Several parents found it much easier to get their child out of bed in the morning or switch tasks during the day (Figure 21). The lighting also helped reduce meltdowns.

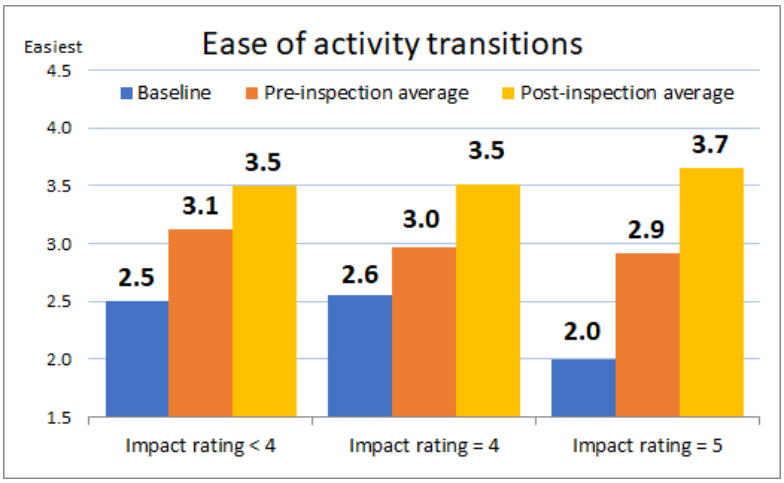


Figure 21: Some parents who described the lights as "Life-changing" found it much easier to get their child out of bed in the morning or switch tasks during the day.

4. Observations & Lessons Learned

By all accounts, this project was an overwhelming success. However, it is very important to note that simply delivering lights to these families would not have produced the same results. There were several key factors including:

- **LED technology:** The lighting system used for this project offers tremendous flexibility with advanced control options. This enabled the project team to develop and implement solutions tailored for each family. Many families experienced energy savings moving from traditional bulbs to LEDs. During the final interviews, we asked the project participants several questions about the Hue system, and they offered the following feedback:

    - Overall, most participants were satisfied with the system, but felt that is was too expensive or overpriced.

    - Having different types of light bulbs, wireless control options and LED light strips was very helpful (especially the light strips).

    - They really liked the capabilities of the Hue app, but also said it was somewhat difficult to use at times and not very intuitive (note the project team spent many hours answering questions about the Hue app and providing technical support).

    - Most participants liked the motion sensors and found them easy to use.

    - Most participants liked the wireless Smart Dimmer Switches but experienced a lot of problems with the Hue Tap switches.

- Some of the participants who visited the Philips Hue website looking for helpful user information felt that the website was too heavily focused on marketing the system for entertainment purposes.

- **Project Steering Committee:** During the Gold Ridge Elementary School study, our recruitment efforts for obtaining families did not work very well. Fortunately, the two families who participated experienced very positive results and strongly recommended using tunable-white lighting systems to other parents who have children with ASD. One of these parents suggested working with agencies that provide support to children with ASD would increase our credibility for future studies. This turned out to be great advice!

  At the beginning of this project, SMUD assembled a Steering Committee that included the UC Davis Mind Institute, the Fly Brave Foundation, a special education high school teacher and a wildlife biologist who is on the autism spectrum. These thoughtful individuals provided tremendous insights and gave this project credibility. As a result, we were able to recruit 36 families to participate in this study.

- **Parental engagement:** The success of this project was largely due to the active participation of the parents. Under the guidance of the project team, parents used the lighting system to develop and maintain new routines to help deal with behavioral challenges.

  One of the participants made an interesting observation: he said that having to complete the weekly surveys forced him to pay attention to his son's sleeping habits. For example, when he noticed that the amount of time required for his son to fall asleep had increased significantly, he decided to investigate. He found out that his son was hiding an electronic game under his pillow. Once the device had been taken away, his son returned to his newly established sleeping patterns.

- **Project team:** The project team spent literally hundreds of hours educating parents, conducting lighting assessments, commissioning lighting systems and conducting final interviews. Each of the members cared deeply about helping these families and worked very hard to ensure the success of this project.

5. Recommendations & Next Steps

Recommendations

Based upon the dramatic improvements experienced by the majority of the families who participated in this project, more research should be done in homes for children with ASD. Here are some recommendations for future studies:

- **Prescreen participants based upon baseline conditions:** The participants for this project were selected solely based upon the following criteria:
    - SMUD customers only
    - Children must be between the ages of 5 and 10 (at the beginning of the study)
    - Children diagnosed as having ASD
    - Parents or guardians must attend a training session which covered circadian lighting principles, a project overview and participation requirements.
    - Parents or guardians must sign a participation agreement and be willing to complete the surveys and meet other contractual requirements.

  Because all of the families who ranked their children at a 3 or lower on the baseline survey experienced significant improvements, it may be a good idea to include a baseline questionnaire when selecting participants for future studies.

- **Focus on children up to 7 years old.** Some parents with children over 9 years old experienced some initial pushback during this project. The project team believes that working with younger children may be easier because their routines, habits and medications may not be firmly established, and they are not yet experiencing hormonal changes associated with puberty.

- **Include the winter months.** Due to time constraints, the monitoring period for this project only included spring, summer and fall. The project team believes that this lighting system will have more impact upon people during the darker winter months.

- **Provide progress reports.** For some of the participants, completing 29 weeks of surveys without any feedback regarding the results was challenging. For future projects, it may be helpful to provide participants with an online tool that is compatible with mobile devices to track their progress.

- **Include final interviews.** In our experience, survey tools cannot fully capture the full story for projects such as this one (or any of our circadian projects for that matter). The

final interviews provided numerous valuable insights and provided an opportunity for the participants to express how the lighting had impacted their lives.

- **Create a Circadian Lighting Starter Kit for participants.** During our final interviews, we discussed the idea of working with Philips to develop a circadian lighting starter kit with the participants. Based upon these conversations these kits would cost between $300 to $500 and include:
    - A Philips Hue Hub
    - Hue White Ambiance (i.e. tunable white) A19 light bulbs
    - Wireless Smart Dimmer switches
    - At least one White Ambiance + Color A19 light bulb
    - One LED light strip (White Ambiance + Color)
    - Video links for learning about circadian lighting principals and specific techniques
    - A printed circadian lighting guide
    - Tracking software for participants and researchers to monitor progress

Next Steps

SMUD's next steps will be focused on education and outreach. We hope to share the results of this exciting project with organizations that support families with children on the autism spectrum, special education teachers, behavioral therapists, lighting professionals and our community. In addition to presentations, SMUD will be creating a variety of resources and making them available via our circadian lighting webpage: smud.org/CircadianLighting. We are also currently in discussions with Philips Lighting regarding ideas for rolling out these solutions to the ASD and Special Needs communities.

Appendices

Appendix A – Baseline Survey Questions

1. What is your name?

2. What is your family name? (e.g. Smith family)

3. How old is your child? ___ years, ___ months

4. Where would you place your child on the Autism Spectrum?

   Level 1 Mild: Condition requires limited special attention when planning for the person's school or day program, living arrangements, and/or extra supervision or care. For example, the person is living at home and is receiving minimal behavioral intervention or other special services.

   Level 2 Moderate: Condition has a major impact upon the ability to obtain an appropriate school or day program, residential placement, and/or it requires a considerable amount of supervision or care. For example, the person lives at home or is in a community residential setting and needs moderate behavioral intervention such as a one-to-one aide at school but not at home.

   Level 3 Severe: Condition is such that it is exceedingly difficult to find an appropriate program or residence for the person and/or constant supervision/care is required. For example, the person is at home or in a residential setting and needs extensive professionally supervised behavior intervention services, such as in-home behavioral supports provided on a one-to-one basis.

   I'm not sure of the level

5. Does your child attend school?

6. What school does your child attend?

7. What grade is your child in?

8. Is your child involved in any therapeutic, educational, or other programs during the summer months? If so, please describe

9. Overall, how would you rate your child's emotional state?
    1. Very unhappy
    2. Somewhat unhappy
    3. Neither happy nor sad
    4. Somewhat happy
    5. Very happy

10. Generally, how difficult is it to get your child to go to bed?
    1. Very difficult
    2. Somewhat difficult
    3. Neither difficult nor easy
    4. Somewhat easy
    5. Very easy

11. Approximately how long in minutes does it take your child to fall asleep (nightly) after going to bed?

12. Please provide any additional comments you have regarding getting your child to go to bed.

13. Generally, how difficult is it to get your child up and out of bed in the mornings
    1. Very difficult
    2. Somewhat difficult
    3. Neither difficult nor easy
    4. Somewhat easy
    5. Very easy

14. Please provide any additional comments you have regarding getting your child up in the morning.

15. In general, how easy or difficult is it for your child to transition from one activity to another (ex. switching from doing homework to getting ready for bed)?
    1. Very difficult
    2. Somewhat difficult
    3. Neither difficult nor easy
    4. Somewhat easy
    5. Very easy

16. Which of the following are issues for your child? Please select all that apply:
    - Meltdowns or tantrums
    - Studying and academics
    - Level of social engagement (positive or negative)
    - Anxiety
    - None of the above
    - Other, please describe

17. Do you have any other comments or feedback?

Appendix B – Weekly Survey Questions

1. What is your name?

2. What is your family name? (e.g. Smith family)

3. Comparatively speaking, how would you rate you child's emotional state this week? (1-5).
   1. Very unhappy
   2. Somewhat unhappy
   3. Neither happy nor sad
   4. Somewhat happy
   5. Very happy

   Please explain your reason for the above rating.

4. How difficult was it to get your child to go to bed this week? (1-5)
   1. Very difficult
   2. Somewhat difficult
   3. Neither difficult nor easy
   4. Somewhat easy
   5. Very easy

   Please briefly describe any changes that you have noticed in your child's sleep patterns.

5. Approximately how long in minutes did it take for your child to fall asleep (nightly) after going to bed this week. Comments?

6. How easy or difficult were transitions from one activity to another for your child this week? (e.g. doing homework, then getting ready for bed). Please briefly describe any changes in activity transitions.
   1. Very difficult
   2. Somewhat difficult
   3. Neither difficult nor easy
   4. Somewhat easy
   5. Very easy

7. Have you noticed any changes in your child's behavior compared to last week?
   - Meltdowns or tantrums?
   - Studying and academics?
   - Social engagement?
   - Anxiety?

   Please briefly describe any changes that you have noticed (including any areas not listed above).

8. How easy or difficult were transitions from one activity to another for your child this week? (e.g. doing homework, then getting ready for bed). Please briefly describe
   1. Very difficult
   2. Somewhat difficult
   3. Neither difficult nor easy
   4. Somewhat easy
   5. Very easy

9. Do you have any additional comments or suggestions? Please note below.

Appendix C – Final Interview Questions

Hue System

A. How would you rate your satisfaction with your Hue lighting system?
   1. Very dissatisfied
   2. Dissatisfied
   3. Neutral
   4. Satisfied
   5. Very satisfied

B. What did you like about the system?

C. What did you not like?

D. How easy was the system to install and use?
   1. Very difficult
   2. Difficult
   3. Neutral
   4. Easy
   5. Very easy

E. If the Hue system you have been using cost $1,500 to purchase, would it be worth it to you?

F. Based upon the benefits you have experienced how much would you be willing to pay for your Hue system?
   1. Less than $500
   2. Between $500 and $700
   3. Between $700 and $900
   4. Between $900 and $1,200
   5. Over $1,200

Formulas & Strategies

G. Which of the following Hue Labs formulas or features did you use? Did you find them helpful?

   1. Feel better with light? yes ☐ no ☐
   2. Wake up routine? yes ☐ no ☐

3. Got to bed routine? yes ☐ no ☐
4. Scheduling events? yes ☐ no ☐
5. Other? yes ☐ no ☐

H. Which lighting strategy (e.g. circadian lighting, nighttime navigation, cuing for transitions, using color for rewards, etc.) had the greatest impact upon you and/or your family? Please tell us why.

I. Would you recommend the Hue lighting system to other families who have children with Autism Spectrum Disorder?

1. Strongly do not recommend
2. Would not recommend
3. Neutral
4. Recommend
5. Strongly recommend

J. (Question for after reviewing the personal survey data). How would you rate your experience with this lighting system?
1. No significant changes
2. I enjoy the lights, but they are a luxury that I could live without
3. The lights have helped my family somewhat
4. The lights have really helped my family
5. The lights have changed our lives