June 13, 2023

Creative Solution for Delivering Circadian-Effective Light

Enhancing daytime light levels for older adults living with Alzheimer's disease and related dementias (ADRD) using light tables

Abe's Garden Community

115 WOODMONT BLVD. NASHVILLE, TN 37205

Funding provided by the Care Foundation of America

Final report prepared by Allison Thayer and Mariana Figueiro

MOUNT SINAI LIGHT AND HEALTH RESEARCH CENTER

Creative Solution for Delivering Circadian-Effective Light
Final Report – June 2023

Contents

Summary

Interior spaces like senior care facilities generally do not provide enough daytime light to stimulate the circadian system. Older adults living with Alzheimer's disease and related dementias (ADRD) can experience sleep disturbances that disrupt their daytime and nighttime routines and increase the burden of the disease, both for the individuals themselves and their caregivers. Introducing supplemental lighting to complement daily routines has proven beneficial for promoting better sleep at night. The use of local light sources (i.e., positioned close to the eye rather than emanating from the ceiling) is the most efficient way to achieve this goal, although such products are not widely available on the market.

The team at the Light and Health Research Center (LHRC) worked with Abe's Garden and a furniture designer, Dean Babin, to come up with a light table solution. The team then tested the long-term (3-month) effect of exposure to these light tables on measures of sleep and mood in a volunteer group of residents with moderate to severe dementia who were experiencing sleep problems. Although there were not enough participants to lend statistical significance to the study's results, those results trended in the right direction and are similar to the findings of previous studies by the LHRC [1-4] and other researchers.[5-7]

Our results from monitoring wake/activity patterns found that participants fell asleep faster, woke up less frequently in the night, and had better sleep efficiency (i.e., percentage of time spent asleep while in bed). Once the light tables had been turned off for 4 weeks, the participants' sleep habits began to trend back toward the conditions that prevailed before the light tables were introduced. The effects of the intervention on participants' mood were inconclusive. Scores from sleep quality, depression, and agitation questionnaires did not see any change from the end of the intervention compared to 4 weeks after the tables had been turned off.

Our research highlights the importance of the continual use of bright light solutions to supplement daily routines. Follow-up studies should be conducted to increase the number of participants to better determine the significance of these data. Overall, the light tables were well received by the residents and staff of Abe's Garden.

See *Appendix A – Contact Information* for more information about the individuals involved in the project.

Background

Bright light during the day and dim to dark light at night is essential for human health. The pattern of light and dark received at the eyes tunes our circadian system so we sleep better at night, feel refreshed and revitalized in the morning, and are better able to ward off physical and mental health problems like metabolic disease, cardiovascular disease, cancer, and depression. But people living in nursing homes, who are often at elevated risk for experiencing these health problems, typically spend their days in constantly dim lighting conditions that can offset the benefits accorded by a healthy circadian system.

Project Goals

Abe's Garden aims to be a model facility to showcase circadian-effective design solutions for older adult community living. For this study, Abe's Garden partnered with the LHRC to determine which space should be renovated to achieve the project's circadian-effective lighting goals. Ultimately, the dining area where residents spend a consistent portion each day was chosen for the upgrade. As an alternative to upgrading the overhead wired lighting, the team chose to use light tables instead. This small study looked into the long-term (3-month) impact of this tailored circadian-effective lighting intervention on volunteer residents.

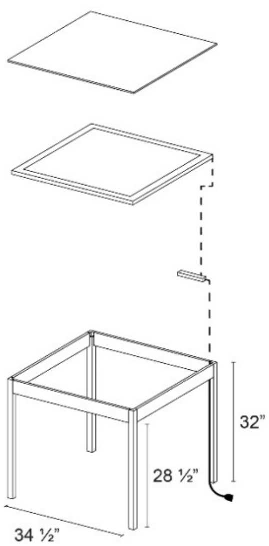
Feature

An article about the study was written and will be featured in *designing lighting magazine*'s June/July 2023 issue.

Light table

Photo credit: Richard Walker

Abe's Garden requested 5 light tables for the study. The team partnered with a furniture designer, Dean Babin, to custom build light tables for the upgrade. After many iterations and testing, the team arrived at a simple solution that checked the boxes for all the design requirements. Abe's Garden received a prototype table in March 2022 to test and approve before final production of the remaining 4 tables. The light table houses a 36" x 36" custom-sized, 4-edge-lit LED panel with a 3700 K source providing ≈3735 lumens at 40 watts. A custom frame was built to support the light fixture. The final tables were delivered in August 2022.



Components	Design Goals
3/8-inch glass	• Safe/sturdy for long-term use • Waterproof and easy to clean • Accessibility to light for maintenance
Custom light panel	• Bright light capable of stimulating the circadian clock • Uniform, diffuse, and non-glary source
Power source	• Discrete access to power switch • Energy Efficient • Discrete, adjustable wiring
Custom wood frame	• Americans with Disabilities Act (ADA) compliant • Sturdy, yet elegant construction

Figure 1. Breakdown of the light table's components and how they fit the design goals.

Researchers from the LHRC tested the light tables to determine if they would provide sufficient light levels to stimulate the circadian system. The amount of light that reaches the eye depends on multiple factors, such as a person's proximity to the table and whether their gaze is directed forward or down at the table. At a height of 13" above the table, the team measured 550 lux for a forward gaze straight across and above the table and upwards of 1000 lux at the eye for a gaze directed at the center of the table. Testing a worse case of partial coverage of the table with 4 semi-opaque dinner plates, the brightness levels for both gazes reduced by about 50%. Researchers recommended keeping any items on the tables to a minimum to decrease light loss from obstructions.

See Appendix B – Light Table Details for more information

Figure 2. Laboratory testing of the prototype table to determine light stimulus.

Assessment for Study Enrollment

Mini Mental State Examination (MMSE):

During the MMSE, a health professional asks a patient a series of questions designed to test a range of everyday cognitive skills. The maximum MMSE score is 30 points. A score of 20 to 24 suggests mild dementia, 13 to 20 suggests moderate dementia, and less than 12 indicates severe dementia.

Recruitment/Enrollment:

Abe's Garden completed MMSE and PSQI (questionnaire to determine sleep quality, see below) screening for 13 subjects to enroll subjects with mild to severe dementia and sleep problems. Abe's Garden obtained voluntary consent from all participating subjects or their families.

Study Questionnaires

Pittsburgh Sleep Quality Index (PSQI):

The PSQI is a tool that can be used to measure sleep quality in clinical populations. It is composed of 19 items that generate 7 component scores (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction). The sum of the 7 component scores yields one global score. A person with a global score above 5 is considered to have sleep disturbances.

Cornell Scale for Depression in Dementia (CSDD):

The CSDD is a 19-item tool designed to rate symptoms of depression in persons with dementia. This tool evaluates the presence and extent of mood-related signs (anxiety, sadness, irritability), behavioral disturbances (agitation, loss of interest), physical signs (loss of appetite, weight loss), cyclic functions (mood variation, sleep quality), and ideational disturbances (suicidal thoughts, poor self-esteem). A score ≥10 points indicates clinically significant depression and a score >18 points suggests severe depression.

Cohen-Mansfield Agitation Inventory (CMAI):

The CMAI is used to assess the frequency of manifestations of agitated behaviors in elderly persons. This caregivers' rating questionnaire evaluates participants for 29 agitated behaviors, each rated on a 7-point scale of frequency. A total score of >45 points is usually regarded as clinically significant agitation.

Study Protocol

A one-week baseline period at the beginning of the protocol was conducted to gather baseline information about participants' current sleep. Following a week-long baseline assessment (W1), the light tables were installed and manually turned on by Abe's Garden staff from 6:00 AM to 6:00 PM, 7 days per week, over the course of 3 months (months 1–3). The participating residents were periodically exposed to the light table on a voluntary basis, starting at breakfast (as early as 7:00 AM), lunch (12:00 PM), dinner (5:00 PM), and/or other occasional gatherings/activities.

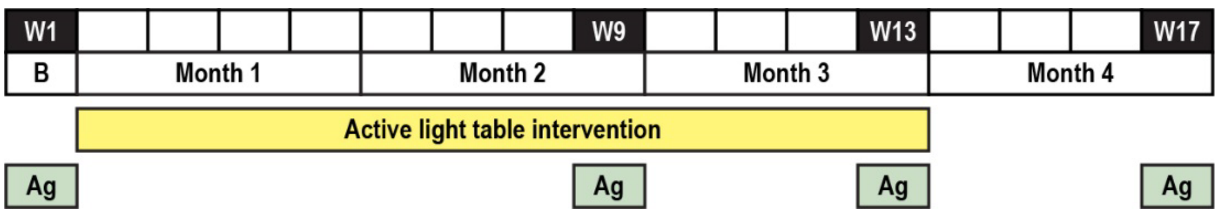


Figure 3. Breakdown of study protocol. The assessment weeks (W1, W9, W13, W17) are indicated by black boxes.

Actigraphy data (keyed "Ag" in Figure 3) were collected from participants at baseline (W1, keyed "B") and over the course of 3 subsequent assessment weeks (W9, W13, and W17). After a 4-week washout period, data were collected during the final assessment week (W17) some 3-4 weeks after the light table intervention had ceased. During weeks 13 and 17, CSDD, PSQI, and CMAI questionnaire data were to be collected by a nursing staff member who closely worked with the participants.

Assessment week components

Actigraph (Ag)

Actiwatches were worn by participants on their non-dominant wrist for one week at each assessment time to monitor sleep/wake patterns. The LHRC provided Abe's Garden with 15 wrist actiwatches to be worn during assessment weeks and devices were shipped back, downloaded, and analyzed by LHRC.

Participant Room Sensors

Originally, Abe's Garden worked with a representative from StackCare to determine the cost and feasibility of using this manufacturer's products to measure participants' nighttime activity and thereby supplement the actigraph measures of sleep/wake. Due to cost, it was decided to switch to *Third Reality* motion sensors. Sensors were purchased and installed in participants' rooms by Abe's Garden staff. A phone app was used to control the sensors and continually collect data. The LHRC scope of work did not include the analysis of the room sensor data.

Study Questionnaires

At the end of each assessment week, Abe's Garden nursing staff filled out the PSQI, CCSD, and CMAI, questionnaires and returned them to the LHRC for analysis.

Results

Actigraph (Ag)

Most of the participants did not comply with wearing the actiwatches (typical of this population). Useable data were obtained for 5 compliant participants (actiwatches 1, 2, 4, 9, and 11) to assess trends throughout the study. Those data trended in the right direction: participants fell asleep faster, woke up less frequently in the night, and had better sleep efficiency (i.e., percentage of time spent asleep while in bed). Average sleep onset latency (Figure 4, top) showed that participants took about 13 minutes less time to fall asleep after 3 months (week 13) of the lighting intervention, compared to baseline. The average wake after sleep onset (Figure 4, middle) decreased to 60 minutes, compared to 105 minutes during baseline. Additionally, sleep efficiency (Figure 4, bottom) increased as the intervention went on. For all actigraph measures, after the washout period without the lights (week 17), the values began trending back toward the conditions observed during the baseline assessment. These very preliminary data are consistent with our previous research[1-4] and what others[5-7] have found, but additional data should be collected to confirm these results, as the present results are not statistically significant.

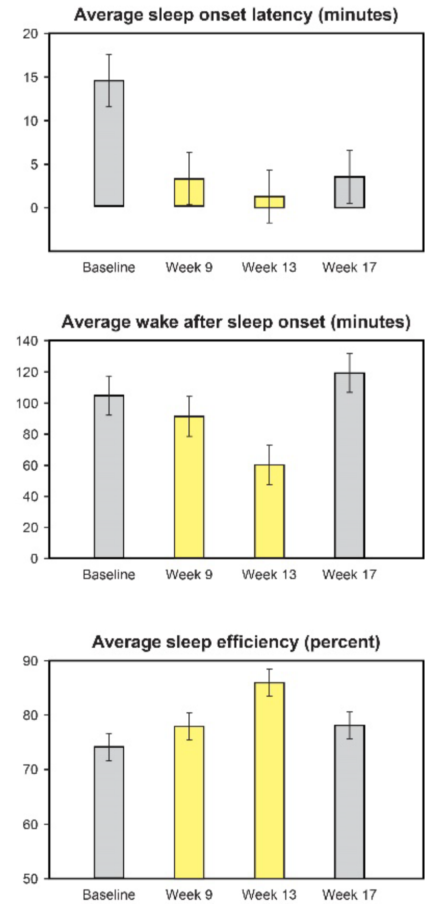


Figure 4. Actigraph data for comparing sleep patterns for baseline (week 1), weeks 9 and 13 during the intervention, and week 17 after the washout period.

Participant Room Sensors

Difficulties connecting to the Third Reality phone app prohibited the collection of readable data, so no participant room sensor results are available.

Study Questionnaires

The questionnaires for sleep quality (PSQI), depression (CSDD), and agitation (CMAI) produced usable data only from week 13 (3 months after the lights had been on) and post-intervention (after a one-month washout period with no light tables on). It should be noted that no baseline data for the questionnaires were collected due to miscommunication. The month 2 (week 9) data were also omitted from the analysis because they were collected by a staff member who was not as familiar with the participants as the one who performed the assessments at weeks 13 and 17. (The validity of the questionnaires is contingent on consistent assessments by persons who are familiar with the participants. Ideally, the same individual should score all the questionnaire data.) Figure 5 shows the average trends in the questionnaire data. Lower scores are better in all assessments, so the higher scores after month 3 means participants scored slightly worse. The limited number of participants precluded statistical significance in the questionnaire results.

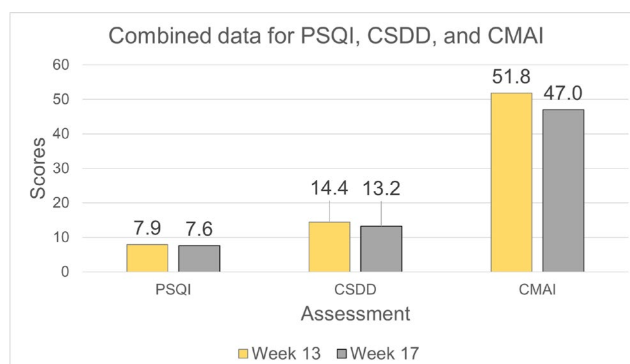


Figure 5. Average subjective sleep quality (PSQI), depression (CSDD), and agitation (CMAI) scores at the end of the intervention (W13) compared to a post intervention assessment after a 4-week washout period (W17).

On an individual basis for these subjective assessments, some participants' results trended in the right direction (highlighted in green boxes), but others trended in the opposite direction, reflecting individual differences and perhaps highlighting the high variability of the participants' conditions (Figure 6).

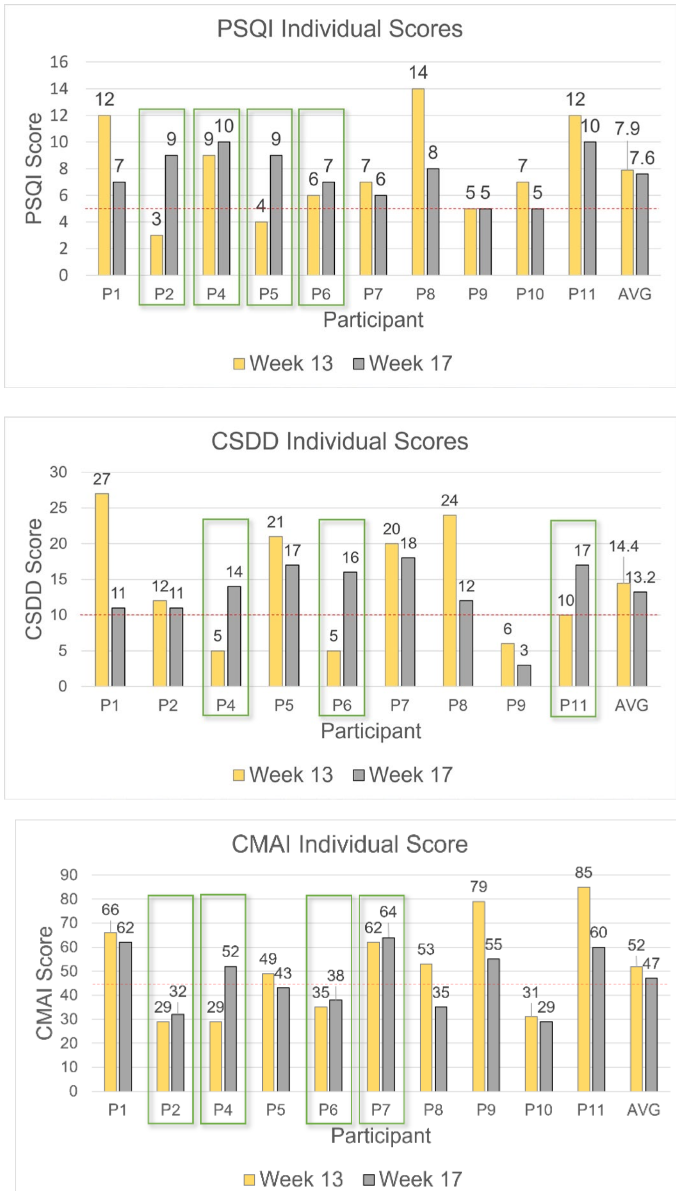


Figure 6. Individual results for participants, looking at scores for subjective ratings on sleep quality (PSQI), depression (CSDD), and agitation (CMAI), at the end of the intervention (W13) compared to a post intervention assessment after a 4-week washout period (W17).

Conclusion

Limited participation and compliance in the study resulted in data that is not statistically significant. Initial usable data showed promise, however, trending in the same direction as multiple internal[1-4] and external[5-7] studies, especially in the objective actigraph sleep data. After 12 weeks of daytime exposure to the light table, participants fell asleep faster, woke up less frequently during the night, and had better sleep efficiency (i.e., percentage of time spent asleep while in bed).

Additionally, the process provided a valuable experience of the difficulties that can be encountered when implementing creative solutions in real world applications. The electrical cords powering the table could create a trip hazard, for example, especially if a table was placed in the center of the room. One solution would be to position tables on the room's perimeter. Alternatively, a battery tucked into the frame could be used for power, but that would add to the facility's maintenance load and necessitate swapping out multiple batteries. Energizing the light tables for only a few hours in the morning would make the batteries last longer. Lastly, if the budget permits in future interventions, the best solution may be to install floor receptacles at the light table locations. These findings can benefit and expedite future designs for other sites looking to integrate light tables into their facilities.

Overall, the light tables were well received by residents and staff of the Abe's Garden community, with comments that the tables were comfortable to use, whether seated in a typical chair or wheelchair, and were not too bright or glaring. The light tables are not only an effective/efficient way of delivering circadian-effective light, but are also an elegant and flexible long-term solution to integrate into a daily routine.

Next Steps

To achieve statistical significance in study results, it is necessary to run more participants under the same protocol. Ideally, this could be done as a follow-up study with Abe's Garden under a supplementary grant since the light tables are already installed. Additionally, the team could monitor individual exposure to light to get a better understanding of how much stimulus participants are getting.

To promote the use of light tables in more senior care facilities, the LHRC could also expand the research to other senior care sites. With the initial design and development process of the light tables complete, Dean Babin could create more custom-built tables to fit the needs of other senior care facilities.

As shown in the final assessment period (week 17) after the light tables had been turned off for 4 weeks, participants began to lose positive progress made while the light tables were on (e.g. sleep efficiency reduced and more nighttime waking occurred). This highlights the importance of integrating the use of light tables into the daily routines of residents to promote better sleep. Abe's Garden should continue to encourage residents to use the light tables during the day.

References

1. Figueiro M, Plitnick B, Rea M. Research Note: A self-luminous light table for persons with Alzheimer's disease. *Lighting Research and Technology*. 2016; 48: 253-259.
2. Figueiro MG, Sahin L, Kalsher M, Plitnick B, Rea MS. Long-term, all-day exposure to circadian-effective light improves sleep, mood, and behavior in persons with dementia. *Journal of Alzheimer's Disease Reports*. 2020; 4: 297-312.
3. Figueiro MG, Plitnick B, Roohan C, Sahin L, Kalsher M, Rea MS. Effects of a tailored lighting intervention on sleep quality, rest–activity, mood, and behavior in older adults with Alzheimer's disease and related dementias: A randomized clinical trial. *Journal of Clinical Sleep Medicine*. 2019; 15: 1757-1767.
4. Figueiro MG. Light, sleep and circadian rhythms in older adults with Alzheimer's disease and related dementias. *Neurodegenerative Disease Management*. 2017; 7: 119-145.
5. Shochat T, Martin J, Marler M, Ancoli-Israel S. Illumination levels in nursing home patients: Effects on sleep and activity rhythms. *Journal of Sleep Research*. 2000; 9: 373-379.
6. Shishegar N, Boubekri M, Stine-Morrow EAL, Rogers WA. Tuning environmental lighting improves objective and subjective sleep quality in older adults. *Building and Environment*. 2021; 204: 108096.
7. Sloane PD, Williams CS, Mitchell CM, Preisser JS, Wood W, Barrick AL, et al. High-intensity environmental light in dementia: Effect on sleep and activity. *Journal of the American Geriatrics Society*. 2007; 55: 1524-1533.

Appendix A – Contact Information

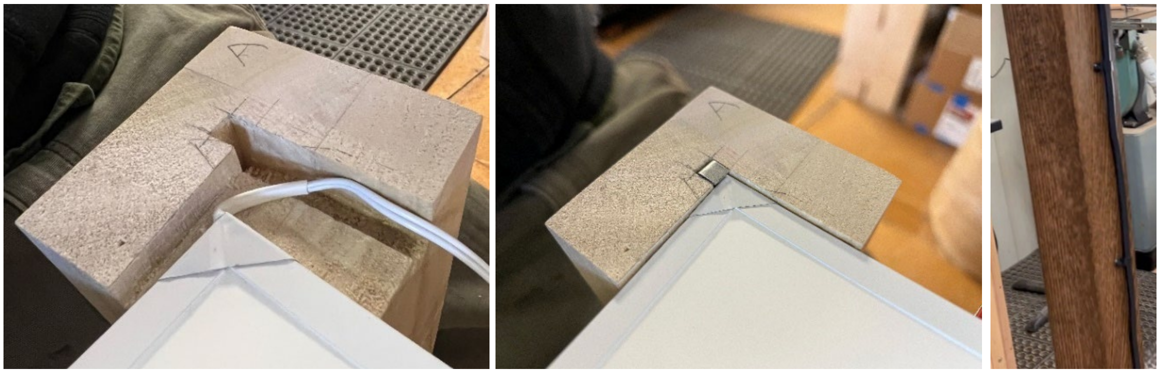
Association	Name	Contact	Role
Light and Health Research Center (LHRC)	Mariana Figueiro	mariana.figueiro@mountsinai.org	Main contact for decisions and study design
	Allison Thayer	allison.thayer@mountsinai.org	Main contact for study organizing
	Barbara Plitnick	barbara.plitnick@mountsinai.org	Actiwatch data
	Martin Overington	martin.overington@mountsinai.org	Technical support for lights and measurements
	Charlie Jarboe	n/a	Technical support and initial study design
Abe's Garden	Chris Coelho	chris.coelho@abesgarden.org	Main contact for decisions
	Misty Hogan	mhogan@abesgarden.org	Main contact for data collection
	Lacola Parker		Administered subjective CSDD, CMAI, and PSQI assessments to participants
Dean Babin Furniture	Dean Babin	deanbabin@gmail.com	Light table design and construction
Diode LED	Michelle	quotes@diodeled.com	Provided quote for light panel

Appendix B – Light Table Details

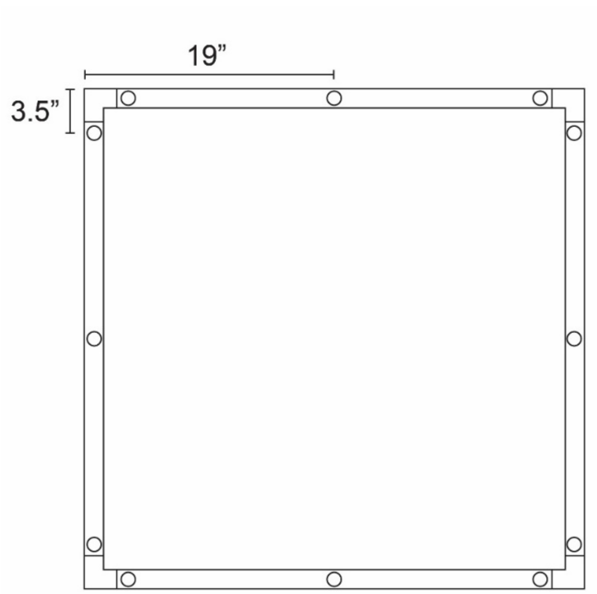
Table Components

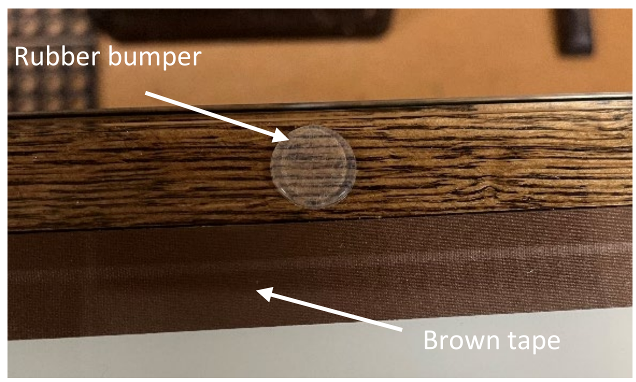
- **Glass**: 39" Square Clear Glass Table Tops – 3/8" – Flat Polish
- **Driver**: LED Driver 60 Watts Waterproof IP67 Power Supply Transformer Adapter 100V-260V AC to 12V DC Low Voltage Output for LED Light, Computer Project, Outdoor Light and Any 12V DC led Lights
- **Electrical Enclosure**: Armacost Lighting 970002 Armacost Screw Cover Power Supply 14x3x2 (Medium) Electrical Enclosure, White from Amazon
- **Power Switch**: APIELE 10Pcs Rocker Switch ON Off KCD1 Mini Round Toggle Switch SPST 2Pin Snap-in Design Car Boat Automotive with Wires Pre-Wired AC 6A/250V 10A/125V 12VDC
- **Light panel**: Custom 36" x 36" 4 edge-lit light panel
- **Adhesive-backed rubber disc bumpers**

The prototype table has a 10-foot cord, while the other 4 have a 15-foot cord. This cord length can be adjustable by using the holder to contain cord slack.



The framework contains a channel to support the wiring from the light fixture (Left and middle). The power cord runs discretely down one table leg and fastened intermittently so that it is not dangling (right).





Location of rubber bumper placement to avoid sliding of glass top. If replacement of the custom light panel is needed, the glass top can be removed. It is suggested to have 2 people handling the removal of the glass top, wearing gloves (e.g. rubber or cloth) when handling to prevent smudge marks on the bottom of the glass. Brown gaffer's tape around the edges was used to cover the bright hotspot created by the light.