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I, Andre Anderson, hereby submit this original work as part of the requirements for the degree of Master of Design in Design.

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Psychological Lighting Guidelines for Designers

Student's name: Andre Anderson

This work and its defense approved by:

Committee chair: Gerald Michaud, M.A.

Committee member: Nicholas M. Germann, M.A., MARCH

Committee member: Tony Kawanari, M.A., I.D.
Psychological Lighting Guidelines For Designers

A thesis submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of

Master of Design

In the school of Design
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(DAAP)

Andre Anderson
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Committee
Chair - Gerald Michaud, MA
Member - Nicholas Germann, MArch & MDES
Member - Tony Kawanari, MA & ID
Some designers create things to show you what they did.
I design things to tell you what I solved.

- Brian Yerkes
The proliferation of handheld electronic devices, and other sources of nighttime lighting have contributed to a rise in light-related behavioral issues. Researchers have determined that the color temperature of light we utilize throughout the day can affect our circadian rhythms, mood, and levels of melatonin. Because of this, we can design lights that will positively affect users. This thesis explores designing lights specifically for their positive effects. In doing so, we will have illustrated the beneficial crossroads that results from combining information from two disparate fields, (psychology and design). We will also explore the design of fixtures surrounding these lighting sources, and develop a set of lighting design guidelines, (specifically for the bedroom, bathroom, kitchen, home office, and living room) based on the positive effects of lighting on human behavior.
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Background

How does lighting affect us?

Problem Statement

While the community—and research—around lighting is robust, there are no resources for lighting designers that spell out how they can utilize current trends in lighting research in their designs. This thesis addresses this problem, and combines two fields of study by analyzing, and summarizing lighting research, and providing examples of how it can be applied to light fixture design.

Introduction

Manipulating light is a daily ritual for people. From opening and closing window shades, to placement of lamps, to turning artificial light sources on and off, we all bend light to our will. However, with our modern dependence on lighting, and the extra usable hours in a day it brings, we need to be cognizant of the effects such dependence can have. I was initially intrigued by these potential effects when I noted the increasing prevalence of software like “f.lux” which is touted as a way to make your life better by making your computer screen adapt
to the time of day; making it warm at night and cool during the day. I needed to know if this was true, and if there were any measurable effects from warm or cool light. I dove deep into lighting research and found that lighting does have a significant impact on us as humans.

In order to shed some light on these effects, I have analyzed research regarding lights, and its effects on humans. We utilize this research to inform the design decisions around both light source and fixtures for designers. Prior to this research, there was no guidebook for product designers that wanted to make lighting that had positive effects.

Within the broad category of lighting one could conceivably go back in time millions of years, as the sun is our original light source. However, we will deal in the realm of man-made lighting, the first instance of which was harnessed around 125,000 BC (8). As a result, Homo Erectus was no longer forced to constrain activities to daylight hours. After some time, there was a refining
**TIMELINE**

Major Historical Developments of Light Sources and Selected Luminaires

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**Seventeenth Century**
Candles made in molds.

**Eighteenth Century**
Ami Argand fixture late 1700s.

**Nineteenth Century**
Gas streetlights and fixtures.
Electric arc lamps: Sir Humphrey Davy (early 1800s).
Kerosene fixtures.
Incandescent lamp: Joseph Swan and Thomas Edison (late 1800s).

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**Twentieth Century**
Transitional fixtures: electric combined with gas (gas-electric).

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**Twenty-first Century**
Advancements in LEDs.
Exploration of OLEDs.
Sharon Marston.
(Courtesy of Sharon Marston Studio.)

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**Sixteenth Century**
Oil lamps: copper and bronze.
Candles made by dipping: expensive from beeswax; least expensive and most common tallow (dense animal fat).

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**Seventeenth Century**
Candles made in molds.

---

**Eighteenth Century**
Ami Argand fixture late 1700s.

---

**Nineteenth Century**
Gas streetlights and fixtures.
Electric arc lamps: Sir Humphrey Davy (early 1800s).
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**Twenty-first Century**
Advancements in LEDs.
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Sharon Marston.
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in the technique of harnessing fire; 70,000 BC (7) Humans of this time would fill a hollow rock of some sort with moss, then soak it in animal fat and ignite it. It was over 50,000 years before humans took this technology and created the oil lamp. It was over 1,000 years after that, wherein humans took the oil lamp and created candles in 3000 BC.

*How do we see Light?*

Our early invention and control of fire may have driven our species’ evolution. This is what Richard Wrangham of Harvard University argues in his book “Catching Fire: How Cooking Made Us Human” in it, he argues that our brains and digestive tracts grew because of our increased ability to cook food. Cooking food makes it easier and faster to digest. Because of this, it could be said our desire to illuminate the night has always been a driving factor for our species.
Humans have had a long time to perfect lighting. From an object filled with moss to light switches in our homes that ignite combustibles on demand. Throughout time, we have benefitted from the additional time for activities that artificial lights provide us with. However, we may finally be experiencing adverse effects from our increasingly nocturnal lifestyles.
People are going to sleep later in the evening. A number of experts believe society’s use of artificial light at night influences this trend; a trend that may have far reaching effects. In today’s world we are seeing many more instances of Seasonal Affective Disorder, with more than 3 million U.S. cases last year. Seasonal Affective Disorder is a mood disorder, or type of depression, that’s related to changes in seasons. Often these changes start in the fall and continue into the winter months. However, we are able to combat these growing trends with the cause of the problem itself, artificial light. A number of companies, (including Phillips) have begun to address this with light therapy devices meant to mimic the sun’s rays. The research that has been conducted into light and its therapeutic effects shows a link between color temperature of light, and levels of melatonin, mood, and alertness.

In an experiment designed to measure alertness and cognitive performance, S.L. Chellappa found that color temperature significantly impacts circadian rhythm and cognitive performance. Volunteers were exposed to lights of temperatures 6500k, 3000k, and 2500k for two hours. These volunteers completed questionnaires and cognitive tasks during the experiment. What they found was when volunteers were exposed to light at 6500k, they reported being less
sleepy, a finding supported by the fact that their bodies secreted less melatonin with 6500k light exposure. In addition, both lower color temperatures made volunteers sleepier, secret more melatonin, and self-report feeling subjectively less good.

A paper by JJ Gooley, “Exposure to Room Light before Bedtime Suppresses Melatonin Onset and Shortens Melatonin Duration in Humans” shows evidence of this trend. Gooley states: Exposure to light both resets the circadian rhythm of melatonin and acutely inhibits melatonin synthesis. In Gooley’s study, 116 healthy volunteers lived in a research center for five days. These volunteers were exposed to 200 lux and 3 lux lighting in the eight hours before bedtime. 99% of these volunteers experienced later melatonin onset, and shorter melatonin duration when exposed to 200 lux, in comparison with 3 lux lighting. Gooley states:

These findings indicate that room light exerts a profound suppressive effect on melatonin levels and shortens the body’s internal representation of night duration. Hence, chronically exposing oneself to electrical lighting in the late evening disrupts melatonin signaling and could therefore potentially impact sleep, thermoregulation, blood pressure, and glucose homeostasis.
Gooley’s statement is backed up by A.J. Lewy and T.L. Shanahan, who state: [We] report that light of higher intensity than that used in previous studies unequivocally suppresses melatonin secretion in humans,” and “Bright-light exposure induced substantial and equivalent phase shifts of the melatonin and temperature rhythms.” Not only does light affect melatonin and circadian rhythm, but it also affects mood. Blue shifted light has been shown to elevate mood in many people (10), as shown in a preliminary study by Noguchi et al. These findings indicate color temperature and brightness of lighting can affect humans in psychological, behavioral, and physical ways. Specifically, lighting can affect: attitude, stress, satisfaction, levels of melatonin, perception of space, Seasonal Affective Disorder, motivation, mood, cancer, hormones, growth, and sleep, among many other things.

This can—and should—be used to inform design decisions in all disciplines. It would be a shame to detract from all of these positive effects by creating a lamp which is purely functional, one which utilizes the correct color temperature, (for the bedroom environment) is task oriented, and positioned correctly, but is ugly. Why frustrate the user by providing something that helps them, but make it hard to use and aesthetically unpleasant? This is an important aspect for lighting design—all design—because humans perceive there to be a strong correlation between beauty and usability; and products that are easy to use contribute to feelings of positivity, which will aid in typical office tasks.
Donald A. Norman directly addresses this:

… emotions aid in decision making. Positive emotions are as important as negative ones—positive emotions are critical to learning, curiosity, and creative thought, and today research is turning toward this dimension. One finding particularly intrigued me: The psychologist Alice Isen and her colleagues have shown that being happy broadens the thought processes and facilitates creative thinking. Isen discovered that when people were asked to solve difficult problems, ones that required unusual “out of the box” thinking, they did much better when they had just been given a small gift – not much of a gift, but enough to make them feel good. When you feel good, Isen discovered, you are better at brainstorming, at examining multiple alternatives. And it doesn’t take much to make people feel good: all Isen had to do was ask people to watch a few minutes of a comedy film or receive a small bag of candy.

This explains the need for good usability, and partially, aesthetics. Perceived beauty is a very important factor in lighting design, and design as a whole. Again, products that are aesthetically pleasing are seen as more easy to use than their less pleasing counterparts. On a more subjective level, designs that can be considered “beautiful”, inspire a visceral response in those that experience them.
As humans, we are genetically predisposed to prefer certain conditions: warmth, rhythm, symmetry, smiles, laughter, harmony, sweets, melody, and saturated hues. These conditions often manifest themselves in product characteristics. Visceral reactions to a device affect how one feels while using it. Hence, if a light source was designed to create positive moods in the user, but the fixture inspired a negative visceral reaction, it would work against the very beneficial effects of the light source itself.

*Argument*

When designing for any environment, there are many questions a designer should ask themselves in regards to lighting. In addition, the research into the health benefits of color temperature complicates lighting design. In order to guide designers through the process of lighting an area for the positive health benefits proper lighting can bring, I have compiled a list of guidelines.
Lighting and Color
Correlated and Non-Correlated

Lighting can relate to color in two ways: Color temperature, and Color Rendering Index. Color temperature is how white a light source appears on a scale from reddish/orange to bluish white. Typically, temperatures 5000K and over are referred to as cool, and 2,300K-4000K are referred to as warm.

CRI, or Color Rendering Index is a measure of how accurately a light source reveals the colors of other objects. You’ll see CRI on the specifications of light sources as a number 0 to 100, (100 would be a light source identical to daylight) the closer to 100 the CRI, the more likely it will be for objects to look the same under the light source as under daylight.

Cool Vs. Warm
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**CRI Values**

In this image we can see how light sources with high CRI values accurately reveal more colors. The LED is missing some colors in the blue wavelength, while the fluorescent example has some peaks and misrepresents some colors.

**Color Temperature Values**

The black curving line on this diagram represents the different temperatures light sources can be. Here we can clearly see the progression from warm to cool.

**Other Types of Color**

This information does not apply to lights that are not similar to a black body (the sun is a black body). As such, purple, green, pink lights, etc. are not referred to as having a color temperature, and not tested for accurate color rendering.

“What is color? No object of itself alone has color. We know that even the most brightly colored object, if taken into total darkness, loses its color. Therefore, if an object is dependent upon light for color, color must be a property of light. And so it is.” Paul Outerbridge
This research has led to a number of guidelines that would assist a product designer when designing light fixtures. All potential variables will not be addressed in this manual, but it will provide a number of possibilities which can then be adapted to specific use-case scenarios.
When thinking about form for any light fixture, keep three steps in mind:
1. Enticement
2. Relationship
3. Fulfillment

Julie Khaslavsky and Nathan Shedroff suggest these steps will tap into the seductive power of design:

The seductive power of the design of certain material and virtual objects can transcend issues of price and performance for buyers and users alike. To many an engineer’s dismay, the appearance of a product can sometimes make or break the product’s market reaction. What they have in common is the ability to create an emotional bond with their audiences, almost a need for them.

Seduction...is a process. It gives rise to a rich and compelling experience that lasts over time. Yes there has to be initial attraction. But the real trick—and where most products fail—is maintaining the relationship after that initial burst of enthusiasm.

Enticement alludes to making an emotional promise to users. This is achieved by intriguing them, which will divert their attention to your form. Deliver novelty, or surprise, and you will create a visceral reaction in your users. This step is all about the visceral reaction of users to beauty. The relationship step expands upon this by continually fulfilling the promise designs make while enticing users. This step is more concerned with how design manages to connect to the values of users. The goal is to change the routine act of turning a light on, or lighting a space into an experience.

...innovative approach, simplicity, and elegance in shape and performance creates an appreciation and the desire to possess not only the object but the values that helped create it, including innovation, originality, elegance, and sophistication. It speaks as much about the person that owns it as it does about its designer.
Ensure the form is something that can stand on its own in a space, and manage to entice, and create a relationship with users. Ensure the form is elegant in a way that many sculptures are; this will serve to continually fulfill the promises set forward in the enticement step. In doing so, the fixture will be transformed into something that not only speaks for the designer, but for the user as well; for in owning this fixture, they are ascribing to the values used to create it. Fulfillment, refers to the need to end the experience in a memorable way. This requirement can be fulfilled by giving thought to some ways the fixture, and its form, can lead the user to discover something. This discovery need not be about the fixture, it can be something as simple as “even the ordinary things in life can be interesting.” This meaningful thought will lead users to enter into a deeper relationship with the fixture; the fixture will now serve as a physical representation of these positive feelings, in addition to a light source.

Lighting provides a unique challenge. The number of design issues that can present themselves are almost limitless, and encompass an enormous variety of structures. The ways a client can use a space varies widely, not to mention the large difference in furniture and other decorations that can greatly change how one would light a space. All of this only adds complexity to an already complex design challenge. As such, the most important guideline is to be sensitive to potential users’ needs.
The water bottles on the left and right are clearly aimed to please at the viseral level; the middle one, well, it is efficient, it is inexpensive, and it works. The bottle on the left, for *Perrier* water, has become so well known that the shape and its green color are the brand. The bottle on the right is by *TyNant*, a bottle of such a pleasant shape coupled with its deep, cobalt blue color that people save the empty ones to use as vases. The clear plastic bottle is by *Crystal Geyser*: simple, utilitarian, effective when you need to carry water with you.
BEDROOM

Occupants will appreciate a diffuse, ambient light with a low temperature—2700k—will create the relaxing, and less visually compelling atmosphere necessary in the bedroom, and in turn, inhibit melatonin less than that of more blue shifted lights. This will enhance occupant’s quality and duration of sleep. When designing fixtures for this environment, incorporation of lighting for the evening should be considered; this can be easily achieved through incorporation of occupancy, or motion sensors. Evening illumination promotes safe travel through the space. In addition, if more than one person is sharing the bedroom, the designer should consider how to create a suitably lit environment for the first person to get up, while keeping the environment dark for the other occupant(s).

Form

When deciding on materiality keep in mind the light source for this environment is a soft light, which is slightly red in hue. Avoid materials that will not look as you intend them to in this light. Natural materials will compliment the red shifted light in this environment well, as the light source is close to fire in terms of color temperature.

Mood

Combining the soft edges of the fixture with low temperature lighting will
support a relaxed environment. This could help with user sleep quality by making the bedroom an unsuitable environment to do work, making the user more likely to seek out other work environments. This will make it easier for users to reserve the bedroom for sleeping, and limit the prevalence of devices that will negatively affect their circadian rhythms in bed.
Guidelines for the Bedroom

• Ensure the color temperature of your lights is warm. 2,000K - 3,000K

• Consider adding options for evening illumination, such as motion sensors.

• Keep your color temperature in mind when selecting materials. Place a sample of your material in the intended light to see how it will look.

• Remember, the bedroom is supposed to be used only for sex and sleep. Ensure the mood you are creating supports these activities.
KITCHEN

The kitchen requires a delicate combination of ambient and task lighting in order to support the various activities that occur in this space. Remember to be flexible in designing for this area. A combination of ambient and task lighting is recommended in order to reduce the danger of burns and cuts. Lights above 6500k in temperature will allow for detail oriented tasks to be performed equally well in this space throughout the day and night. Task lighting should be concentrated around the sink, counters and cooking ranges. Some common locations for lighting include: the underside of wall cabinets, recessed ceiling cans, and suspended cabinets. Because many surfaces in kitchens are shiny, glare is often a problem in kitchens. As previously discussed, you can combat this with careful placement of luminaries, or diffusion, which will reduce the brightness of a light source, and make it more palatable.

Please take care with the color rendering of lights used in this area. Color rendering is a measure of how accurately a light source shows color of objects. The International Commission on Illumination defines this as: “Color rendering: Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant.”
Form

The kitchen is a dynamic workstation. This means form, and subsequently, the mood you would like to set need to be even more firmly rooted in chosen potential user personas. However, keep in mind that the kitchen is a dirty place. The materials used should be made easy to clean, and should address the problem of glare in the kitchen.

Mood

The kitchen, like the living room, will be used in many different ways by users. Some will see the space as strictly a task oriented space, while some will treat the space as a communal area, talking, eating, and helping the food preparer. Ensure that your lighting can serve as task lighting for at least a portion of the time it is being used and you will have made great strides towards a very good kitchen light. In addition, floor and counter space are some of the most precious in the kitchen. Stay away from fixtures that would take up this valuable space.
Your lights should have a high CRI, for accurate color rendering of vegetables, meats, etc.

- Avoid taking up floor and counter space
- Look into easily cleaned materials
- Try to incorporate task lighting

**COMPARISON OF HIGH AND LOW CRI**

The left image was shot with a fluorescent lamp of CRI 92+, while the right image was shot with a fluorescent lamp of approximately CRI 80. Note that the two images have some similar colors, but the floor, cutting board, and carrots appear very different.

Guidelines for the Kitchen
In the home office, most tasks that will take place are detail oriented. From drawing, and writing to checkbook balancing, the lighting needs to adapt to these tasks. In addition, keeping in mind that layout, or furniture arrangement can change to support different tasks is advisable. Lighting that supports these tasks should be of a high, blue shifted color temperature. Keep in mind glare occurs when light is reflected into a user’s eyes, or a light source is much too bright for the surrounding environment. As the designer, you may want to design several fixtures that can be used in conjunction to address the multiple potential working areas in this space. Task lighting combined with general, ambient lighting can have some wonderful effects.

**Form**

The office is strictly a task oriented environment and the form should reflect that. Users should be able to adjust the height and amount of their lighting illumination. As mentioned before, glare is a concern in the office. Ensure the placement of your fixture can be adjusted to account for possible sources of glare. If the placement cannot be changed, account for this by diffusing the light source to mitigate any possible glare.
Mood

The mood being cultivated is that of productivity, for this the color temperature of 6500K is appropriate. In addition to the color temperature, and the form’s ability to support task based work, we may want to look into color psychology here. However, rather than discussing the aspects of color psychology that are more anecdotal, (red will lead people into wanting to talk more, etc.) we will focus on one thing that color psychology seems to have more clout regarding. Specifically, that different cultures and regions perceive certain colors differently. For example, a Japanese person may not associate the color red with anger, as an American might. This is all to say, keep in mind cultural differences, if making something for an East Asian Market, do research into what colors are associated with a productive mood in that culture.
**ARTICULATION**

The joints on the common articulating desk lamp are a perfect example of designing to allow users the ability to adjust illumination. With the many different joints, users can account for glare, and different types of tasks.

**PLACEMENT**

The placement of a light source can have far reaching effects. It can lead to glare, eye strain, or general discomfort. Allowing the user to adjust the light source mitigates these issues.

Guidelines for the Home Office

* Utilize a high color temperature, 6500K or more
* Incorporate ways for your users to change the height, angle, and amount of illumination
* Keep cultural differences in mind when designing
“Bathrooms require a combination of lighting, task, and mood. A high color rendering lamp, one that shows colors accurately, is best for grooming.” (IENSA, 2000) Lighting for the mirror area should be careful to light the user’s face, and not the mirror itself. Tasks around the sink, and vanity area are typically very detail oriented, and as such should employ lights of 6500k or higher. However, these lights should not be relied upon to create the mood and atmosphere of the bathroom. In order to create a warm and inviting atmosphere, indirect lighting of 2700k in color temperature should be employed. This temperature can also be used for night time lighting, as it will disturb the user’s circadian rhythm less than lights of a higher color temperature, such as that of the task lighting. Night lighting is as important, if not more important, as in the bedroom. This space is often frequented in the dark hours of early morning and late night.

Form

The bathroom shares similarities with both the kitchen and bedroom. This area of the home will likely be frequented at night, and fixtures placed within its boundaries should be careful not to encroach on valuable floor and counter space.
Mood

While many people “escape” to their bathrooms, it is also an environment for tasks. Therefore, the mood you set cannot be too relaxing. It would be in your best interest to create a fixture that could serve as relaxing lighting, and also be changed to switch the mood to a more work friendly environment. A good way to accomplish this would be dimmable wall sconces. These can be positioned to reduce glare from any mirrored surfaces, and set both a working mood for tasks, and a relaxing mood for bubble baths and the like.
A MIX OF MOOD AND TASK

The placement of the light sources in this bathroom is excellent. The lights surrounding the mirrors provide bright, blue illumination, while the hanging light we can see in the mirror provides a relaxing mood.

Guidelines for the Bathroom

• Ensure your fixture lights the user’s face, not glare prone surfaces like the mirror
• Indirect lighting should be 2700K, direct lighting 6500K
• Consider ways to light the environment for night, and use lights of 2700K for this purpose
A multi-purpose space like the living room would need to accommodate a variety of tasks, and as such should provide occupants with color temperature options. Blue shifted light of higher wavelengths would be useful in daytime hours, or for detail oriented work in the night (such as putting together a puzzle).

Lighting may be diffuse or directional. Diffuse light minimizes shadows and provides a more relaxing and less visually compelling atmosphere. When diffuse light is used alone, no object in the visual scene is given prominence. Artful use of directional light can provide highlights and shadows that emphasize texture and form.

Light of a lower, more red shifted temperature (2500k) would help in creating the aforementioned relaxing and less visually compelling atmosphere. In the evening hours, this light would aid in melatonin production, helping the occupants go to sleep faster, and stay asleep longer.

Form

Unlike some of the other environments one could be designing for, the living room typically has an abundance of floor space. Feel free to experiment with floor lamps, table lamps, etc. While one can certainly adopt an adaptable approach similar to the bathroom for the living room, I would suggest some specialization in this environment—especially if you see yourself
designing for large, expansive living rooms. Uplights are a common sight in living rooms, and for good reason; they provide a lot of ambient light and mitigate harsh glare.

Mood

As this is another multi-purpose space, I would let my form inform my mood. If your form is a downlight meant to help the family perform tasks on the living room coffee table, you should be looking to set a mood that enhances productivity (and as such, would want a higher light source temperature). Match your form to your mood, and your mood to the temperature of your light source. If you decide to design a type of uplight, a lower temperature light source is your friend. You want the mood of your ambient light to be relaxing, but still visually compelling.
OPPORTUNITIES TO EXPERIMENT

The living room is a great place to experiment with different types, and forms of light sources. It is an area wherein lights are often displayed as art, and shown to guests.

DIRECTIONAL LIGHTING

Lights can emit light in distinct ways. Some of these ways are, (a) down/direct lighting, (b) up/indirect lighting, (c) direct-indirect lighting.

Guidelines for the Living Room

• Consider all the different types of tasks that can, (and will) take place in living rooms
• If you are looking to create a relaxing mood, use 2700K lights
• If you are looking to set a more productive mood, use 6500K lights
This thesis illustrates the crossroads that occurs from combining information gathered from two separate fields. By combining research from the field of psychology with guidelines for good design and good lighting, we can positively affect users on a physiological level, in a very palpable manner. The guidelines defined, when applied to lighting, can make for interesting new user interactions. It would be wonderful for all bedside lamps to make their users tired, instead of more awake.

My argument is psychology and its findings provide designers with interesting insights to utilize when designing, and as such, more evidence based research should be visibly incorporated into designs, especially those involving lighting.
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GLOSSARY
Color Rendering Index (CRI) – The measure of a light source’s ability to show object colors “realistically” or “naturally” compared to a familiar reference source, either incandescent light or daylight. (Lighting Research Center, 2015)

Diffuse Light - Light that is spread out at many angles, as opposed to specular light

Specular Light- Light that has a single outgoing direction. Also known as direct light

Lumen – Lumen is the unit of luminous flux. One lumen is the amount of light striking a one-square-foot area, all points of which are 1 foot away from a point source of 1 candela intensity. Lumen is abbreviated Lm (Applied Illumination Engineering, 1991)

Lux - One lumen per square meter
LIST OF ILLUSTRATIONS
• Light Spectrum, n.d. diagram <http://www2.estrellamountain.edu/faculty/farabeec/BIOBK/spectrum.gif>
• Neon (2003) by Paul Cockedge. (P. Cockedge_NeON_03_photo © Richard Brine)
• Light Reflecting, n.d. diagram <http://www.uen.org/Lessonplan/preview.cgi?LPid=33096>
• Color Temperature Room Lamps, Total. picture <http://media.totalfluorescentretrofits.com/media/images/cms/color-temperature-room-lamps.jpg>
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