TASK-AMBIENT LIGHTING: A SUSTAINABLE DESIGN METHOD INVESTIGATION

by

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Abstract

Today's engineers of building lighting systems must maintain a careful balance between the demands of accepted standards of practice, the necessity of life safety, the system performance needs of the client, and the developing national energy standards and certifications gaining prominence in the public eye. These sources of influence on the design process can create conflicts between the pressing need to conserve system energy usage and a costlier and perhaps unacceptable end-result for the client. In this climate, various governmental organizations and industry cooperatives have been funding published research and case-studies in order to promote sustainable design practices. Within these publications are repeated references to a "Task-Ambient" lighting fixture layout strategy. Multiple recent publications cite profound energy-saving benefits attainable using this design method. However, there is a noticeable lack of measured data concerning other qualities of this layout scheme, such as the end-user's comfort and ability to perform tasks under the resulting light distributions. Whether this lack of data resulted from the added complexity associated with such non-numerical measurements, or for some other unknown reason, this report explores this gap in the available data. An extended survey procedure was developed to approach the problem of measuring these unknown qualities of the Task-Ambient design strategy. This involved constructing multiple physical lighting layout mockups, defining the features of the Task-Ambient strategy which necessitated measurement, and designing objective tasks tailored to measure each of these non-numerical qualities. The careful analysis of this study's data results yields trends indicative of the Task-Ambient strategy, relative to a standard uniform layout, *adversely* affecting productivity, concentration, and the participants' subjective perceptions of the space's light distribution. The lowered level of energy use was however affirmed. The implications of these results are that the Task-Ambient strategy, while an efficient method of lighting system layout design, may not be beneficial for the client in other respects.

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Dedication

I would like to dedicate this work to my father – Tony Mark Caton. He passed away for medical reasons in his early thirties as a Major in the United States Army. This happened before he could see me finish middle and high school, before he could see me accepted into college, before he could have met the fiancé I met there and before he could witness my completion of a minor, bachelors and masters degree in engineering.

There have been many moments I would like to have shared with my father in this time span. He was an outstanding person, who shaped my character and values in a way I aspire to one day do for my own children. I occasionally wonder, even in these happiest times, what advice he would give, or what he might think of the decisions I make. I like to think that with this report, and at this stage of my life, my father would have been very proud and happy.

CHAPTER 1 - DISCUSSION

1.1 Scope

Task-Ambient is an approach used when designing the lighting layout for a space. In performance-oriented approach, the designer must define what lighting tasks exist in the space, intentionally deliver the desired light to those locations and restrict the amount of light distributed elsewhere in the space. The intended effects of this lighting layout strategy, relative to the typical uniform distribution commonly used otherwise, are improved levels of concentration and productivity for the end users, as well as savings in system installation and operating costs.

The intended reading audiences for this report are engineering students and design professionals with an interest in incorporating more energy-efficient lighting design practices into their careers. Knowledge expected of the reader will include terminology and procedures introduced in introductory lighting systems design courses offered for engineers at the undergraduate level. This report includes discussions in the fields of psychometry (the measuring of subjective feelings to gauge system performance), sustainable design, and lighting code and standards interpretation as well.

The case study discussed within this report is not principally intended to be an "application guide" for other lighting design projects, but rather to fill the holes in the available research on the Task-Ambient strategy. However, to that end, the case study does offer the interested lighting designer thoroughly documented objective and subjective feedback from the participants which may be directly applied to designs for similar projects. The reader intending to apply this data is asked to observe and weigh the stated limitations on this data including the restrictions on the chosen body of participants, the characteristics of the environment used, and the qualities of the light fixture configurations for each layout involved.

1.2 Why research this?

1.2.1 Conflicts: Energy Codes vs. Safety vs. System Performance.

The prospect of dealing with conflicts between accepted design practice, energy standards, and the client's performance needs is an intimidating one for a new engineer. Ultimately, such conflicts are unavoidable, so students preparing to work in the field of building systems design must push themselves to expand their capacity to work around these restrictions. The initial drive to explore alternative lighting design practices was fueled particularly by published debate regarding the restrictiveness of existing energy codes.

One such argument has appeared in the *LD+A Lighting Design and Application* journal against a proposed update for the lighting section of the 2010 version of Standard 90.1, co-published between ASHRAE and IESNA. The author, Willard L. Warren, PE, claims the proposal to lower the existing Lighting Power Density (LPD) limits in this standard by 30% is "preposterous." He reasons the LPD values cannot be lowered any further, because they already represent the lowest W/SF "that will produce the IESNA Lighting Handbook recommended illuminance levels." (Warren) This evidence of clashes between accepted design practices based on *The IESNA Lighting Handbook's* illuminance recommendations and today's energy standards was a key component in choosing to investigate the issue and explore ways to provide working solutions for such design problems.

Above all, engineers are held professionally to a standard of care that explicitly mandates "Hold paramount the safety, health, and welfare of the public" (NSPE). The safety, or lack of safety, provided by any lighting layout design, regardless of its level of sustainability, must not allow for unsafe conditions. This fact makes any attempt by an engineer to experiment with new methods of lowering a lighting system's energy efficiency through levels below the accepted standards a liability from a safety standpoint. Studying such techniques outside of a commercial design project and inside a controlled environment affords an interested engineer lowered levels of financial and safety risks.

1.2.2 Sustainable Design

The United States' national, state, and some city governments are, to varying degrees, pushing the concept of ecologically sustainable design in various ways, from national tax credits (Darragh) to city and state mandates and codes (Libby). Less than a decade ago, the US Green Building Council launched the LEED certification program, with the intent to develop buildings

which are "… environmentally responsible, profitable, and a healthy place to live and work" (USGBC: Why Certify?). The United States Department of Energy (DOE) is also funding research on sustainable technologies and concepts while promoting the benefits of energy-conscious design to commercial and industry building owners ("Efficient…). As a result, building owners and government officials are gradually becoming more aware of the immediate and long-term economical, social, and environmental benefits of "going-green" (Department…).

As a result of this changing climate in the commercial building industry, building systems engineers have a pressing need for more knowledge of and strategies for sustainable design. The Task-Ambient approach is one such strategy for meeting specific energy performance levels already mandated with standards published by the IECC, ASHRAE and IESNA, and encouraged by the current USGBC LEED building certification standards (USGBC 173-176).

1.2.3 Psychometrics and Evaluation of Lighting Design

A useful skill for any engineer to develop is the capacity to evaluate a finished design. In some cases, the question of whether a system's performance is adequate is simple to answer. Flex in a structural beam, flow through a water main, and the sustainable amperage in a power circuit can all be measured directly through various instruments and techniques. Systems whose performance is primarily based on comfort, however, such as mechanical, acoustic, and lighting systems, have a variable which cannot be measured directly – the subjective perceptions of the environment by the end-user. While we design such systems under directly measurable and quantifiable variables – such as the footcandle, cubic feet per minute (CFM), horsepower, and decibel levels – it is impossible to calculate the most base and indisputable measure of performance: comfort.

Psychometrics is the field of study concerned with how we can measure human attitudes and opinions (Hopkinson 133). Knowledge in this field is important for the development of any building systems engineer desiring an end-performance level meeting the needs of "comfort," above and beyond the accepted minimums and standards which we all learn to work within. This field of study offers rules and guidance for developing the questions and procedures necessary to make collected data useful and appropriate for drawing conclusions. Without investing the time and thought to ask the right questions, in the right manner, efforts to evaluate

one's own design may result in inconclusive, or worse, misleading data which may adversely affect future design work.

The application of this psychometric knowledge in this case study is to be found throughout the study preparation and data discussions in this report. The aspiring lighting system designer will do well to take note of the pitfalls of subjective measurements that were and were not anticipated, and how they were dealt with. Careful attention to proper psychometric measurements will assist in any future endeavors to evaluate one's lighting design work.

CHAPTER 2 - THE TASK-AMBIENT LAYOUT STRATEGY

This chapter explains in detail the Task-Ambient layout concepts and procedures, presents the benefits and detriments attributed to this lighting system scheme, states the hypotheses gleaned from this research, and asserts the need for a case study to test these hypotheses.

2.1 What is Task-Ambient?

It is easiest to begin a discussion of the Task-Ambient strategy by first reviewing and analyzing the defining aspects of the Uniform lighting layout strategy. Uniform layouts aim to provide a predetermined, even level of illuminance within a space across a fixed task plane. This level of illuminance is determined based on anticipated occupant activity. Light fixtures are selected and the minimum number required to meet the predetermined illuminance level is calculated. Finally, the fixtures are spaced and positioned in a manner that considers the actual space dimensions and shape, sometimes necessitating an increase beyond the required minimum number of fixtures. This increase is often due to the inability to place the fixtures in the rectangular, regular spacing that the Uniform calculation method assumes. This may result from existing devices or ceiling grids which cannot economically be moved, non-rectangular plan-view room shapes, or structural restrictions, affecting how the fixtures may be hung. The Uniform layout approach has certain established benefits. First, this model enjoys all the advantages of being a prescriptive method of problem solving – the rules, calculations, and application of Uniform layout design are identical within a wide variety of spaces and occupant classifications. As a result, this method saves time and money for the design engineer and client, due to the reduced time spent analyzing the unique characteristics of the project. Secondly, the use of Uniform layout generally results in a uniform distribution of light on the task plane, which can in some cases be viewed as a definite benefit: varying levels of light or patterns of light and dark on the task plane can be considered distracting or confusing for the end-user, and the location of actual task-surfaces on the task plane may not be determinable. It is important to note, however, that varying light levels may also provide a benefit (IESNA Lighting Handbook 10-5), which the Task-Ambient strategy will capitalize on.

Task-Ambient layouts, on the other hand, are concerned with distributing different levels of light energy to task and non-task surfaces. Task surfaces are those locations where the visual task being designed around actually occurs, such as a series of desktops, a marker board, or a drafting table. Non-task surfaces include areas of circulation and surfaces which require a very small amount of or, in some cases, zero light for tasks or safety purposes. Such surfaces may include the tops of bookshelves in a library, the carpet in a small office, or the walls of a corridor. Figure 2.1 Illustrates two layouts showing how a Uniform layout does not give regard to non-task areas, while a Task-Ambient layout positions fixtures with this in mind.

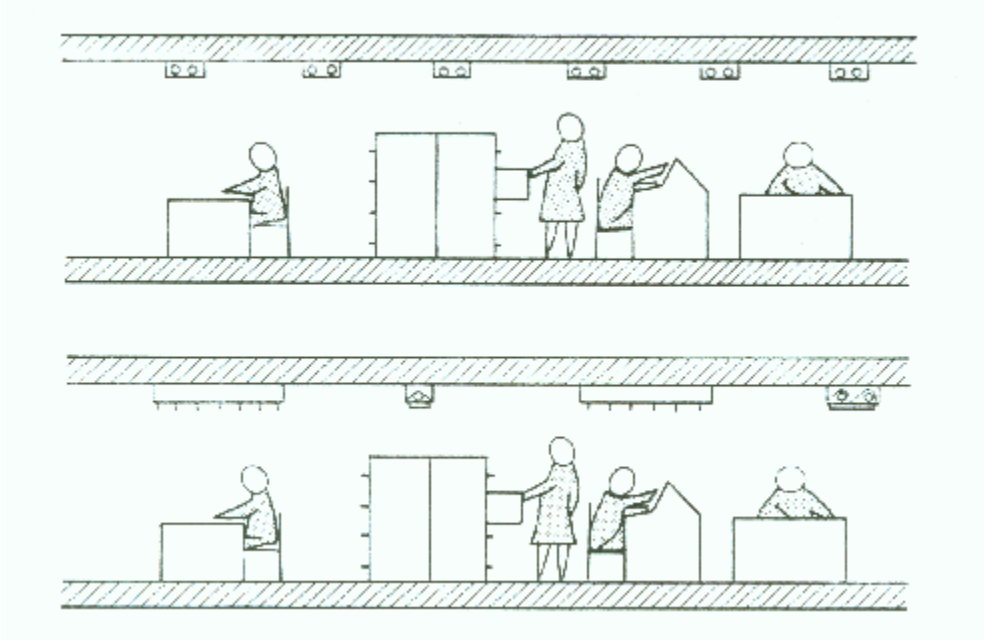

Figure 2.1 Uniform vs. Task-Ambient Layout Strategy.

Adapted from *Lamps and Lighting, 4th ed.*, by J.R. Coaton and A.M. Marsden, p.396

"Critics describe uniform lighting schemes as boring at best and wasteful at worst" (Trost 45). This statement introduces two potential drawbacks for the prescriptive Uniform Lighting approach. As previously stated, Uniform Lighting layouts generally feature luminance values with little variance across the task plane. This lack of variance can be considered "boring" by the client and/or the end-user. A more objective view of the uniform illuminance drawback is the resulting lowered distinction and contrast between areas of visual interest and background surfaces. Prescriptive, Uniform layouts may also be "wasteful" from an energy-use perspective.

Uniformly distributing light energy across the task plane may be likened to a farmer spreading fertilizer uniformly over a property, without regard to the location and orientation of the cornfield he or she planted. A more economical approach for the farmer would be to place fertilizer only where it is needed – using less fertilizer, saving money and helping the environment in the process. The Task-Ambient layout approach attempts to remedy both uniformity and energy-waste criticisms against the Uniform layout approach.

The Task-Ambient Lighting layout strategy is not a prescriptive, but a performance based design solution. The design process itself is characterized by necessitating more thought and time in fixture selection, anticipating tasks and their locations, and calculating the resulting luminance ratios between task and non-task areas. As a rule, this approach will consume more of the designer's time than a prescriptive one. As a result, the client must spend more money to obtain the design solution. The financial justifications for this are that the Task-Ambient strategy provides:

1. The potential for fewer fixtures, lowering the cost-of-construction
2. The potential for energy savings, lowering the operating cost of the system
3. Improved lighting design quality, potentially indirectly increasing the client's profits

To explain how the client may benefit from the improved lighting design quality, discussion on a few lighting distribution fundamentals is required. When an object in the visual field is brighter than its surroundings, eyes will instinctively focus on that object. This visual reflex has been well documented in merchandising applications, where the sales of impulse items can be directly related to brightness contrast (Trost 4). Conversely, object with little brightness contrast to their surroundings, will not as easily hold the focus of the viewer. This link between the visual senses and the mind is a central concept to the application of the Task-Ambient strategy. Lighting the task surfaces or areas of intended focus, in a space should increase the level of focus, simultaneously decreasing the level of distraction from sources in the surrounding visual field.

The implications of Weber's Law are another fundamental piece of the Task-Ambient layout strategy. Weber's Law of contrast states that the smallest perceptible change in luminance is proportional with the level of luminance. This assertion leads to the conclusion that "equal *proportional* differences of luminance should look equally noticeable" (Coaton 29). That

proportional difference between two luminance values is called a luminance ratio (IESNA Handbook 10-5). As an example, a painting in a museum illuminated with 50fc with the areas around it receiving 10fc (luminance ratio of 5:1) will look just as distinctive as the same painting given 25fc with 5fc surroundings. This is a very important thing to keep in mind when designing lighting solutions around the restrictions placed by stringent energy codes: the magnitude of energy put into lighting an area is not as important as the *relative* amount of light for the intended area of illumination.

Luminance ratios are therefore, for the purposes of energy conservation, an important concept to apply when developing performance requirements within the Task-Ambient layout strategy. The IESNA Lighting Handbook suggests lighting ceilings and walls within a luminance ratio of 3:1, to avoid "extremely different brightnesses." It also suggests work surfaces be given illuminance values of 1.5 to 3 times higher than the surroundings, in order to "assist in directing occupants' attention to the task." This particular ratio of 3:1 will be regarded for the purposes of studying this Task-Ambient strategy as the ideal ratio to approach in terms of maximizing the focus/distraction level benefits established through Weber's Law.

Task-Ambient is not exclusive to a certain lamp type, fixture type or quality of light, but is instead defined by the resulting applied lighting illuminance pattern. To this end, the designer must still consider other qualities of a lighting solution, such as the intended CRI values, potential for flicker and glare, lighting controls, and other aspects of the final design independently from the desire to benefit the client through the application of variance in illuminance values.

The process of Task-Ambient Lighting layout design is summarized as follows:

1. Define task surfaces, their location in the space, and the nature of the associated tasks.
2. Establish the desired illuminance for the expected task and non-task surfaces. These levels should be influenced both by industry accepted standards as well as the potential for benefit through applied luminance ratios.
3. Select fixtures with light distribution patterns providing focused light in a shape similar to the task surfaces', as well as diffuse lower levels of light for non-task areas.

4. Lay out the fixtures primarily using the shapes of the fixtures' light distribution as a guide. This is more easily accomplished using lighting design software which can quickly generate luminance measurements, as illustrated in the Figure 2.2:

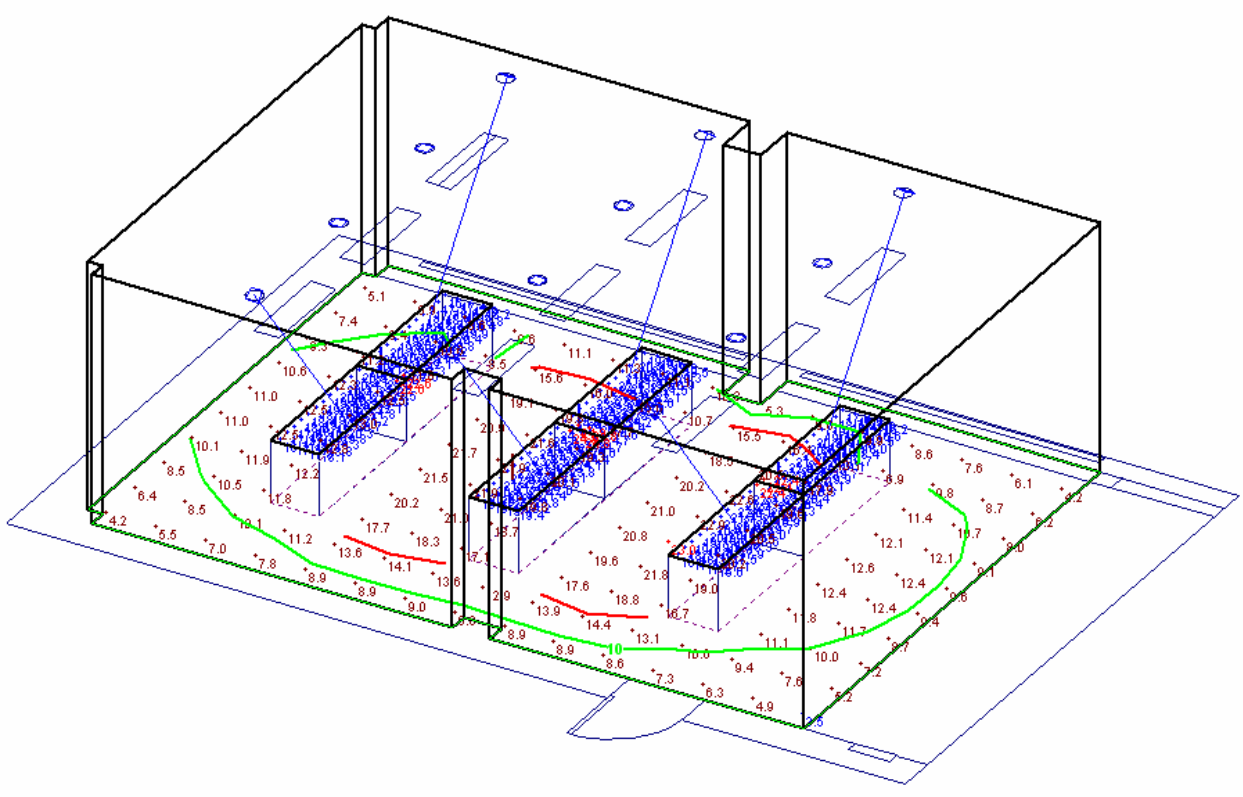

Figure 2.2 Visual - Lighting Design Software

2.2 The Need for a Case Study

Many sources unreservedly describe the potentially significant benefits of a Task-Ambient layout, from an energy perspective (Coaton, Newsham, Energy). Conceptually, this is the logical conclusion – light energy is not being "wasted" on non-task areas, allowing for less light to be produced, and thus less energy to be consumed by the lighting system. A case study published by the E-source Technology Assessment Group at Platts produced impressive energy-savings through a case study comparing a typical Uniform layout with the improved Task-Ambient scheme. These findings, typical of this sort of comparison, are presented plainly in Figure 2.3.

Table 1: Task/ambient lighting

This task/ambient lighting scheme costs no more to install than a standard one, but reduces installed lighting power by 35 percent.

	Typical (uniform)	Improved (task/ambient)
Ambient lighting system		
Design lighting level (foot-candles)	60	30
Luminaire quantity	18	9
Luminaire power (watts)	60	60
Total power (watts)	1,080	540
Task lighting system		
Task light quantity	0	10
Task light power (watts)	–	16
Total power (watts)	0	160
Total system economics		
Run time (hours per year)	2,000	2,000
Total system power density (watts per square foot)	1.08	0.70
Energy consumption (kilowatt-hours per year)	2,160	1,400
Incremental installation cost		0
Operating cost ($/year)	$216	$140
Savings ($/year)	–	$76
Savings (percent)		35%
Payback		Immediate

Notes:
- Ambient luminaire for both cases is a two-lamp T8 recessed troffer, electronic ballast, fixture coefficient of utilization = 0.80. Task light is a 13-watt compact fluorescent consuming 16 watts with ballast losses.
- Calculations assume a 20 percent difference between initial and maintained lumens (from lamp phosphor degradation, thermal effects, and dirt).
- Area of space = 1,000 square feet.
- Task light quantity assumes one task light per 100 square feet.
- Incremental cost for task/ambient system is zero or less, assuming $75 per ceiling fixture and a task light budget of less than $225 each.
- Electricity cost = $0.10 per kilowatt-hour.

Courtesy: Platts

Figure 2.3 Uniform vs. Task-Ambient Comparison ("Energy Design Resources" 5)

These results clearly illustrate the potential for reduced installation and operating costs when using the Task-Ambient strategy, relative to a uniform lighting layout. However, something is missing. While this study makes a compelling and logical argument for energy-efficient and economically sensible system design, it noticeably lacks hard data indicating that the "Improved" system is an acceptable lighting system for the end-users. This observation directly led to the conclusion that performing a similar but more thorough comparison study of

the Task-Ambient strategy would benefit the engineers and students concerned with the quality of their system designs. This more thorough study will include quantifiable, measured data that the Task-Ambient strategy also provides those elements of improved concentration and productivity, as well as savings for the end-client in energy use – complete with a return-on-investment analysis.

2.3 Hypotheses

After a careful review of the published articles and guidelines available concerning the Task-Ambient strategy, a number of recurring potential benefits were observed between the sources. The following three statements summarize

1. Task-Ambient Lighting improves the end-user's concentration on a given task by lessening the potential for distraction and diversion of the user's line of sight – through the beneficial effects of applied luminance ratios.
2. Task-Ambient Lighting improves the end-user's productivity, or the speed at which work is done, as an indirect benefit of the improved concentration.
3. The strategy of Task-Ambient lighting layout will generally save on installation and operating (energy) costs, relative to a uniform lighting layout for the same space.

CHAPTER 3 - TASK-AMBIENT CASE STUDY

3.1 Preparation for the Case Study

To establish the validity of the three hypotheses, a case study was designed, comparing a typical Uniform lighting layout with an "improved" Task-Ambient layout. The introduction of objective, measurable psychometric and performance data added complexity to the development of this case study. This chapter focuses on the key steps and concepts followed to prepare for the case study.

3.1.1 Defining What is Being Measured

To establish the validity of the three hypotheses, the developed case study must attempt to measure a difference in the study participants' concentration and productivity as well as establish the difference in installation and operating energy costs between the lighting layouts under consideration. Concentration is the ability for the participant to stay focused on the task at hand. Staying focused entails not being distracted by the environment surrounding the task-surface. Productivity is the rate at which work is done. In a set amount of time, a participant completing more work will be said to have higher productivity. Installation and Operating Energy Costs are defined by the costs associated with the purchase and installation of the fixtures, and the costs associated with energy used by a given fixture layout.

3.1.2 Methods of Measurement

With the objects of measurement defined, the task of defining a manner of objectively measuring them must follow. The following sections present the logic and reasoning applied to construct the tasks so that valid and accurate measurements could be taken. The assumptions and decision made concerning the method chosen for measuring each variable shaped and formed the final procedure used. The actual results along with the exact nature and compositions of these of these tasks are presented in Section 3.3 of this report – *Case Study Data and Discussion*.

3.1.2.1 Concentration

Measuring concentration is the most difficult of my intended measurements to make in a direct manner. However, making the assumption that an individual with a higher level of concentration, being more focused, will produce more accurate work relative to a distracted person, then we may indirectly measure concentration through accuracy. To reinforce this indirect link between accuracy and concentration, all conceivable variables with an effect on distraction, minus the lighting layouts, must be eliminated in the procedure. These potentially intrusive sources of distraction are discussed more fully in Section 3.1.3 of this report - *Isolating the Layout Variable*. Because the measurement of concentration is being made through the level of distraction in the environment, choosing a task which will have its results directly affected by time-consuming distractions is desirable. With this perspective, a timed reading comprehension task was selected, utilizing passages of sufficient length and difficulty so as to amplify the effects of environmental distraction on scoring, ideally affected only by the lighting layouts.

3.1.2.2 Productivity

Measuring productivity is achieved by designing tasks to have measurable, equal increments at which the participants stop when called to do so. A ratio or percentage between the number of complete and incomplete increments may then be observed and followed to observe trends between trials. If these increments are made to be small in terms of the time required to complete each one, the productivity will be more accurately measured (Berger 203). If, in many trials, all of the increments are completed in the allowed time, the test data will be less valid, as this indicates the participants' productivity levels exceed the measurable threshold of the test. The resulting desired characteristics in a task for a measurement of productivity are a set time limit, small increments, and a sufficiently large number of increments. The selected task, intended to encompass all of these qualities, was a timed "Algebra Marathon" test consisting of a large number of simple, uniformly difficult addition and subtraction problems. For this case study, productivity has been defined as the rate at which work is done, and this task will measure the number of small increments, or individual problems, completed within the set time limit, thereby allowing the surveyor to calculate a productivity rate.

3.1.2.3 Installation and Operating Energy Costs

Measuring the installation and operating energy costs associated with each layout does not require any special consideration in the construction of the tasks. However to make this

comparison, the wattage and ballast configurations of each used fixture were recorded for each layout. In order to make a fair cost comparison, fixtures with performance characteristics closely matching those used in the actual lighting lab were selected, arranged in an orientation and fashion similar to the layouts designed for the mockups, and sent to a lighting fixture manufacturer representative for a comparative price quote. For the purposes of cost comparison, identical fixtures to those installed in the lighting lab were not utilized in the submitted information. This was done to simplify the comparative cost comparison, and to allow for a uniform "cost of installation" factor of 20% to be applied for the cost analysis. In reality, the lighting lab is equipped with a variety of similar, but different fixtures providing similar light distributions from a variety of manufacturers. While this is helpful for the educational potential of the space – it would be very unusual for a more typical installation, and would incur extra costs associated with the use of multiple manufacturers. The operating energy costs were calculated using the rated wattage for the ballasts specified alongside the fixtures. These ballasts were selected to accommodate the dimming properties required in the layouts, and to match the number of lamps used in each fixture.

3.1.3 Isolating the Layout Variable

To make valid conclusions between the effects of different lighting layouts, it is important to isolate the different layouts as the only variable between tests.

Of particular importance are the variables within the testing environment which may distract the participants from their tasks. These variables that affect the measurement of concentration include extraneous noise, smells, rapidly fluctuating room temperature and any other changes in environment during and between trials. By removing these distracting conditions from the survey environment, the only remaining element which may affect concentration shall be the lighting layout in the room. How is this accomplished?

To minimize the possibility of invasive natural light altering the predetermined layout configurations in the survey space, the tests were held after the sky turned dark. The sunset times which can be found in various sources are not a reliable indicator of the time when the sky is truly dark. A more useful forecast of appropriate lighting conditions is the estimate of nautical twilight time. Astronomically, this is the point when the sun is located 12 degrees below the horizon. Visibly, this is the point at which the horizon, under clear skies, becomes indistinct.

The time chosen for the case study was set at 9:00 PM, and actual testing did not begin until the nautical twilight time of 9:13 PM had passed (Sunrise 1). Following these steps ensured that no sun light would affect the lighting layouts or the light levels between trials.

All fenestrations along the envelope of the testing area were covered as well. This involved taping opaque paper materials over the door glass, lining the edges of the door with carpet, temporarily covering the light of an exit sign, and blocking light from the exterior of the building using the blinds equipped in the room along with more opaque paper. The purpose of this fenestration covering was to eliminate contaminate light sources from both the street lighting present through the windows, as well as from the fixtures installed in the hallway. Again, these additional steps to ensure consistent lighting levels were necessary to validate the collected data in a manner allowing fair comparisons between trials.

Another great source of distraction may include the participants themselves. For example, an individual participant shuffling papers, asking to leave the room for a restroom break, and slamming the door shut on leaving would certainly have an adverse effect on the distraction level present for a given trial. This was addressed by first asking the participants to wait quietly upon finishing their tasks for the time to be called, if and when they finished early. Additionally, a small break was established between each trial for the participants to allow their minds to relax and discussion to occur.

Other unforeseeable distracting variables were a possibility. To anticipate these potential distractions, it is useful to consider the body's senses, notably sound, smell and touch. Sound distractions may have included noises due to adverse weather; nearby traffic; or an emergency in the vicinity. Another possibility may have been distracting smells, resulting from food or an unhygienic participant. The most concerning distraction related to the sense of touch would be the temperature of the surfaces and air within the room. The possibility for uncomfortable temperatures and fluctuation was anticipated and addressed by adjusting the thermostat to a comfortable temperature for the participants during the stage of the survey's introduction. The potential for unforeseeable noise and smell distractions was mitigated to some degree through the closed windows and door, as well as the selected time of the day for the case study, in which little activity is observable. While no distractions of this nature occurred, establishing a procedure for such situations would be an advisable preparation step to salvage useful collected data.

3.1.4 Location

The KSU Department of Architectural Engineering and Construction Science uses a lighting lab, located in Seaton Hall, as a classroom equipped for instruction of building electrical and lighting system design courses at Kansas State University. Figure 3.1 shows a view from each of the room's four corners, for reference.

Figure 3.1 The Kansas State Lighting Lab – Room S223A

It is equipped with a wide range of light fixtures and control apparatus wired to work in tandem, for educational use. Of special interest to this study are the directional and fixed can CFL and pendant linear fluorescent fixtures installed in the room, as well as the Digital Addressable Lighting Interface (DALI) computerized lighting control system. These features allowed for the development of lighting fixture layouts closely matching the intended light distribution schemes associated with the strategies involved in this case study. The room's finishes include a dark-colored carpet, off-white grayish walls, and a hung 2x2 grid ceiling with

white acoustic tiles. These surfaces are representative of the assumed reflectances used by lighting designers: 20%, 50% and 90% for the floor, walls and ceiling respectively. The HVAC system serving this room monitors temperatures with the thermostat also located in this space – allowing for consistent temperature control between lighting layouts. This helps by eliminating another potential variable in the tested environment. Another important feature of this room is the motorized sheet-style window blinds which block exterior light fairly effectively. Based on these features, the resources available, and the scope and size of the project this space was chosen as the ideal location for the case study.

3.1.5 Selecting Survey Participants

To design an effective procedure and an appropriate series of tasks, certain characteristics of the survey participants is required. When selecting participants for subjective data collection – it is very important to ensure that the individuals are able to provide the desired information (Gay 164). Consideration of many factors led to the final decision to select ARE undergraduate and graduate students as having the ideal characteristics for the body of survey participants in this case study.

Ten students volunteered and participated in the case study. The Kansas State IRB Informed Consent Document (Appendix A.3) requires the surveyor to state to the participants the extent of confidentially afforded by this study. It was decided that, in the interest of gathering as little personal information as possible to ensure "Complete" confidentiality, data such as the gender, age, background and experience of the participants would intentionally be left unknown. Such information was considered inapplicable to the analysis of the survey data, as the intent of this data is purely for comparison purposes. Provided each of these variables is kept constant throughout the study, observations on the data trends between the layouts will remain valid.

First, these individuals are used to the environment chosen. These students have considerable experience utilizing the lighting lab as a classroom and study area. As a result, there can be no "effects of acclimation" caused by introducing a body of individuals into an unfamiliar space which may alter the survey results over the course of the numerous trial-runs during the procedure.

Second, limiting the participants this narrowly allows for certain generalizations to be made regarding task-aptitude. Because the participants were all in their 3rd through 5th year of

engineering education, algebra and reading comprehension tasks could be constructed with a targeted level of aptitude, with the intent to avoid issues of lack of skill affecting the survey's objective results. Further, such tasks may be designed in a manner that closely mimics tasks already familiar to the participant body, avoiding the effects of unfamiliar tasks on the survey results.

Third, the performance of any group of subjects in making assessments of their surroundings is strongly affected by their experiences in the field of study concerned (Hopkins 141). For example, a group of participants composed of car salesmen, asked to assess a vehicle showroom, will make their assessments more quickly, with less error, and with more consistency than a group of individuals inexperienced in that industry. Such "experienced" subjects will also provide more useful feedback to the conductor of the experiment, if prompted to do so. The selected body of ARE undergraduates was familiar with, interested and experienced in analyzing various lighting solutions and their effects. As a result, this group of individuals may be considered "experienced" participants.

Finally, because all of the individuals are within a relatively narrow age range, the effects of macular degeneration, a variable which would considerably alter the relative survey results between changing light conditions (IESNA 10-16), shall not adversely affect the results of this survey procedure.

3.1.6 Establishing Procedure

Establishing a written procedure for any performed survey is extremely important for a number of reasons. It is implausible that any individual would foresee all potential data-invalidating conditions arising from an imperfect procedure. For this reason, writing out multiple drafts, while procuring the insight of others through review, is a very good idea. Most importantly, an established, written procedure is vital when making the claim, implicit or directly, that the collected data has validity. A withheld or unavailable procedure for any case study immediately casts doubt and suspicion on the data – which makes any conclusions or speculation drawn from such data disputable and/or meaningless. For this survey, written procedures were required at multiple points to meet the university's ethical research validation requirements. Please reference Appendix A – *Survey Materials* and Appendix F - *Committee for*

Research Involving Human Subjects (IRB) Documentation for examples of such procedural documentation.

3.2 Established Lighting Layouts

This chapter provides descriptions for the three lighting layouts prepared for comparison in the survey process. Information collected on the measurements taken to establish these layouts, as well as the procedures used to do so, is available in Appendix B - *Lighting Layout Establishment Information*. Figures 3.2.1, 3.2.2 and 3.2.3 each provide a visual reference, respectively, for the first, second and third layouts. Supplementary photographs of the lighting layouts and the methods of measurement are available in Appendix C - *Photographs*.

3.2.1 Lighting Layout #1 – Uniform, 50fc

Figure 3.2 50fc Uniform Lighting Lab Mockup

The first layout presented in the survey procedure was established to be the control for the test. This control was included to remove the influences of the survey tasks' "learning curve" and misunderstandings of the survey procedure from the comparative data between the Uniform 30fc and Task-Ambient layouts. The uniform illuminance of 50fc was chosen for this control for a number reasons: First, this illuminance level at the working surface is a full illuminance category higher than the other two layouts (IESNA Lighting Handbook Figure 10-9), providing a similar but distinctly different layout. This allows for potentially informative data interpretation between the control and targeted layout survey results (the Task-Ambient and 30fc Uniform layouts). Specifically, the objective and subjective effects of a higher illumination level, with the distribution pattern being identical to the 30fc layout, may be observed. Second, the lighting lab classroom, under ordinary instructive use, uses a preset layout with a uniform illuminance of 50fc. This will allow for possible constructive analysis and comparisons of a layout used for the visual tasks being replicated by the survey procedure. The fixtures used to create this and the 30fc layouts are the same. They consist of eight regularly spaced direct/indirect 48" suspended T5 linear fluorescent fixtures. To create the different illuminance levels between the two layouts, the fixtures are equipped with fluorescent dimming ballasts, tied to the control systems of the room.

3.2.2 Lighting Layout #2 – Task-Ambient

Figure 3.3 Task-Ambient Lighting Lab Mockup

The second layout was designed to utilize the Task-Ambient strategy. The goals in establishing this design were to provide a uniformly distributed illuminance of 30fc on the task surfaces – on top of the tables, and a uniform illuminance of 10fc on the surrounding circulatory areas of the room – the floor and vertical surfaces of the room. These values were chosen based on recommendations for task illuminance and luminance ratios presented in the IESNA Lighting Handbook, discussed fully in Section 2.1 of this report. In theory, this state could be achieved by combining an effective 10fc uniform illuminance layout with an additional 20fc of "task light" provided on the surfaces. Utilizing a combination of the recessed fluorescent can fixtures and incandescent utility shop lights available to us, an average illuminance level of 20.5fc was achieved on the task surfaces. To this we added a diffuse, uniform and low level of light from the direct-indirect fluorescents in the room. The resulting average measured illuminances were

31.8fc on the task surfaces, and 10.8fc on the surrounding surfaces. The mounting of the shop lights along the wall surface, instead of the ceiling was a result of limitations in materials available and in permissions granted for use in the facility. This orientation and its effects receive further discussion in Section 4.3 of this report.

3.2.3 Lighting Layout #3 – Uniform, 30fc

Figure 3.4 30fc Uniform Lighting Lab Mockup

The third layout was designed to provide a reasonable comparison for the Task-Ambient to the Uniform lighting layout strategy. The uniform illuminance level of 30fc was chosen to match the 30fc being provided at the task-surfaces by the Task-Ambient. To establish this layout, we first adjusted the lights and made uniform illumination estimates using the equations and procedure developed by the Illuminating Engineering Society (Lindsey 256-261). The calculations and illustrated procedure for the final estimate attempt, resulting in an estimated

average illuminance of 30.1fc, are provided in Appendix B. After this estimation, a more accurate grid-style procedure was used to accurately measure the average illuminance level. Establishing the grid for measurement involves ensuring an acceptable number of measurement points are utilized. Determination of this minimum number was achieved utilizing a formula based on the Room Index (Smith 199,130). This calculation is also provided in Appendix B. The final measured average illuminance level for the space was 29.5fc.

3.3 Case Study Data and Discussion

The research data presented in this section is selected with the intent to illustrate observable trends and discrepancies. For the sake of brevity and clarity, the collected information which suggests no clear trends is not submitted here. The raw data collected by the survey study is available in its entirety, along with illustrative charts in Appendix C – Survey Data.

The figures presented in this chapter show three interpretations of the participants' averaged scores (given in percentages) over the three lighting layout scenarios. "Accuracy Score" is the percentage of correct answers within the total number of questions answered. "Productivity Score" is the percentage of questions given an answer at all out of the total number of questions available. The "Overall Score" presented is the percentage of correct answers out of the total number of questions available, effectively combining the accuracy and productivity interpretations of the data. An example of each task being referred to in this section is also available within Appendix A – *Survey Materials*. The order of the tasks given remained the same between each layout. First a Math Task, then a Reading Task and then a Survey was given. The lighting layouts themselves were presented in the order suggested by their respective labels in the data charts presented. The first layout was Layout #1: Uniform, 50fc, and so on.

3.3.1 Math Task Data

The "Algebra Marathon" math task is composed of 80 randomized algebra questions involving the addition and subtraction of positive and negative numbers, with absolute values ranging from 1 to 25. Kuta Software's *Infinite Algebra 1* software was used to generate these questions in the intended format. By defining these limits of problem complexity, one may safely assert that any significant drop in task scores will not be the result of a lack of ability.

Informal, preliminary trial runs led to the inclusion of a four-minute time limit. This added restriction added an element of pressure to the task, desirable for the potential to magnify the participants' recognition of defects in the quality of lighting. The time limit also prevented most participants from actually completing the entire marathon, allowing for a better measurement of productivity. Participants were instructed to accurately complete as many problems as possible within this time constraint.

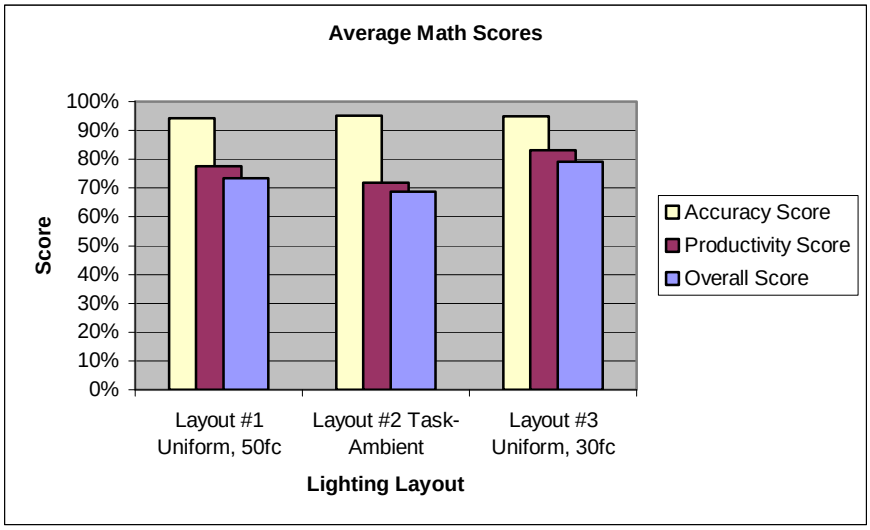

Figure 3.5 Average Math Scores

Figure 3.5 displays the averaged Accuracy, Productivity and Overall scores for each of the layouts. Two important trends may be observed with this data. First, the measured average productivity score for the Task-Ambient layout #2 is considerably lower than either of the uniform layouts #1 and #2. Second, the measured level of accuracy between each trial remained reasonably constant.

There are a few conclusions that may be drawn from these observed trends. First, the unchanging accuracy scores between layouts assert that there is no significant difference in difficulty between the math tasks assigned to each layout condition. This trend also leads one to the conclusion that any other measured changes in the Overall score averages must be for the most part caused by a change in productivity. Considering the care taken to eliminate the potential for any environmental change between trials excepting the lighting layouts themselves,

one may conclude that the Task-Ambient layout was a direct influence on the drop in measured productivity in this survey study.

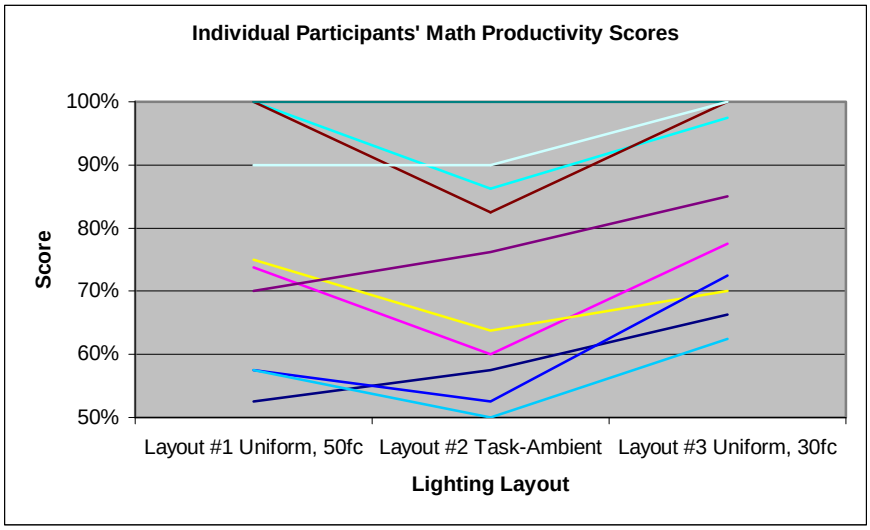

Figure 3.6 Math Productivity Scores – Individual Results

Figure 3.6 illustrates the progression of individual participant productivity scores for the math task. Each line represents the progression of an individual's productivity scores between the layouts. Please note the y-axis scale has been modified to show a range of 50% to 100%, in order to clearly illustrate the shape of the curves. While the actual scores earned for each layout were somewhat varied and widespread between the participants, it is important to observe the relative consistency of the curve shapes. For example, between Layout #2 and Layout #3, every individual curve slopes upward, indicating a relative improvement in Productivity score. This independent consistency further validates the "drop in productivity" trend observed from the data averages. The curves are not absolutely uniform, and this may be partially attributed to the possibility that some persons' productivity levels will simply be less influenced by differing light levels. Additionally, one may observe that most of the individual participants exhibited somewhat higher productivity scores with the 30fc trial relative to the first, 50fc control trial. This may be attributed to the "learning curve" effect, for which the control layout was established.

3.3.2 Reading Task Data

The "Reading Comprehension" task was developed using standardized GMAT (Graduate Management Admission Test) test preparation materials distributed freely on the Internet. This format of testing involves the presentation of a timed reading exercise, followed by a series of multiple-choice questions. Again, the timed element is introduced to add a sense of urgency and pressure to the task.

An important distinction of reading comprehension tests is there can be no "equally difficult" sets of passages and questions. This poses the problem of having the data trends between each layout being adversely affected, where one layout is associated with the "easiest" passage/question set, for example. On the other hand, administering the same passage and set of questions for each layout would also produce skewed results, as the participants will undoubtedly improve their comprehension and scores as they take the same test multiple times. Acknowledging this fact, the solution for this procedure was to administer three versions of the reading task with distinct passages and questions, but to have each test present during each layout. To do this, the participants were split into three groups, designated "K," "S," and "U." Between layout trials, the versions being administered to each group cycled. The end-result is that the scores associated with each layout are equally affected by the overall difficulty of the three versions combined.

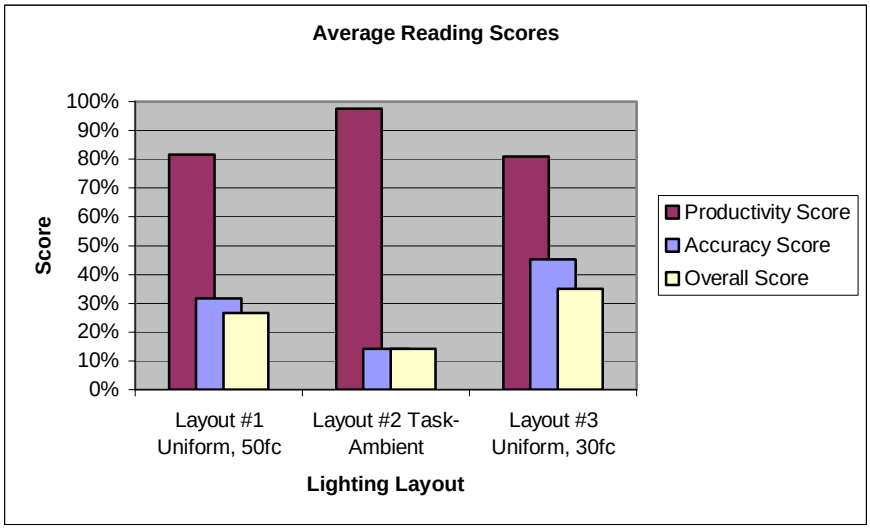

Figure 3.7 Average Reading Scores

Figure 3.7 illustrates the averaged Overall, Productivity, and Accuracy Reading scores for the three layouts. While these average scores seem to represent very distinct and intriguing trends between the lighting layouts, there are inconsistencies in the data the reader is cautioned to examine before drawing any conclusions.

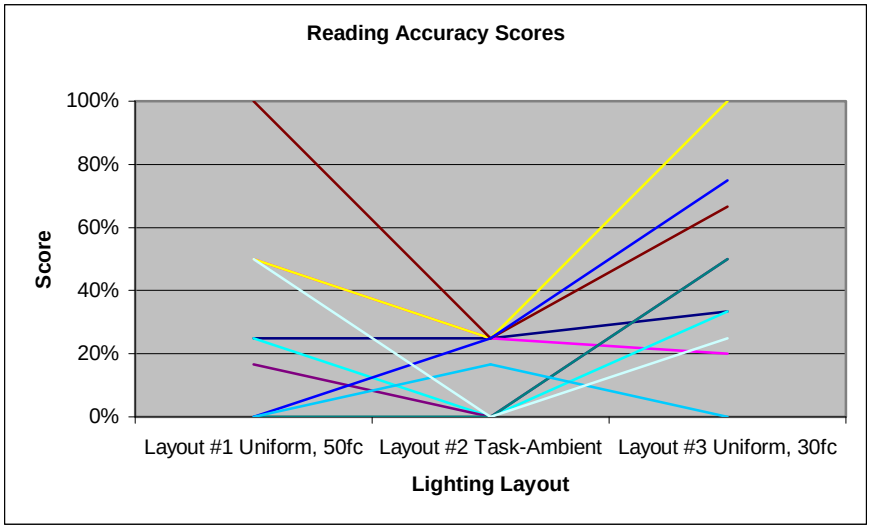

Figure 3.8 Reading Accuracy Scores – Individual Results

Figure 3.8 shows the deviations in accuracy for each participant – with each line representing an individual participant's scores. The stark differences in scores, with the full range of 0% to 100% represented multiple times, suggest both that the number of increments, or questions, available in this test were too few, and that the difficulty level of the questions may have been set inappropriately high for the selected group of participants. Further, the inconsistency of shape in these curves, with a similar number of trends upwards and downwards between each layout, suggests that no trend observed in the averages may be solidly backed with unified results between individuals. Compare the shape of these trend lines with an identical chart representing the same information for the Algebra Marathon task, shown in Figure 3.9:

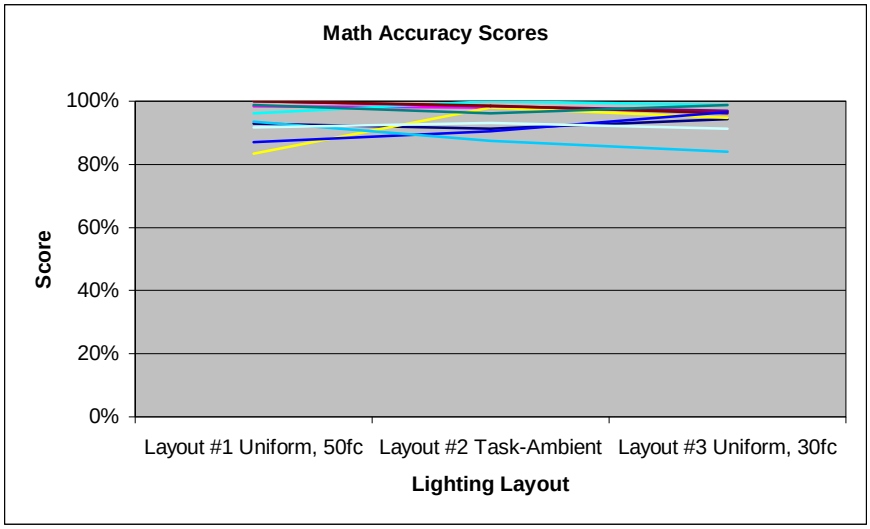

Figure 3.9 Math Accuracy Scores – Individual Results

In comparison, the reading accuracy scores are not only inconsistent in values between trials, but also distinctly non-uniform in shape. If the accuracy values varied greatly, but the accuracy trend lines of the participants remained similar in shape, one might make the conclusion that some condition during the testing procedure changed (such as the noise of a low-flying aircraft scaring everyone in the room), affecting everyone's ability to accurately complete the task. However, in this case, the generally non-uniform shapes suggest the task itself was flawed in some manner.

Further analysis of the data (again referring to Figure 3.7) shows the overall scores of the participants remained relatively low. Examining the raw data on the overall reading score data from which these averages were constructed (available in Appendix D - *Survey Data*), the observation is made that within all trials, the highest overall score attained for an individual test was 75%, with the next highest scores tied at 50%. This information leads to the conclusion that the reading task's content and/or procedure were designed at a level too difficult for the selected participants in the study. The large variation in accuracy scores observed also may indicate that the number of questions asked may have been too few, lowering the accuracy of the measurements intended. For these reasons, no trends that may have otherwise been considered in the resulting data may be given much weight, and the Reading task must be altered for future use, if useable data is to be created. Suggestions for such alteration are discussed in Section 4.3 – *Future Study Improvements*.

3.3.3 Survey Results

A survey questionnaire was administered following the first two tasks for each layout configuration. This series of questions specifically asked the participants to answer queries about their perceived comfort, level of speed and accuracy, and level of focus by choosing a number between 1 and 10. This portion of each trial run was not time-restricted, so each participant had the opportunity to answer the questions with as much consideration as they felt necessary. The questions and the answer format presented on the surveys were as follows:

1. How comfortable or uncomfortable do your eyes feel after completing these tasks in this lighting configuration?

Uncomfortable Comfortable

1 2 3 4 5 6 7 8 9 10

2. How do you feel the lighting conditions affected your speed/accuracy?

Negatively Positively

1 2 3 4 5 6 7 8 9 10

3. How well were you able to focus on the tasks?

With Difficulty Easily

1 2 3 4 5 6 7 8 9 10

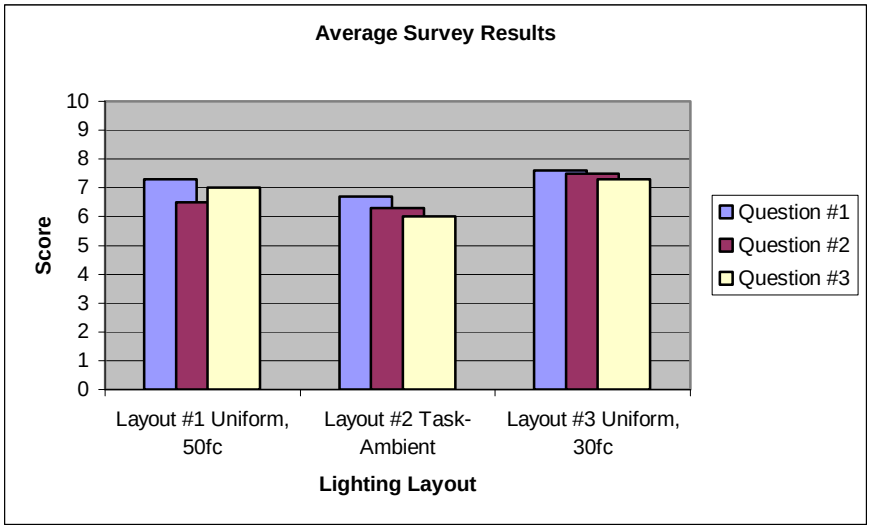

Figure 3.10 Average Survey Results

It is important to note that these results reflect a measurement of the subjective feelings of the participants, not the objective measurements of accuracy and productivity explored with the previous tasks. While close observation of these results shows a certain trend indicating the participants generally favor the 30fc Uniform layout over the Task-Ambient layout, the actual numerical differences between these averages is subtle. Therefore, another trend which deserves consideration is the fact that the participants did not deviate very much in their scoring between the layouts. As a result, the best conclusion based on this data would be that none of these layouts holds a distinct advantage over the other from the perspective of the participants' subjective feelings. This trend also suggests within the three layouts, none were distinctly uncomfortable relative to the others.

Open-ended comments collected in the survey questionnaire indicate a number of participants felt the shadows caused by the Task-Ambient lighting layout, reminiscent of "stadium lighting," as well as the glare caused by the wall-mounted fixtures, were major sources of distraction. These distractions identified by the participants indicate definite flaws in the fixture layout and orientation for the Task-Ambient trial. The problem of glare would have been eliminated if the utility lamps were positioned above the participants' field of vision, near the ceiling height. The "stadium lighting effect" also could have been mitigated if the source of light for the task surfaces was more diffuse, or coming from multiple directions. Both of these negative conditions were the result of a limitation of resources, and their full remedies are discussed in Section 4.3 – *Future Study Improvements*.

3.3.4 Installation and Operating Cost Data

In order to make a fair economic comparison between the Task-Ambient and Uniform layouts, fixtures with configurations similar to the ones utilized in the lighting lab were selected, modeled in Visual, scheduled and priced. The 50fc Uniform layout was omitted from this analysis, because the 30fc Uniform layout is identical in fixture number and layout, and will necessarily use less energy – providing the more competitive and comparable energy usage to the Task-Ambient layout. Being similar to the 30fc layout, the higher energy usage associated with higher luminance will certainly produce a poorer performance from an operating cost

perspective. While the full calculations, references, Visual prints, assumed variables (and their sources) and fixture information is available in Appendix E - *Cost-Comparison Calculations and Data*, their results are summarized in the Table 3.1 below for clarity.

Lighting Layout Comparative Cost Analysis

	30fc, Uniform	Task-Ambient
Power Density Calculation		
Space Area (SF)	600	600
Total Operating Power (watts)	675	558
Power Density (W/SF)	1.13	0.93
System Energy Use		
Energy Consumption (kWh/yr)	5913	4888
Incremental Demand Charge	$288	-
(per year)		
System Economics		
Incremental Installation Cost	-	$3,725
Annual Operating Cost ($/yr)	$545	$212
Annual Savings ($/yr)	-	$333
Payback Period (years)	-	11.19

Table 3.1 Lighting Layout Comparative Cost Analysis

The results show the Task-Ambient layout utilizes less energy, as expected. Notable differences between this and the utility-group sponsored results shown in Figure 2.3 of this report are the difference in incremental installation cost for the "improved" systems and the energy costs. In the previous set of results, it was found that the Task-Ambient system cost less than the Uniform layout. The actual fixture costs for their report were not presented, but the statements provided with their summary table indicate the fixtures themselves cost no more than $75 installed, with "Task-Lighting" adding at most $225 to the budget. This budget represents a much lower installed system cost than the fixtures used in this study. The primary reason for this include the "architectural" or aesthetic nature of the fixtures installed in the lighting that were used for the Task-Ambient lighting distribution. This leads to a payback period of 0 for their Task-Ambient layout. In addition, the energy rates used for the previous study were much higher than the representative local (Manhattan, KS) rates used for this study. With no reference to the source utility or other energy billing information, one may only observe that the energy cost per kWh for that study was more than double the rate found to be in use for this area.

For this comparison, it was found the payback period was between 11 and 12 years. This large difference is partly due to the scale of this case study (one 20'x30' room) and to the high difference in installation costs between the two layouts. The self-imposed limitation of selecting fixtures similar to the ones actually used from the lighting lab had a significant effect on the installed price for both systems. Given the financial freedom to choose fixtures, it is likely that the difference in budgets for both systems would lessen – decreasing the payback period, as more economical fixtures would be substituted for the Task-Ambient layout.

CHAPTER 4 - SUMMARY

4.1 Summarized Case Study Conclusions

The data collected from the algebra marathon task, intended to measure productivity, yielded a uniform and consistent *drop* in productivity between the participants for the Task-Ambient layout strategy. This is a direct divergence from the first hypothesis (Section 2.3 – *Hypotheses*). The data collected from the reading comprehension task, intended to primarily objectively measure concentration, contained inconsistencies, likely arising from flaws in the design of the task and the deficient positioning of certain fixtures in the Task-Ambient trial (fully discussed in Section 4.3 – *Future Study Improvements*), which rendered the observable data trends inconclusive. This leaves the second hypothesis indefinite. Measurements of the averaged subjective feelings of the participants towards Uniform and Task-Ambient layouts showed largely negligible trends. A representative study of the installation and operating cost data between the 30fc Uniform and Task-Ambient layouts shows the Task-Ambient layout uses significantly less energy than the Uniform layout. This supports the third hypothesis. A somewhat long payback period was also calculated, but this could be lessened if more economical fixtures were available for the Task-Ambient layout.

In summary, Task-Ambient lighting layouts, while certainly effective from an energy-efficiency standpoint, are not necessarily the best option when the end-user's level of productivity and concentration are a top priority.

4.2 Closing Thoughts

"Always check sponsors before accepting research findings. Disposable diaper manufacturers and cloth diaper makers funded separate studies to judge the environmental impact of diapers. Findings were contradictory, both with a 99% confidence level." (Trost 10)

This quotation, coincidentally found in a text used for initial research of the Task-Ambient layout concept, is a lesson reinforced by the findings of this case study. The initial impression given by the published research available was that the end results of a Task-Ambient layout method would be superior to the Uniform method in every aspect, excepting the design

time required. The full expectation was that this strategy should provide a superior end-product relative to a Uniform layout, with energy savings to boot. In reality, despite some inevitable imperfections in the planned procedure, consistent data was accrued strongly supporting the opposite point of view!

In retrospect, a number of those sources recommending this strategy in various forms of publication were perhaps motivated for reasons beyond "good will towards man." It would seem a significant portion of the research available in this area is funded by sources with publicly known agendas to push all methods of energy-efficiency, such as NEEP - the Northeast Energy Efficiency Partnerships ("Office…"), the California Public Utilities Commission (Energy), and the U.S. Department of Energy (Efficient).

Additionally, while this was an artificially constructed and operated task-environment, the analysis of an existing, real-world lighting design would be able to suggest to an owner a "cost of production" difference between two designs. Where the difference in the amount of work completed in a set time was objectively measured between layouts, the engineer may have gone further by multiplying this figure with the number of persons regularly working the space, to find a difference in man-hours. This figure could then be multiplied by the average hourly salary rate in the space under scrutiny to find a "cost of production" difference. In many cases, this will potentially greatly exceed the energy savings in magnitude.

4.3 Future Study Improvements

Given additional time and funding, and the benefit of hindsight, many things could have been done during the survey procedure to improve the quality and volume of the data collected. Certain changes in procedure for future investigations will allow for further exploration of the Task-Ambient Lighting layout Strategy. This section is included to outline the issues which arose concerning such improvements, and to suggest manners of remedy for future research endeavors of this nature.

More control over luminance values (and through them, luminance ratios) present between the task surfaces and surrounding surfaces would be possible if the associated materials for those surfaces could be customized for each layout in the space. For example, while it is easy

to maintain definite *illuminance* (fc) values incident on a dark carpet and a light table surface, it is much more difficult to control the *luminance* values (light reflected to the eye) from each surface, on which luminance ratios are based. This added control would allow for the measurement of the actual luminance ratios present within each layout for the end-users, and would open the door for another unexplored variable worth investigation for Task-Ambient layout design.

Analysis of the data collected for the reading comprehension task suggests the questions provided for each reading passage were too few in number to provide absolute trend analysis between lighting layouts. In addition, the high percentage of missed questions suggests the source of these passages and questions (GMAT test preparation resources) may have been inappropriately difficult for the selected participant body.

As discussed many participants indicated the Task-Ambient layout resulted in distractive) shadows. As this was not an intended quality of the Task-Ambient strategy, provisions for mounting the utility lights along the ceiling would have alleviated this condition.

Increasing the number of 'takes' given for each layout would be a great way to improve the reliability of the data. This could be done by performing the same survey procedure on a different night with the same group of participants. However, this would add to the complexity of the "uniform task difficulty" dilemma presented in Section 3.3.2 – *Reading Task Data*.

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Software Cited

Name: Visual – Professional Edition

Version: 2.04

Description: Lighting Design Software

Website: http://www.visuallightingsoftware.com

Name: Infinite Algebra 1

Version: 1.20

Description: Algebra Worksheet and Assignment Generating Software

Website: http://www.kutasoftware.com/trial.html

Appendix A - Survey Materials

This appendix contains the collective prepared contents, in the presented order, of the folders handed out to the participants for the survey case study.

Figure A.1 Alphanumeric Designation (blue sheet)

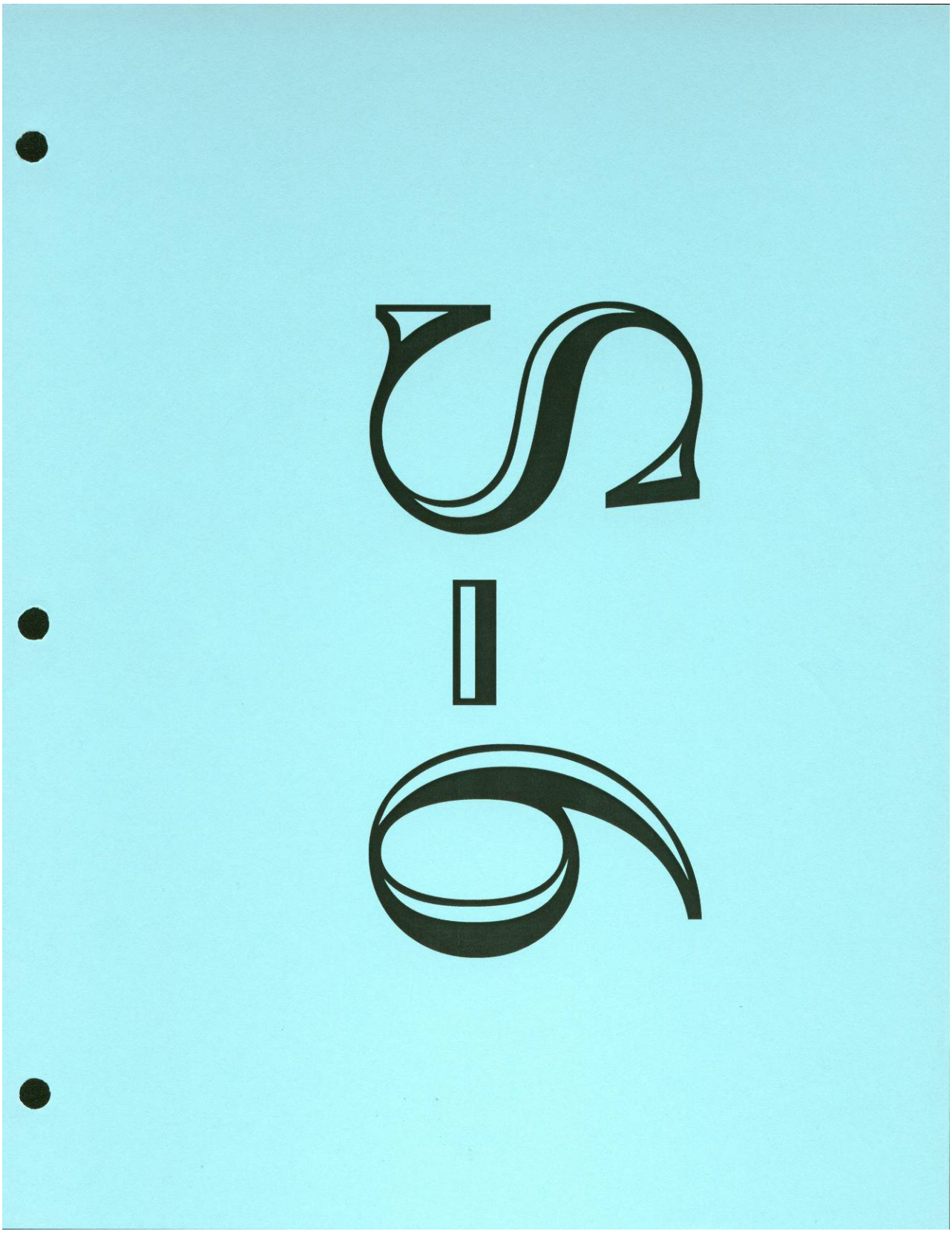


Figure A.2 Survey Guidelines and Procedure

GUIDELINES

- After finishing with any sheet, please stash it underneath the provided manila folder.
- The order I get these sheets back in isn't important
- The order you receive these sheets in is deliberate, please don't shuffle the contents as you receive the folder.
- This page is intended for you to take notes on and keep for your own future reference – please leave all other materials in your folder, at your seat when you leave.

BASIC SURVEY PROCEDURE

Here is what we will be doing:

1. Go through this page together – reviewing the survey procedure and what is contained in your folder.
2. Discuss anonymity of this research, liability, leading into…
3. Reviewing and signing the K-State Research Informed Consent form
4. Begin the Tasks/Survey for the First Lighting Layout (of three)
   a. There are two tasks, Algebra and Reading, begin with the first (Algebra)
   b. Each is timed, to measure productivity and accuracy under a time constraint
   c. After time is called, lay down your pencil and move on to the second timed task, until time is called again.
   d. Immediately fill out the green survey form. This asks questions related to how the end-user feels, physically. There are also inquiries as to how the end-user felt performance/ productivity improved or was degraded by the lighting layout. This will be compared to the actual performance/ productivity measured by scoring the tasks. Each survey also presents a space where the participants may provide additional commentary.
5. Repeat the procedure in Step 4 for the remaining two lighting layouts.

FOLDER CONTENTS

Your folder should contain, in this order:

- This page –Survey Procedure and folder Contents
- Informed Consent Document
- Task A – Algebra Marathon
- Task B – Reading Comprehension
- Survey Form 1/3 (Green Sheet)
- Task A – Algebra Marathon
- Task B – Reading Comprehension
- Survey Form 2/3 (Green Sheet)
- Task A – Algebra Marathon
- Task B – Reading Comprehension
- Survey Form 3/3 (Green Sheet)

Figure A.3 IRB-required Informed Consent Document

INFORMED CONSENT DOCUMENT

PROJECT TITLE: Task-Ambient Lighting: A Tool for Sustainable Design and Code Compliance

APPROVAL DATE OF PROJECT: April, 2007 **EXPIRATION DATE OF PROJECT:** December, 2007

PRINCIPAL INVESTIGATOR: CO-INVESTIGATOR(S):	Nicholas A. Caton
CONTACT AND PHONE FOR ANY PROBLEMS/QUESTIONS:	Nick Caton – 785-410-3317
IRB CHAIR CONTACT/PHONE INFORMATION:	Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224.
SPONSOR OF PROJECT:	N/A
PURPOSE OF THE RESEARCH:	To present to lighting system design engineers the concept of Task-Ambient Lighting, and to show it's uses in energy conservations, while discussing its application in meeting and exceeding energy code and IESNA requirements.
PROCEDURES OR METHODS TO BE USED:	Participants will be asked to perform prescribed and controlled tasks under varying lighting conditions, then surveyed, in order to evaluate the performance of each system from an end-user's perspective.

ALTERNATIVE PROCEDURES OR TREATMENTS, IF ANY, THAT MIGHT BE ADVANTAGEOUS TO SUBJECT:

N/A

LENGTH OF STUDY:	One evening
RISKS ANTICIPATED:	None
BENEFITS ANTICIPATED:	Participants will experience first-hand lighting design evaluation procedures, as well as receive a short lecture on the Task-Ambient Strategy for Lighting Systems design. The participants will thusly gain marketable knowledge for their future careers as Architectural Engineers.
EXTENT OF CONFIDENTIALITY:	Complete
IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS:	No
PARENTAL APPROVAL FOR MINORS:	N/A

TERMS OF PARTICIPATION: I understand this project is research, and that my participation is completely voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

Participant Name: _____

Participant Signature: _____ **Date:** _____

Witness to Signature: (project staff) _____ **Date:** _____

Last revised on May 20, 2004

Figure A.4 Task A – Algebra Marathon (1 of 3)

Task A - Algebra Marathon - v1 Name_____

Stop and Start with the Timer!

Evaluate each expression.

1) 10 – (–6)
2) (–25) + (–17)
3) (–11) – (–16)
4) (–22) + 12
5) 21 + (–17)
6) (–12) – (–19)
7) 2 + (–3)
8) (–11) + 23
9) (–11) + 1
10) 22 – (–9)
11) (–16) – 13
12) (–3) – 24
13) (–8) – (–14)
14) 2 – (–14)
15) (–14) + 5
16) (–17) + (–23)
17) 15 + (–15)
18) 1 – 20
19) (–3) + (–24)
20) (–18) – 13
21) 20 + (–11)
22) (–10) + (–16)
23) 20 – (–21)
24) 18 – 1
25) (–2) – (–1)
26) 24 – 18
27) (–24) + (–17)
28) (–18) – (–2)
29) (–2) – 8
30) 4 – (–11)
31) 20 – 6
32) 25 – 11
33) (–9) + 7
34) (–5) – 20
35) 12 – (–19)
36) (–5) – 16
37) (–20) + 2
38) 13 + (–16)
39) (–12) – 7
40) (–11) – (–1)
41) (–16) – 23
42) 15 – (–4)
43) (–25) + (–11)
44) (–1) + 8
45) (–12) – 17
46) 16 – (–2)
47) (–10) – (–12)
48) 21 + (–21)
49) (–2) – 18
50) (–5) + 17
51) 10 – (–10)
52) 20 + (–20)
53) 2 – 12
54) (–6) + (–7)
55) 3 – 14
56) 15 – 6
57) 19 + (–17)
58) (–5) – (–7)
59) 8 – 21
60) (–25) – 20
61) 25 + (–24)
62) (–5) – 2
63) (–4) – (–20)
64) 13 – (–20)
65) 8 – (–17)
66) (–12) + 16
67) 23 + (–2)
68) (–5) + (–5)
69) (–4) – 25
70) (–10) + (–8)
71) 12 – 23
72) (–22) – (–22)
73) (–3) – (–24)
74) (–4) – (–23)
75) (–12) + 14
76) (–16) + (–2)
77) (–15) – (–11)
78) (–6) – (–18)
79) (–24) + 13
80) (–15) – (–7)

Figure A.5 Task B – Reading Comprehension Passage(s) (1 of 3)

Task B – Reading Comprehension – v2 Name:_____

Stop and Start with the Timer!

Read the following text until the time is called. Mark the location of your reading progress when the time is called, if you have not finished. Read the text at a pace that you can understand the material completely – you will be tested!

Each Passage will have 3 associated questions.

Passage 1:

In nearly all human populations a majority of individuals can taste the artificially synthesized chemical phenylthiocarbonide (PTC). However, the percentage varies dramatically--from as low as 60% in India to as high as 95% in Africa. That this polymorphism is observed in non-human primates as well indicates a long evolutionary history which, although obviously not acting on PTC, might reflect evolutionary selection for taste discrimination of other, more significant bitter substances, such as certain toxic plants.

A somewhat more puzzling human polymorphism is the genetic variability in earwax, or cerumen, which is observed in two varieties. Among European populations 90% of individuals have a sticky yellow variety rather than a dry, gray one, whereas in northern China these numbers are approximately the reverse. Perhaps like PTC variability, cerumen variability is an incidental expression of something more adaptively significant. Indeed, the observed relationship between cerumen and odorous bodily secretions, to which non-human primates and, to a lesser extent humans, pay attention suggests that during the course of human evolution genes affecting body secretions, including cerumen, came under selective influence.

Passage 2:

The poetic expressiveness and creativity of Japanese women poets of the Manyoshu era is generally regarded as a manifestation of the freedom and relatively high political and economic status women of that era enjoyed. During the Heian period (A.D. 794-1185) which followed, Japanese women became increasingly relegated to domestic roles under the influence of Buddhism and Confucianism, which excluded women from the political and economic arenas. Yet, since poetry of the period came to be defined solely as short lyrical poetry, known as waka, and became the prevailing means of expressing love, women continued to excel in and play a central role in the development of classical Japanese poetry. Moreover, while official Japanese documents were written in Chinese, the phoenetic alphabet kana was used for poetry. Also referred to as onna moji ("women's letters"), kana was not deemed sufficiently sophisticated for use by Japanese men, who continued to write Chinese poetry, increasingly for expressing religious ideas and as an intellectual pastime. Chinese poetry ultimately yielded, then, to waka as the mainstream of Japanese poetry.

Figure A.6 Task B – Reading Comprehension Answers (1 of 3)

Question 1 It can be inferred from the passage that human populations vary considerably in their

(A) sensitivity to certain bodily odors
(B) capacity for hearing
(C) ability to assimilate artificial chemicals
(D) vulnerability to certain toxins found in plants
(E) ability to discern bitterness in taste

Question 2 Which of the following provides the most reasonable explanation for the assertion in the first paragraph that evolutionary history "obviously" did not act on PTC?

(A) PTC is not a naturally occurring chemical but rather has been produced only recently by scientists.
(B) Most humans lack sufficient taste sensitivity to discriminate between PTC and bitter chemicals occurring naturally.
(C) Variability among humans respecting PTC discrimination, like variability respecting earwax, cannot be explained in terms of evolutionary adaptivity.
(D) The sense of taste in humans is not as discriminating as that in non-human primates.
(E) Unlike non-human primates, humans can discriminate intellectually between toxic and non-toxic bitter substances.

Question 3 Which of the following best expresses the main idea of the passage?

(A) Artificially synthesized chemicals might eventually serve to alter the course of evolution by desensitizing humans to certain tastes and odors.
(B) Some human polymorphisms might be explained as vestigial evidence of evolutionary adaptations that still serve vital purposes in other primates.
(C) Sensitivity to taste and to odors have been subject to far greater natural selectivity during the evolution of primates than previously thought.
(D) Polymorphism among human populations varies considerably from region to region throughout the world.
(E) The human senses of taste and smell have evolved considerably over the course of evolutionary history.

Question 4 Based on the passage, mainstream Japanese poetry of the Heian period can best be described as

(A) philosophical in its concern
(B) more refined than the poetry of the Manyoshu era
(C) an outgowth of Buddhism and Confucianism
(D) sentimental in nature and lyrical in style
(E) written primarily for a female audience

Question 5 Which of the following statements about kana finds the LEAST support in the passage?

(A) It was based on the sound of the Japanese language.
(B) It was used primarily by Japanese women.
(C) It was used for Japanese poetry but not for Japanese prose.
(D) It was used in Japan after A.D. 793.
(E) It was considered inappropriate for austere subject matter.

Question 6 The author's primary purpose in the passage is to

(A) refute a commonly accepted explanation for the role of women in the development of Japanese poetry
(B) identify the reasons for the popularity of a distinct form of literary expression in Japan
(C) distinguish between the Japanese poetry of one historical period with that of another
(D) trace the influence of religion on the development of Japanese poetry
(E) provide an explanation for the role of women in the development of Japanese poetry

Figure A.7 Survey Form (green sheet) (1 of 3)

Survey Form
LAYOUT 1 of 3

Name:_____

To be completed immediately following the Tasks A and B.

1. How comfortable or uncomfortable do your eyes feel after completing these tasks in this lighting configuration?

Uncomfortable Comfortable

1 2 3 4 5 6 7 8 9 10

2. How do you feel the lighting conditions affected your speed/ accuracy?

Negatively Positively

1 2 3 4 5 6 7 8 9 10

3. How well were you able to focus on the tasks?

With Difficulty Easily

1 2 3 4 5 6 7 8 9 10

Open Question: Please add any additional commentary you have regarding how the lighting layout may have affected your performance:

Figure A.8 Algebra Marathon (2 of 3)

Task A - Algebra Marathon - v2 Name_____

Stop and Start with the Timer!

Evaluate each expression.

1) $(-22) + (-22)$
2) $13 + (-11)$
3) $(-19) - (-15)$
4) $15 - (-11)$
5) $(-5) + 25$
6) $12 - 25$
7) $24 + (-2)$
8) $(-1) - 15$
9) $25 - 7$
10) $(-12) - (-22)$
11) $(-9) - 11$
12) $11 - 22$
13) $8 + (-1)$
14) $20 - 9$
15) $(-6) - (-24)$
16) $(-5) - 4$
17) $23 - 4$
18) $(-24) + (-21)$
19) $(-3) - (-8)$
20) $3 - (-3)$
21) $22 + (-18)$
22) $21 - 13$
23) $(-23) + (-25)$
24) $(-4) - (-19)$
25) $22 + (-5)$
26) $(-23) + (-5)$
27) $(-11) - (-18)$
28) $15 - (-21)$
29) $5 - (-9)$
30) $11 + (-2)$
31) $7 - (-6)$
32) $(-13) + 3$
33) $3 + (-24)$
34) $(-2) - (-7)$
35) $6 - 14$
36) $(-21) + (-8)$
37) $(-25) - (-18)$
38) $6 - (-7)$
39) $21 - 24$
40) $(-8) + 14$
41) $(-23) + 17$
42) $17 + (-8)$
43) $12 - 18$
44) $4 - 13$
45) $(-8) + (-2)$
46) $(-14) + (-23)$
47) $(-2) + (-13)$
48) $(-17) + (-24)$
49) $(-12) - (-1)$
50) $(-1) - 25$
51) $(-6) + 7$
52) $(-3) - (-5)$
53) $(-23) - 13$
54) $(-9) + 11$
55) $(-3) - (-2)$
56) $(-4) - (-16)$
57) $(-14) - (-15)$
58) $(-23) - 15$
59) $(-4) + 10$
60) $25 + (-6)$
61) $25 - (-25)$
62) $(-19) - (-13)$
63) $(-12) + (-9)$
64) $4 + (-22)$
65) $12 - (-2)$
66) $(-8) + 1$
67) $(-21) + (-23)$
68) $(-7) - (-19)$
69) $5 + (-12)$
70) $(-3) + (-16)$
71) $21 - (-8)$
72) $(-18) - 23$
73) $11 - 12$
74) $25 - 25$
75) $(-3) - 23$
76) $8 + (-3)$
77) $15 - (-17)$
78) $(-18) - (-3)$
79) $(-20) + (-12)$
80) $(-11) + 5$

Figure A.9 Task B – Reading Comprehension Passage(s) (2 of 3)

Task B – Reading Comprehension – v1 Name:_____

Stop and Start with the Timer!

Read the following text until the time is called. Mark the location of your reading progress when the time is called, if you have not finished. Read the text at a pace that you can understand the material completely – you will be tested!

This Passage will have 4 associated questions.

The need to reroute seriously ill patients because the community's critical-care beds are full is not good news. Earlier this week, four of the six local hospitals ran out of space for the critically ill and had to turn people away.

The federal laws require hospitals to treat anyone who walks in. As a result of having to treat large numbers of uninsured patients, the emergency rooms often become an economic drain on their hospitals. Doctors now want to set up their own free-standing ambulatory surgical facilities and diagnostic centers. Critics contend this would leave hospitals with less revenue and the same number of indigents to treat.

A bill was recently introduced to phase out the need for a "certificate of public need" for non-hospital-based facilities, provided those facilities met stringent regulations and requirements. The finance committee balked at the hefty price and killed the bill, another casualty of a failed legislative session.

Unfortunately, the problem of access to medical care is not going to go away anytime soon and, despite the well-intended regulations, too-full hospitals compromise everyone's welfare. Healthy competition with small neighborhood surgical and diagnostic centers may be what is necessary to help dampen rising medical costs. But under no circumstances should the hospitals be forced to care for everybody without health insurance without additional help.

Figure A.10 Task B – Reading Comprehension Answers (2 of 3)

1) The best conclusion to this passage is:

a. If doctors want to run their own facilities, they should be required to take in at least some of the indigents.
b. Something must be done to ensure adequate health care for the uninsured.
c. Voters should tell the finance committee members that they will not be reelected if they do not pass some new legislation.
d. Everyone should be very concerned when the area's emergency rooms turn away patients due to overcrowding.
e. Health care costs have gotten way too high.

2) Which of the following best describes the author's mood?

a. neutral
b. positive
c. persuasive
d. angry
e. reverential

3) Which of the following is cited as a reason why hospitals are being unfairly burdened?

I. Failed legislative session
II. Problem of access
III. Federal law

a. I only
b. II only
c. III only
d. I and II
e. I, II, and III

4) The author cites the failed legislation in order to show that

a. the legislature will never resolve this issue.
b. the finance committee does not care about the uninsured citizens.
c. there will always be uninsured hospital patients.
d. the legislature recently attempted to resolve this issue.
e. the doctors successfully lobbied the finance committee.

Figure A.11 Survey Form (green sheet) (2 of 3)

Survey Form
LAYOUT 2 of 3

Name:_____

To be completed immediately following the Tasks A and B.

1. How comfortable or uncomfortable do your eyes feel after completing these tasks in this lighting configuration?

Uncomfortable Comfortable

1 2 3 4 5 6 7 8 9 10

2. How do you feel the lighting conditions affected your speed/ accuracy?

Negatively Positively

1 2 3 4 5 6 7 8 9 10

3. How well were you able to focus on the tasks?

With Difficulty Easily

1 2 3 4 5 6 7 8 9 10

Open Question: Please add any additional commentary you have regarding how the lighting layout may have affected your performance:

Figure A.12 Algebra Marathon (3 of 3)

Task A - Algebra Marathon - v3 Name_____

Stop and Start with the Timer!

Evaluate each expression.

1) 19 – 23
2) 1 – (–4)
3) 8 + (–1)
4) (–18) + (–22)
5) (–25) – (–23)
6) 6 + (–17)
7) (–15) – 2
8) 20 – (–5)
9) (–18) – 9
10) (–1) – (–15)
11) 11 – 4
12) (–17) – (–11)
13) 4 – (–23)
14) 12 – (–20)
15) (–15) – 22
16) (–14) – 1
17) 15 + (–7)
18) 9 + (–25)
19) (–23) – (–24)
20) 21 + (–11)
21) (–3) + 5
22) 22 – 7
23) (–17) + (–17)
24) 19 – (–22)
25) 13 + (–22)
26) (–4) – 18
27) 7 + (–16)
28) (–6) – 24
29) 17 + (–14)
30) 20 + (–17)
31) (–25) – 1
32) (–16) + (–24)
33) (–19) – 20
34) (–10) + 4
35) 4 + (–22)
36) 12 – 15
37) 8 – 15
38) (–21) + 16
39) 9 + (–1)
40) (–17) + (–22)
41) 5 – (–3)
42) (–16) + 7
43) (–5) + (–24)
44) (–4) + (–17)
45) (–10) + 15
46) (–6) + (–5)
47) (–19) + (–16)
48) (–24) + (–8)
49) (–11) + (–1)
50) (–11) – (–3)
51) 10 – 18
52) 18 – 15
53) 23 + (–1)
54) 7 – (–4)
55) (–25) + 6
56) (–14) – (–14)
57) 2 – (–2)
58) (–13) + 2
59) 13 – 4
60) (–12) + (–4)
61) (–12) – 24
62) (–2) + 23
63) (–5) + 15
64) (–7) + 3
65) 16 – (–7)
66) 2 – 23
67) 19 – (–21)
68) (–24) + (–5)
69) (–1) – 21
70) (–5) + (–19)
71) 6 + (–16)
72) 22 – (–2)
73) 13 + (–5)
74) (–22) + 18
75) 11 – (–21)
76) 22 – 8
77) 16 – (–22)
78) 8 – (–15)
79) (–6) + 2
80) (–17) – (–16)

Figure A.13 Task B – Reading Comprehension Passage(s) (3 of 3)

Task B – Reading Comprehension – v3 Name:_____

Stop and Start with the Timer!

Read the following text until the time is called. Mark the location of your reading progress when the time is called, if you have not finished. Read the text at a pace that you can understand the material completely – you will be tested!

This Passage will have 4 associated questions.

There are two major systems of criminal procedure in the modern world--the adversarial and the inquisitorial. The former is associated with common law tradition and the latter with civil law tradition. Both systems were historically preceded by the system of private vengeance in which the victim of a crime fashioned his own remedy and administered it privately, either personally or through an agent. The vengeance system was a system of self-help, the essence of which was captured in the slogan "an eye for an eye, a tooth for a tooth." The modern adversarial system is only one historical step removed from the private vengeance system and still retains some of its characteristic features. Thus, for example, even though the right to institute criminal action has now been extended to all members of society and even though the police department has taken over the pretrial investigative functions on behalf of the prosecution, the adversarial system still leaves the defendant to conduct his own pretrial investigation. The trial is still viewed as a duel between two adversaries, refereed by a judge who, at the beginning of the trial has no knowledge of the investigative background of the case. In the final analysis the adversarial system of criminal procedure symbolizes and regularizes the punitive combat.

By contrast, the inquisitorial system begins historically where the adversarial system stopped its development. It is two historical steps removed from the system of private vengeance. Therefore, from the standpoint of legal anthropology, it is historically superior to the adversarial system. Under the inquisitorial system the public investigator has the duty to investigate not just on behalf of the prosecutor but also on behalf of the defendant. Additionally, the public prosecutor has the duty to present to the court not only evidence that may lead to the conviction of the defendant but also evidence that may lead to his exoneration. This system mandates that both parties permit full pretrial discovery of the evidence in their possession. Finally, in an effort to make the trial less like a duel between two adversaries, the inquisitorial system mandates that the judge take an active part in the conduct of the trial, with a role that is both directive and protective.

Fact-finding is at the heart of the inquisitorial system. This system operates on the philosophical premise that in a criminal case the crucial factor is not the legal rule but the facts of the case and that the goal of the entire procedure is to experimentally recreate for the court the commission of the alleged crime.

Figure A.14 Task B – Reading Comprehension Answers (3 of 3)

1) The primary purpose of the passage is to

(A) explain why the inquisitorial system is the best system of criminal justice
(B) explain how the adversarial and the inquisitorial systems of criminal justice both evolved from the system of private vengeance
(C) show how the adversarial and inquisitorial systems of criminal justice can both complement and hinder each other's development
(D) show how the adversarial and inquisitorial systems of criminal justice are being combined into a new and better system
(E) analyze two systems of criminal justice and deduce which one is better

2) According to the passage, the inquisitorial system differs from the adversarial system in that

(A) it does not make the defendant solely responsible for gathering evidence for his case
(B) it does not require the police department to work on behalf of the prosecution
(C) it does not allow the victim the satisfaction of private vengeance
(D) it requires the prosecution to drop a weak case
(E) a defendant who is innocent would prefer to be tried under the inquisitorial system

3) Which one of the following best describes the organization of the passage?

(A) Two systems of criminal justice are compared and contrasted, and one is deemed to be better than the other.
(B) One system of criminal justice is presented as better than another. Then evidence is offered to support that claim.
(C) Two systems of criminal justice are analyzed, and one specific example is examined in detail.
(D) A set of examples is furnished. Then a conclusion is drawn from them.
(E) The inner workings of the criminal justice system are illustrated by using two systems.

4) The author views the prosecution's role in the inquisitorial system as being

(A) an advocate for both society and the defendant
(B) solely responsible for starting a trial
(C) a protector of the legal rule
(D) an investigator only
(E) an aggressive but fair investigator

Figure A.15 Survey Form (green sheet) (3 of 3)

Survey Form
LAYOUT 3 of 3

Name:_____

To be completed immediately following the Tasks A and B.

1. How comfortable or uncomfortable do your eyes feel after completing these tasks in this lighting configuration?

Uncomfortable Comfortable

1 2 3 4 5 6 7 8 9 10

2. How do you feel the lighting conditions affected your speed/ accuracy?

Negatively Positively

1 2 3 4 5 6 7 8 9 10

3. How well were you able to focus on the tasks?

With Difficulty Easily

1 2 3 4 5 6 7 8 9 10

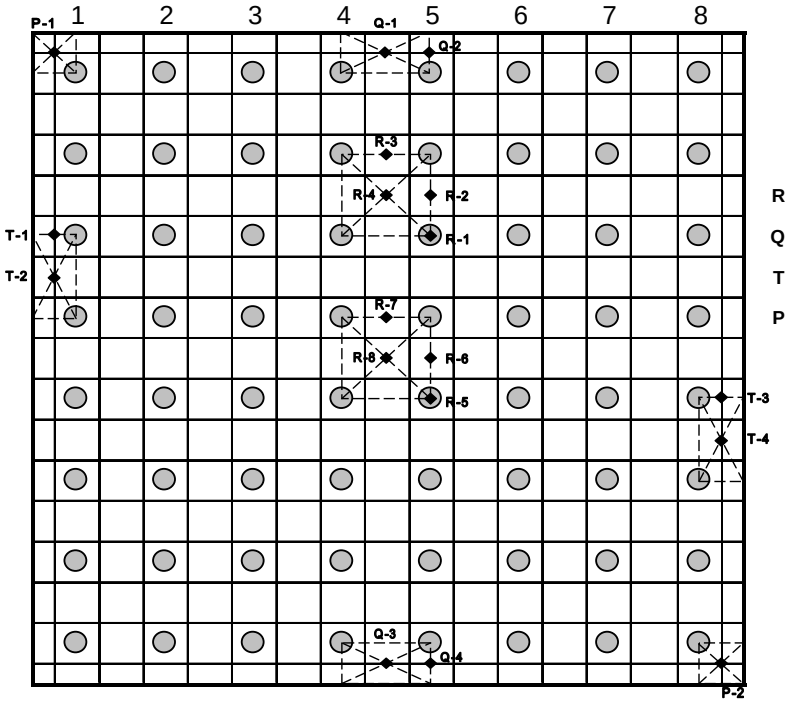
Open Question: Please add any additional commentary you have regarding how the lighting layout may have affected your performance:

Appendix B - Lighting Layout Establishment Information

Figure B.1 Calculation: Uniform Lighting Level Estimation – 30fc Uniform

Cells colored GREEN are to be filled in with data.

Data collected by Nick Caton,
Assisted by Robert Nelson
March 02, 2007
Configuration A



Illuminance Readings (fc)

	1	2	3	4	5	6	7	8
R	32.2	36.5	36.4	41.5	43.5	43.6	40.2	41.1
Q	27.5	29.2	14.1	21.0				
T	25.0	25.2	24.2	24.0				
P	21.0	15.7						

Conditions followed for this data collection:

* Measurements are taken 30" AFF.
* No daylight is present in the room.
* Data collected between 6:30 and 10:00.
* Luminaires are regularly spaced.
* Luminaires are located symmetrically.
* All fenestrations in the room have been covered by materials which will not allow light to pass

Steps: Notes:

1)	Average all "r" values	R = 39	values in center of space
2)	Average all "q" values	Q = 23	values along top/bottom walls
3)	Average all "t" values	T = 25	values along left/right walls
4)	Average all "p" values	P = 18	values in corners

5) Average Illuminance = $\frac{R(N-1)(M-1) + Q(N-1) + T(M-1) + P}{NM}$

where N = 3 = number of luminaires per row,
and M = 3 = number of rows

Using this equation,
Average Illuminance = **30.1** lm/SF

This spreadsheet illustrates an estimation method used to quickly determine an estimate of the Uniform lighting distribution, without taking a full grid's worth of measurements. More information on this and other illuminance estimation methods is available in *Lamps and Lighting, 4th ed.*

Figure B.2 30fc Uniform Layout Measurements

How to establish a horizontal grid with an appropriate number of measurements:

Procedure:

1) Find the Room Index:

RI = (LW)/(mh(L+W)) = 2.53

where:

L = length of room = 30'

W = width of room = 22'

mh = mtg. height above work plane = 5'

2) Define the parameter "x" as the next highest integer from the Room Index

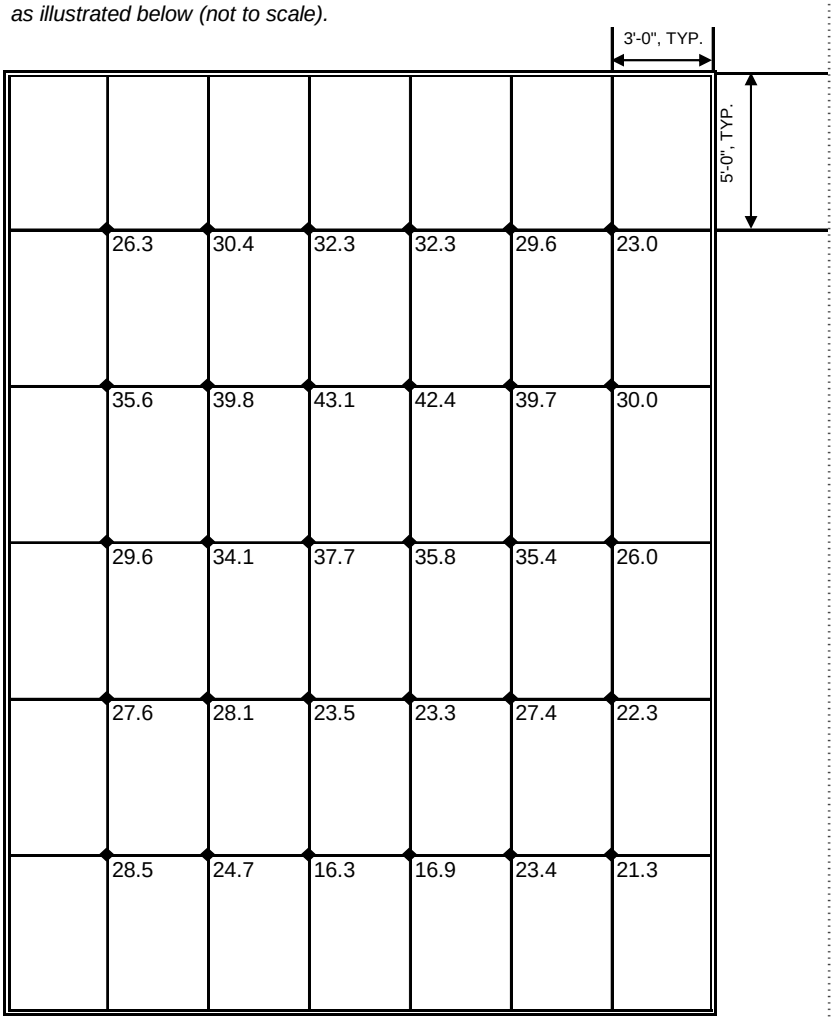
x = 3

3) Find the minimum number of points using the following formula

Minimum number = $(x + 2)^2 = (3 + 2)^2$

4) Judge, based on the room geometry and any defining features (such as a ceiling grid) a number of points to use that will allow easy and accurate measurements.

In this case, a 30-point 3'-0" x 5'-0" grid was used, as illustrated below (not to scale).



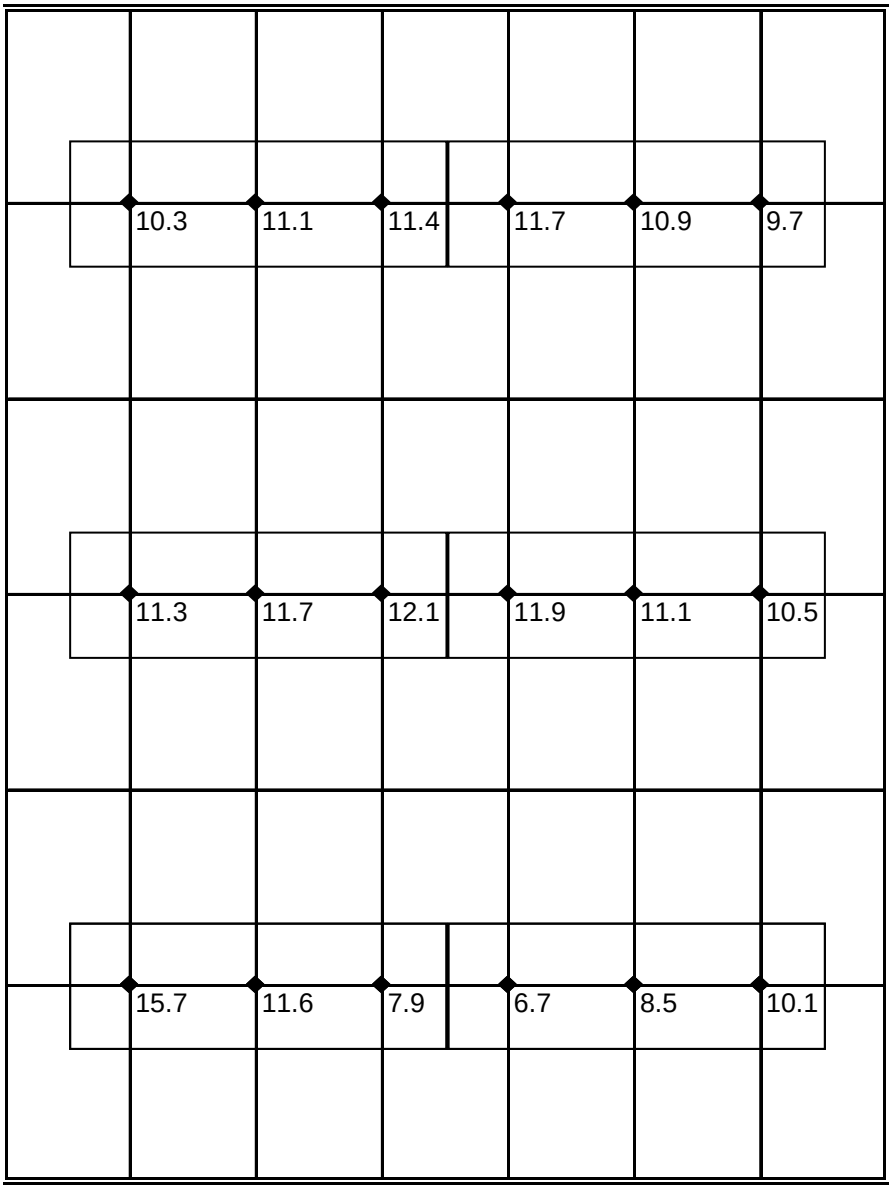
Results:

Average Illuminance level, horizontal plane: 29.5

Shown is the calculation made to determine the correct number of measurement points to establish a Uniform grid measurement, as well as the 30fc Uniform layout's measurements.

Figure B.3 Task-Ambient: Ambient Portion measurements

Task-Ambient Layout - Ambient Only
One measurement is taken in front of each seat, 18 points total
Direct-Indirect fluorescent fixtures used, dimmed down.
This dimmed setting has been saved to Preset 4

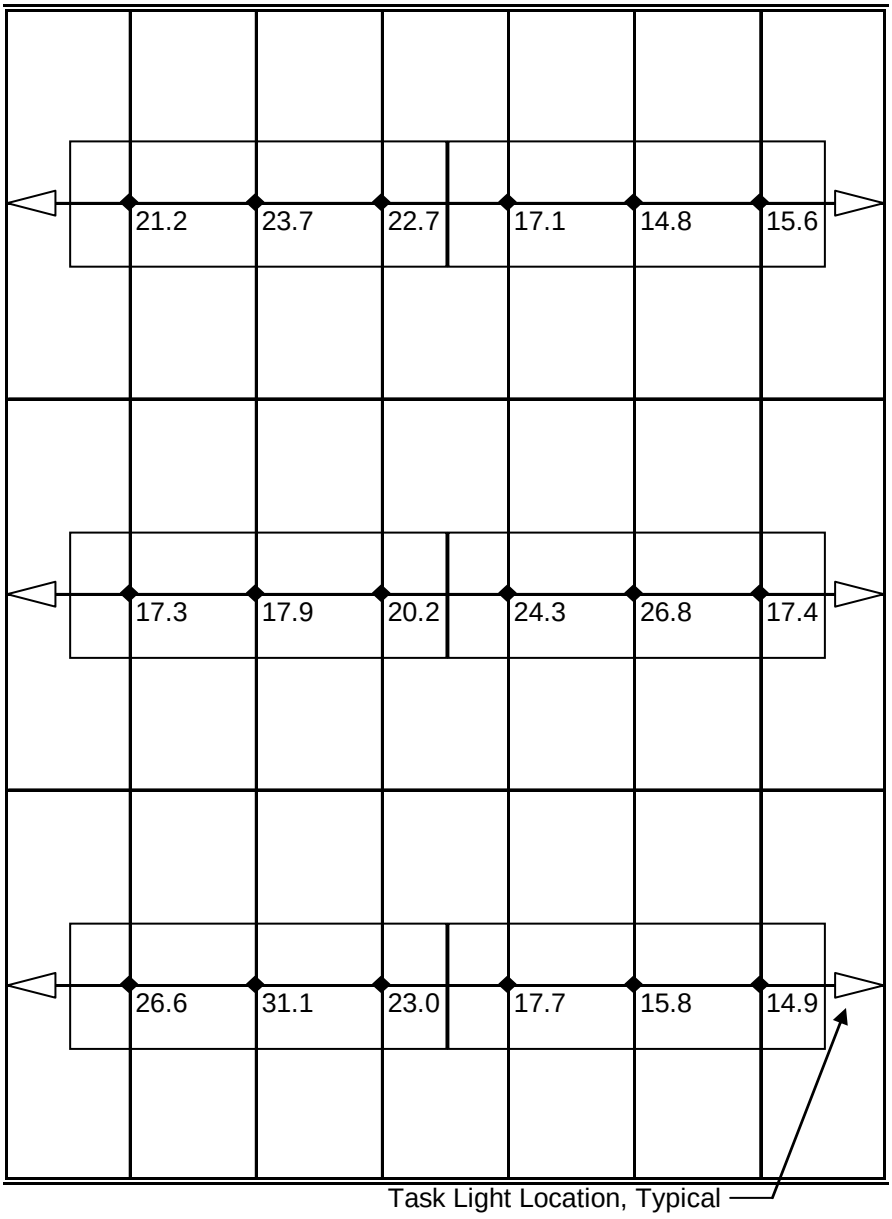


Results:
Average Illuminance level, horizontal plane: 10.8

These are the measurements taken for the Ambient half of the Task-Ambient layout. For simplicity, the Ambient portion was established first, then the Task, then the combination was measured. The Task portion and the combined Task-Ambient layouts follow.

Figure B.4 Task-Ambient: Task Portion measurements

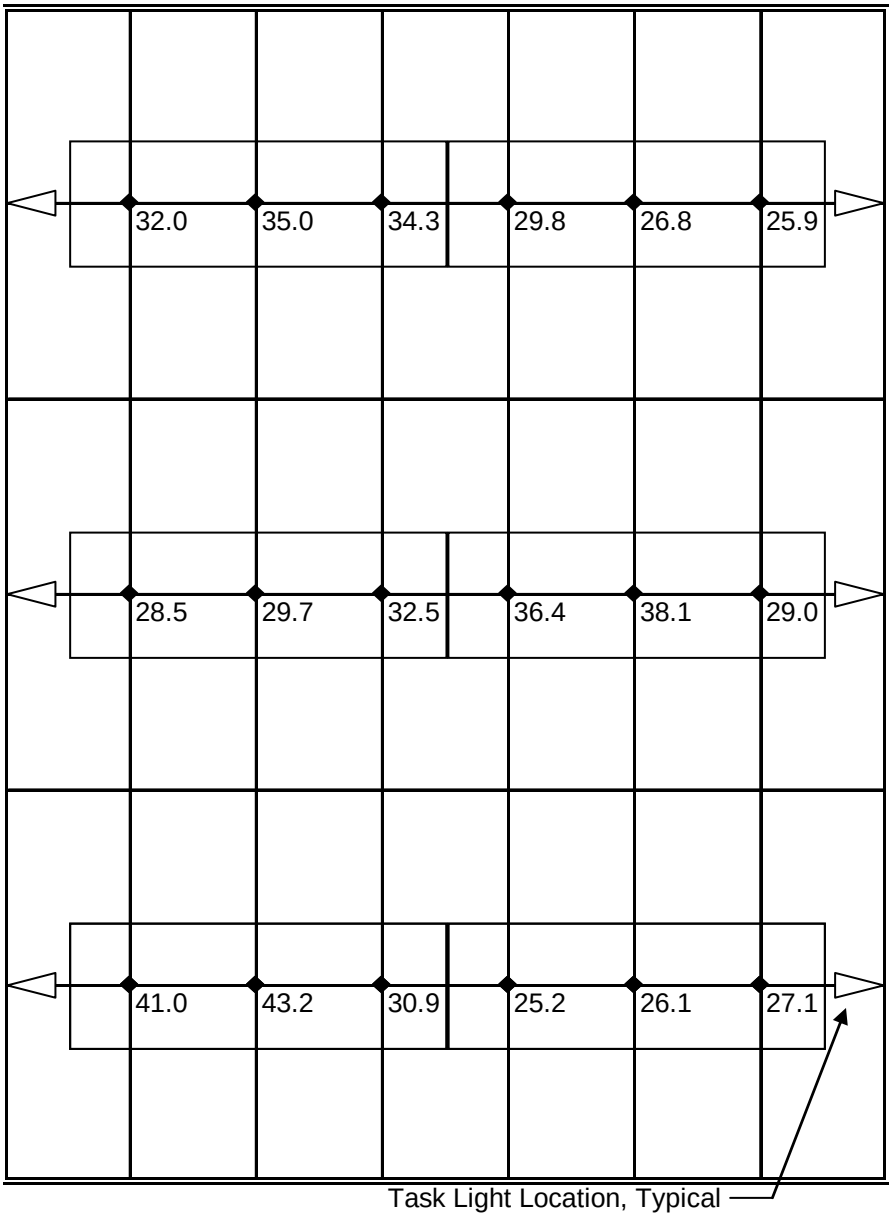
Task-Ambient Layout - Task Only
One measurement is taken in front of each seat, 18 points total
(3) 75W spot incandescent lamps at 6.5' AFF along each wall, aimed towards the center of the nearest table



Results:
Average Illuminance level, horizontal plane: **20.5**

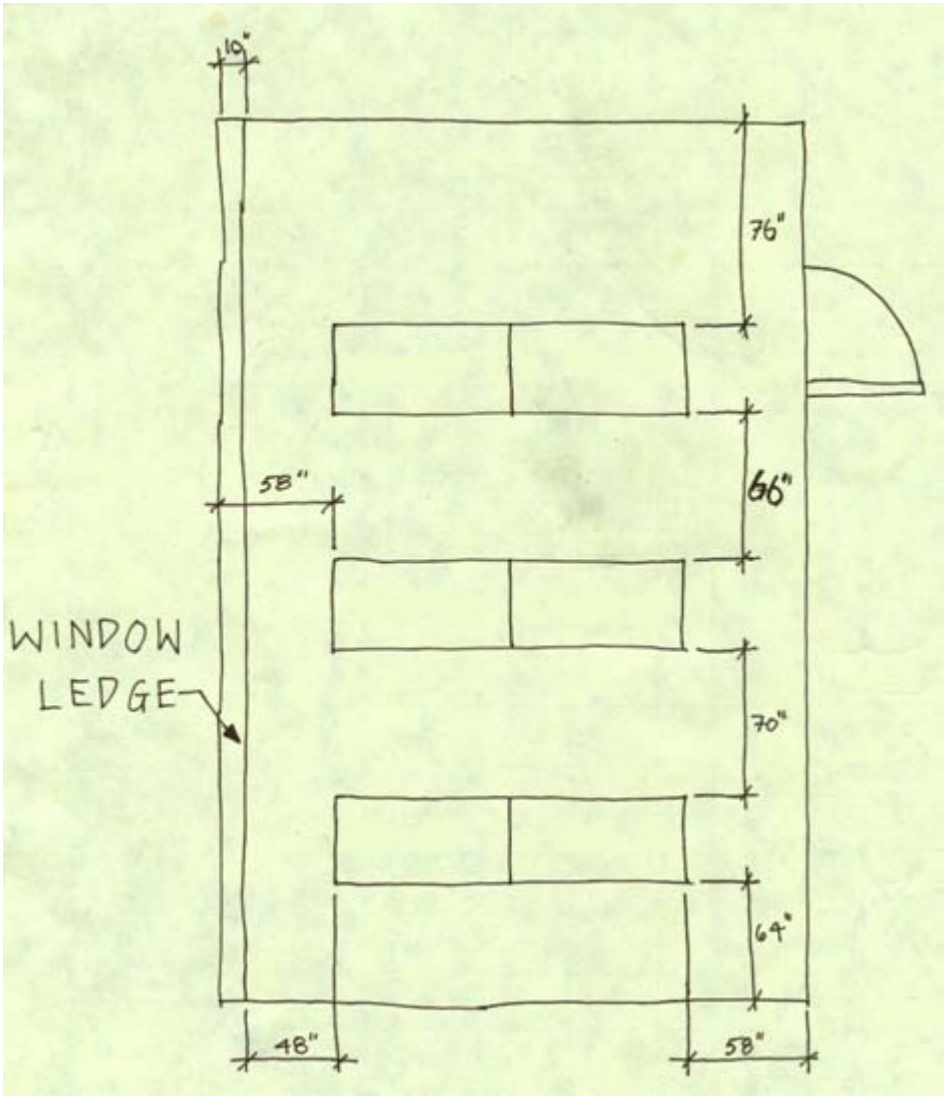
Figure B.5 Full Task-Ambient Layout Measurements

Task-Ambient Layout - Full
This is a combination of the established Task and Ambient components.



Results:
Average Illuminance level, on task surface: **31.8**

Figure B.6 Lighting Lab Table Positioning Measurements



Appendix C - Photographs

Figure C.1 50fc Uniform Lighting Layout

Figure C.2 30fc Uniform Lighting Layout

Figure C.3 Task-Ambient Lighting Layout

Figure C.4 The Kansas State Department of ARE and CNS Lighting Lab

Figure C.5 Robert Nelson properly taking a footcandle reading on the task plane

Figure C.6 Recording of Mockup Illuminance Data

Figure C.7 Elimination of Fenestrations and External Light Sources

Figure C.8 Typical Obscuration Method for Undesired Fixtures

Figure C.9 Motorized Blinds along Lighting Lab West Wall

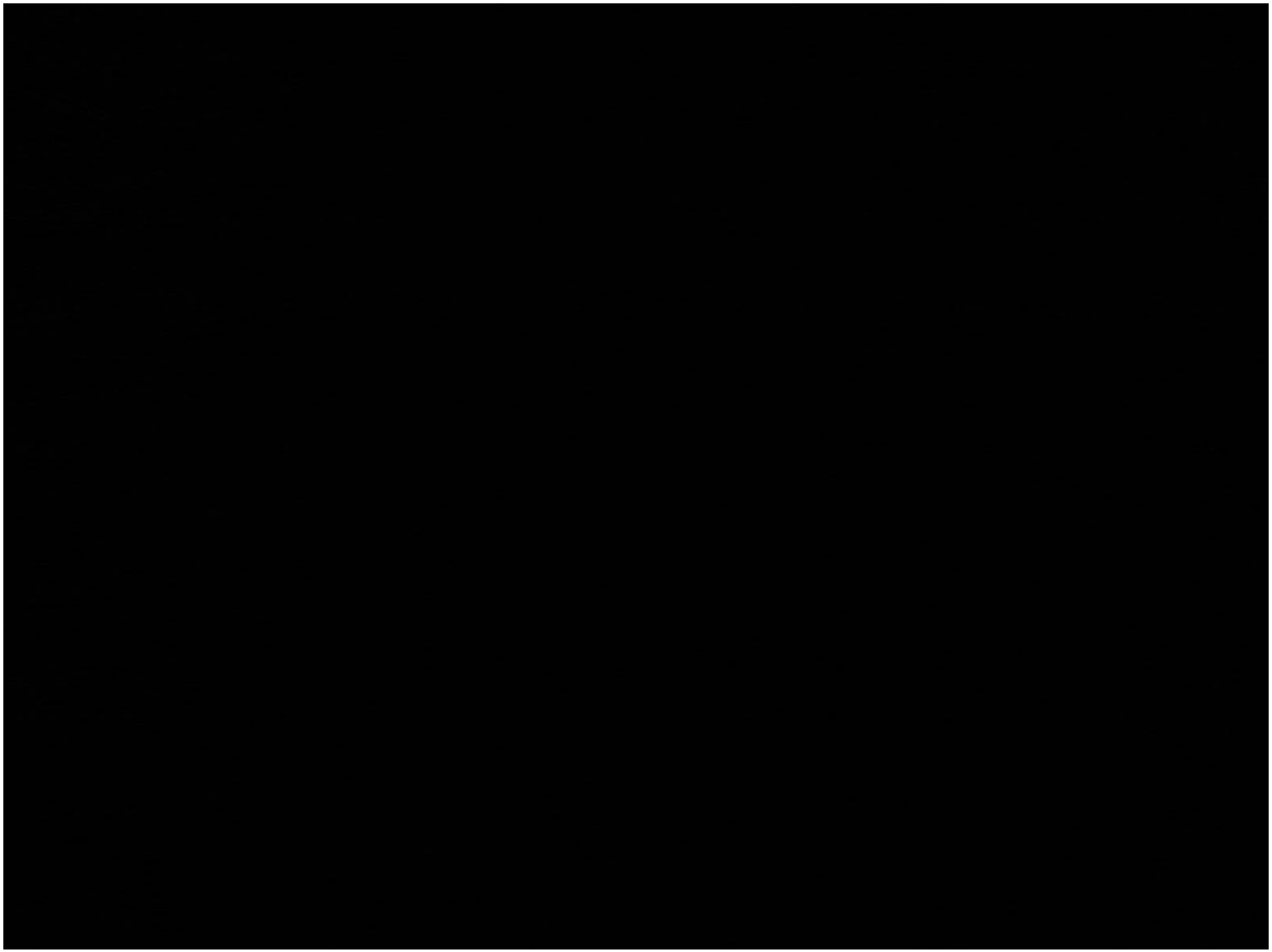


Figure C.10 Identification of Contaminate Light Sources

Appendix D - Survey Data

Table D.1 Raw Math Task Data

Math Scores					Productivity Score (A, NA only)	Accuracy Score (NA = ok)	Overall Score (NA = wrong)
PARTICIPANT	Layout #	Test Version	Incorrect Answers	Number w/ No Answer			
K-1	1 of 3	v1	3	38	53%	93%	49%
	2 of 3	v2	4	34	58%	91%	53%
	3 of 3	v3	3	27	66%	94%	63%
K-2	1 of 3	v1	1	21	74%	98%	73%
	2 of 3	v2	1	32	60%	98%	59%
	3 of 3	v3	2	18	78%	97%	75%
K-3	1 of 3	v1	10	20	75%	83%	63%
	2 of 3	v2	1	29	64%	98%	63%
	3 of 3	v3	3	24	70%	95%	66%
K-4	1 of 3	v1	3	0	100%	96%	96%
	2 of 3	v2	0	11	86%	100%	86%
	3 of 3	v3	1	2	98%	99%	96%
K-5	1 of 3	v1	-	-			
	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
S-1	1 of 3	v1	0	24	70%	100%	70%
	2 of 3	v2	1	19	76%	98%	75%
	3 of 3	v3	2	12	85%	97%	83%
S-2	1 of 3	v1	0	0	100%	100%	100%
	2 of 3	v2	1	14	83%	98%	81%
	3 of 3	v3	3	0	100%	96%	96%
S-3	1 of 3	v1	-	-			
	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
S-4	1 of 3	v1	1	0	100%	99%	99%
	2 of 3	v2	3	0	100%	96%	96%
	3 of 3	v3	1	0	100%	99%	99%
S-5	1 of 3	v1	6	34	58%	87%	50%
	2 of 3	v2	4	38	53%	90%	48%
	3 of 3	v3	2	22	73%	97%	70%
S-6	1 of 3	v1	-	-			
	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
U-1	1 of 3	v1	3	34	58%	93%	54%
	2 of 3	v2	5	40	50%	88%	44%
	3 of 3	v3	8	30	63%	84%	53%
U-2	1 of 3	v1	-	-			
	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
U-3	1 of 3	v1	-	-			
	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
U-4	1 of 3	v1	6	8	90%	92%	83%
	2 of 3	v2	5	8	90%	93%	84%
	3 of 3	v3	7	0	100%	91%	91%
	1 of 3	v1	-	-			
U-5	2 of 3	v2	-	-			
	3 of 3	v3	-	-			
					Productivity Score (A, NA only)	Accuracy Score (NA = ok)	Overall Score (NA = wrong)

Table D.2 Raw Reading Task Data

Reading Scores									Overall Score	Accuracy Score	Productivity Score
		Test	Question								
PARTICIPANT	Layout #	Version	#1	#2	#3	#4	#5	#6	(NA = wrong)	(NA = ok)	(A, NA only)
K-1	1 of 3	v1	D	C	E	D			25%	25%	100%
	2 of 3	v3	B	A	C	B			25%	25%	100%
	3 of 3	v2	E	C	D	NA	NA	NA	17%	33%	50%
K-2	1 of 3	v1	A	C	A	D			50%	50%	100%
	2 of 3	v3	B	C	A	D			25%	25%	100%
	3 of 3	v2	A	B	D	B	NA	E	17%	20%	83%
K-3	1 of 3	v1	D	C	D	D			50%	50%	100%
	2 of 3	v3	B	A	E	A			25%	25%	100%
	3 of 3	v2	E	A	B	NA	NA	NA	50%	100%	50%
K-4	1 of 3	v1	B	C	E	B			25%	25%	100%
	2 of 3	v3	B	C	B	NA			0%	0%	75%
	3 of 3	v2	C	C	B	NA	NA	NA	17%	33%	50%
K-5	1 of 3	v1	-	-	-	-	-	-			
	2 of 3	v3	-	-	-	-	-	-			
	3 of 3	v2	-	-	-	-	-	-			
S-1	1 of 3	v2	A	C	D	C	E	E	17%	17%	100%
	2 of 3	v1	B	A	B	C			0%	0%	100%
	3 of 3	v3	B	A	A	A			50%	50%	100%
S-2	1 of 3	v2	E	A	B	NA	NA	NA	50%	100%	50%
	2 of 3	v1	A	D	A	A			25%	25%	100%
	3 of 3	v3	A	A	A	NA			50%	67%	75%
S-3	1 of 3	v2	-	-	-	-	-	-			
	2 of 3	v1	-	-	-	-	-	-			
	3 of 3	v3	-	-	-	-	-	-			
S-4	1 of 3	v2	A	C	NA	NA	NA	NA	0%	0%	33%
	2 of 3	v1	B	E	C	D			0%	0%	100%
	3 of 3	v3	B	A	B	E			50%	50%	100%
S-5	1 of 3	v2	NA	B	D	NA	NA	NA	0%	0%	33%
	2 of 3	v1	D	C	A	C			25%	25%	100%
	3 of 3	v3	E	A	A	A			75%	75%	100%
S-6	1 of 3	v2	-	-	-	-	-	-			
	2 of 3	v1	-	-	-	-	-	-			
	3 of 3	v3	-	-	-	-	-	-			
U-1	1 of 3	v3	C	E	E	A			0%	0%	100%
	2 of 3	v2	C	C	A	C	B	E	17%	17%	100%
	3 of 3	v1	E	D	A	A			0%	0%	100%
U-2	1 of 3	v3	-	-	-	-	-	-			
	2 of 3	v2	-	-	-	-	-	-			
	3 of 3	v1	-	-	-	-	-	-			
U-3	1 of 3	v3	-	-	-	-	-	-			
	2 of 3	v2	-	-	-	-	-	-			
	3 of 3	v1	-	-	-	-	-	-			
U-4	1 of 3	v3	C	A	A	D			50%	50%	100%
	2 of 3	v2	B	C	E	E	D	D	0%	0%	100%
	3 of 3	v1	B	C	C	D			25%	25%	100%
U-5	1 of 3	v3	-	-	-	-	-	-			
	2 of 3	v2	-	-	-	-	-	-			
	3 of 3	v1	-	-	-	-	-	-			
									25%	30%	87%
									Average Score (NA = wrong)	**Average Score** (NA = ok)	**Average Score** (NA = ok)

Table D.3 Raw Survey Data

Survey Data (Green Sheets)				
		Question		
PARTICIPANT	Layout #	#1	#2	#3
K-1	1 of 3	7	6	6
	2 of 3	8	7	7
	3 of 3	9	8	9
K-2	1 of 3	8	5	5
	2 of 3	9	4	4
	3 of 3	10	7	8
K-3	1 of 3	7	8	9
	2 of 3	4	5	3
	3 of 3	6	6	5
K-4	1 of 3	9	5	7
	2 of 3	3	3	1
	3 of 3	5	4	1
K-5	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-
S-1	1 of 3	10	9	9
	2 of 3	4	6	5
	3 of 3	10	10	10
S-2	1 of 3	9	8	9
	2 of 3	7	6	7
	3 of 3	8	8	9
S-3	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-
S-4	1 of 3	8	9	8
	2 of 3	9	9	10
	3 of 3	9	10	10
S-5	1 of 3	2	3	4
	2 of 3	8	6	7
	3 of 3	1	4	3
S-6	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-
U-1	1 of 3	8	5	8
	2 of 3	9	9	9
	3 of 3	10	10	10
U-2	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-
U-3	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-
U-4	1 of 3	5	7	5
	2 of 3	6	8	7
	3 of 3	8	8	8
U-5	1 of 3	-	-	-
	2 of 3	-	-	-
	3 of 3	-	-	-

Appendix E - Cost-Comparison Calculations and Data

Figure E.1

Demand Rate 6.75 ($/kW)
Energy Rate 0.04347 ($/kWh)

Uniform		Fixture Base Cost		Installation Cost Factor	Annual Energy Cost *					
					Fixture Operating Power		Annual Operating	Energy	Demand	Net Cost
Fixture	Qty.	Unit	Extended	(+30%)	Watts	Extended (W)	Power (kWh/year)	Charge ($/yr)	Charge **	($/yr)
A	0	$141.25 e/a	$0.00	$0.00	47	0	0	$0.00	$0.00	$0.00
B	0	$61.25 /LF	$0.00	$0.00	19	0	0	$0.00	$0.00	$0.00
C	0	$228.75 e/a	$0.00	$0.00	27	0	0	$0.00	$0.00	$0.00
D	15	$55.00 e/a	$825.00	$1,072.50	45	675	5913	$257.04	$288.26	$545.30
			Total:	$1,072.50	**Total:**	**675**	**5913**		**Total:**	$545.30

Task-Ambient		Fixture Base Cost		Installation Cost Factor	Annual Energy Cost *					
					Fixture Operating Power		Annual Operating	Energy	Demand	
Fixture	Qty.	Unit	Extended	(+30%)	Watts	Extended (W)	Power (kWh/year)	Charge ($/yr)	Charge **	Total ($/yr)
A	6	$141.25 e/a	$847.50	$1,101.75	47	282	2470.32	$107.39	$0.00	$107.39
B	6	$61.25 /LF	$1,470.00	$1,911.00	19	114	998.64	$43.41	$0.00	$43.41
C	6	$228.75 e/a	$1,372.50	$1,784.25	27	162	1419.12	$61.69	$0.00	$61.69
D	0	$55.00 e/a	$0.00	$0.00	45	0	0	$0.00	$0.00	$0.00
			Total:	$4,797.00	**Total:**	**558**	**4888**		**Total:**	$212.49

* Calculated with information provided by Westar Energy North (Westar)
* Rate based on "Small General Service" (Electrical Demand < 200kW)
* Energy Charge of $0.0.043471 per kWh
* Demand Charge of $6.75 per kW - based on maximum system draw
** Incremental Demand Charge per year ($/yr) - only applies to Uniform Layout
=kWh/year / 24h x $/kW

Table E.1

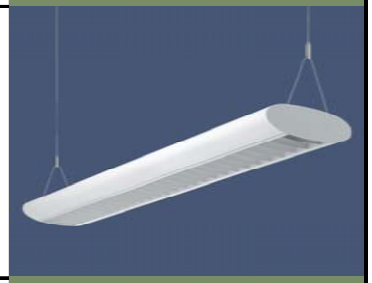
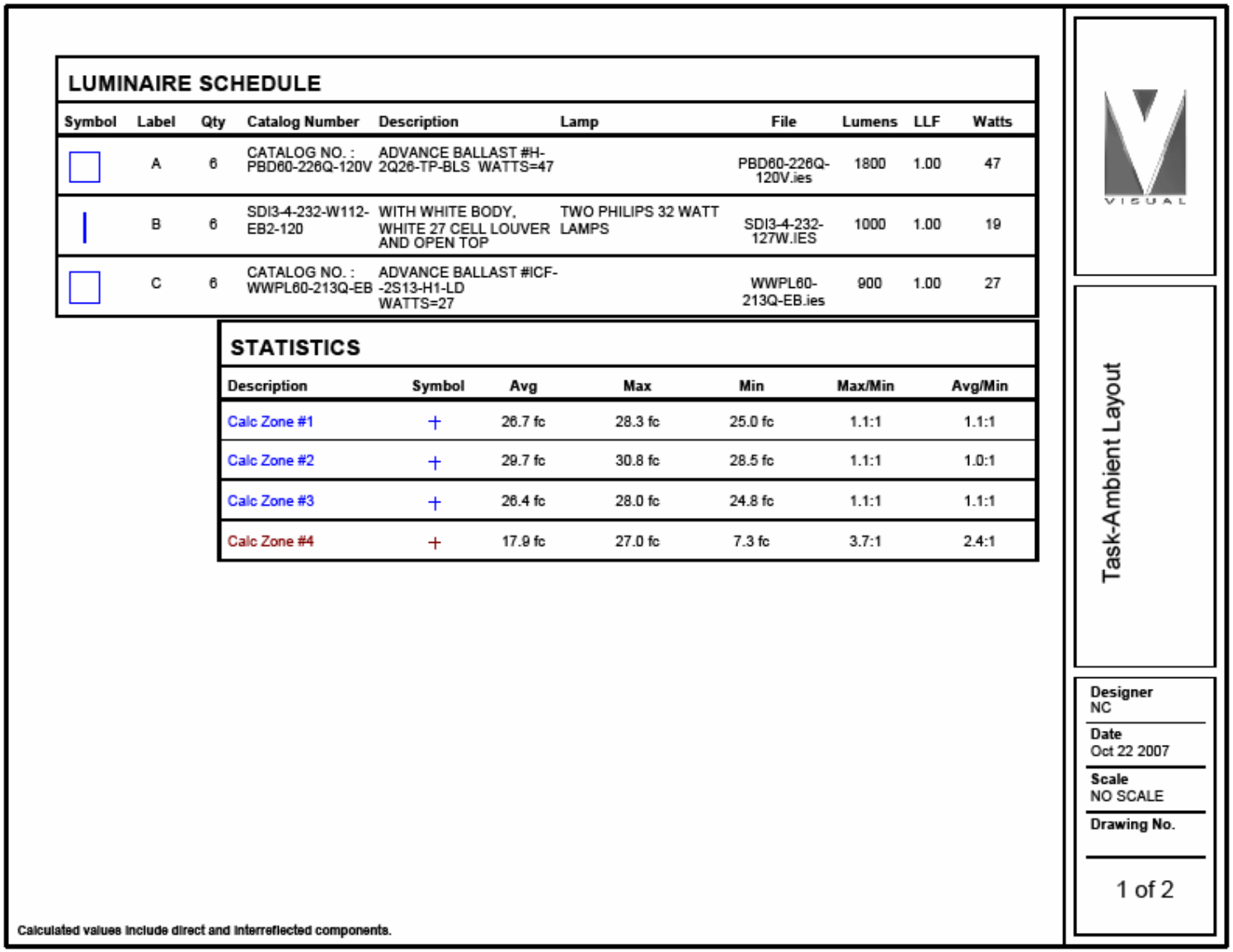
Fixture	Manufacturer	Catalog Number	Ballast	Lamp(s)	Picture
A	Williams	PBD60-226Q-G24d3	Advance ballast #H-2Q26-TP-BLS, factory installed by Williams	(2) 26Watt, 2-Pin G24d-35 Quad-Tube	
B	Williams	SDI3-4-232-128W-120	2-lamp electronic dimming ballast, equivalent to Advance ballast #REZ-2S32	(2) F32T8 Linear Fluorescent	
C	Williams	WWPL60-213Q-EB-G24q-1	Advance Ballast #ICF-2S13-H1-LD, factory installed by Williams	(2) 13 Watt, 4-Pin G24q-1 Base Compact Fluorescent	
D	Williams	50G-S22-217-SA12125-EB2-120	2 lamp electronic ballast, factory installed by Williams	(2) 17 Watt 2' T8	

Figure E.2



LUMINAIRE SCHEDULE

Symbol	Label	Qty	Catalog Number	Description	Lamp	File	Lumens	LLF	Watts
	A	6	CATALOG NO. : PBD60-226Q-120V	ADVANCE BALLAST #H-2Q26-TP-BLS WATTS=47		PBD60-226Q-120V.ies	1800	1.00	47
	B	6	SDI3-4-232-W112-EB2-120	WITH WHITE BODY, WHITE 27 CELL LOUVER AND OPEN TOP	TWO PHILIPS 32 WATT LAMPS	SDI3-4-232-127W.IES	1000	1.00	19
	C	6	CATALOG NO. : WWPL60-213Q-EB	ADVANCE BALLAST #ICF--2S13-H1-LD WATTS=27		WWPL60-213Q-EB.ies	900	1.00	27

STATISTICS

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Calc Zone #1	+	26.7 fc	28.3 fc	25.0 fc	1.1:1	1.1:1
Calc Zone #2	+	29.7 fc	30.8 fc	28.5 fc	1.1:1	1.0:1
Calc Zone #3	+	26.4 fc	28.0 fc	24.8 fc	1.1:1	1.1:1
Calc Zone #4	+	17.9 fc	27.0 fc	7.3 fc	3.7:1	2.4:1

Calculated values include direct and interreflected components.

VISUAL

Task-Ambient Layout

Designer
NC

Date
Oct 22 2007

Scale
NO SCALE

Drawing No.

1 of 2

Figure E.3

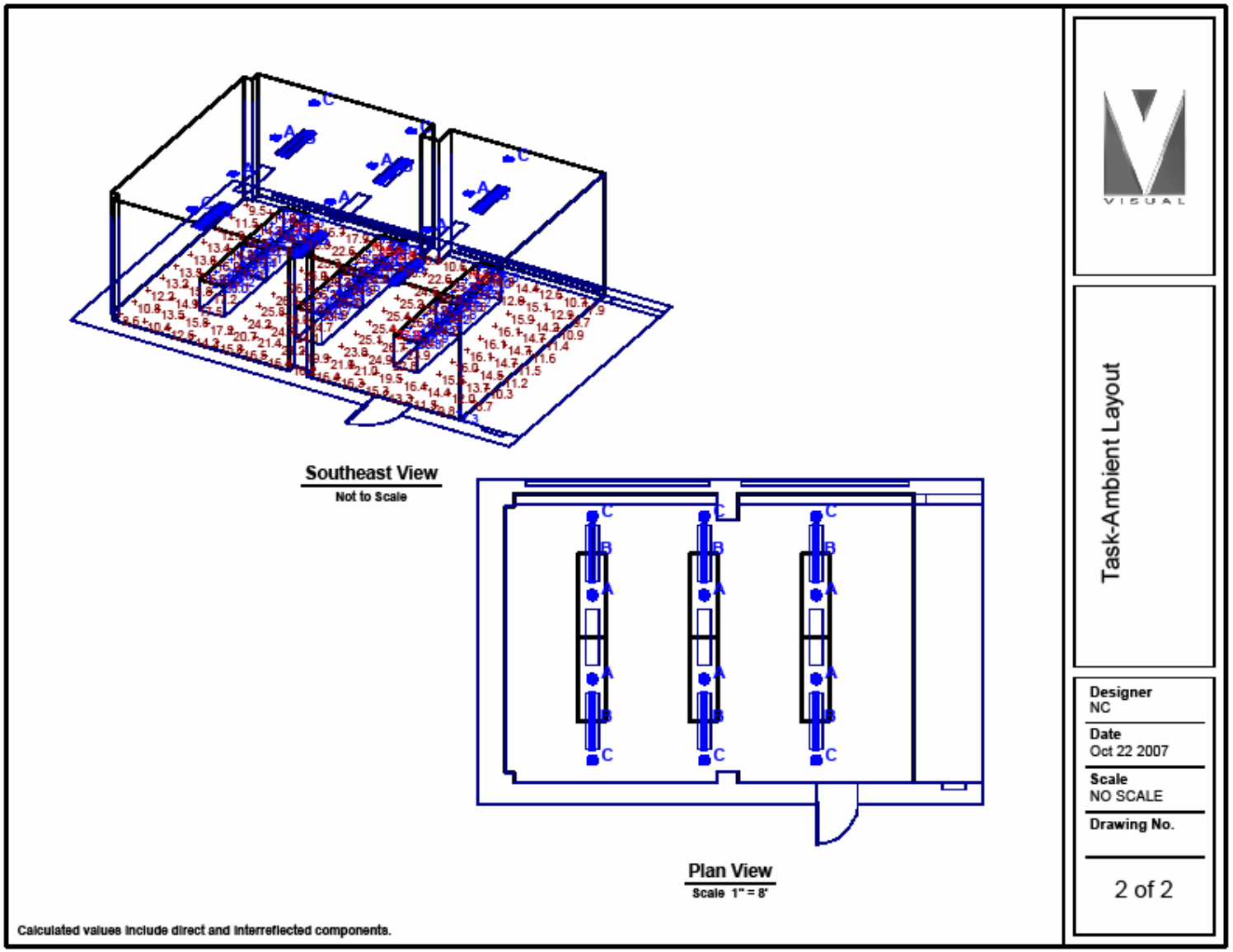

Southeast View
Not to Scale
Plan View
Scale 1" = 8'
Calculated values include direct and interreflected components.
VISUAL
Task-Ambient Layout
Designer
NC
Date
Oct 22 2007
Scale
NO SCALE
Drawing No.
2 of 2

Figure E.4

LUMINAIRE SCHEDULE

Symbol	Label	Qty	Catalog Number	Description	Lamp	File	Lumens	LLF	Watts
	LM-2	15				50G-S22-217-SA12125.ies	1400	0.68	45

STATISTICS

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Workplane	+	N / A	N / A	N / A	N / A	N / A

Calculated values include direct and interreflected components.

Figure E.5

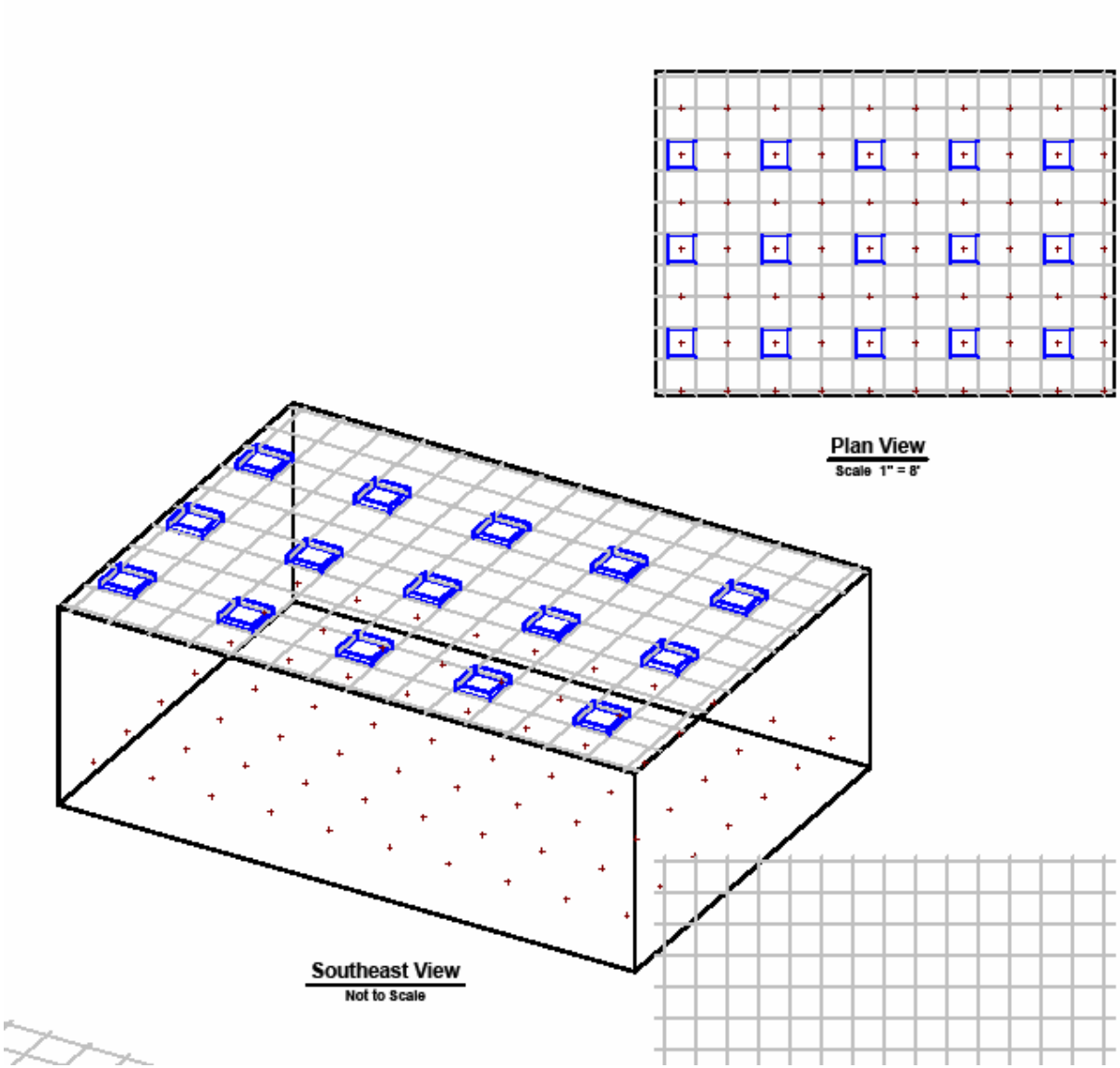


Figure E.6

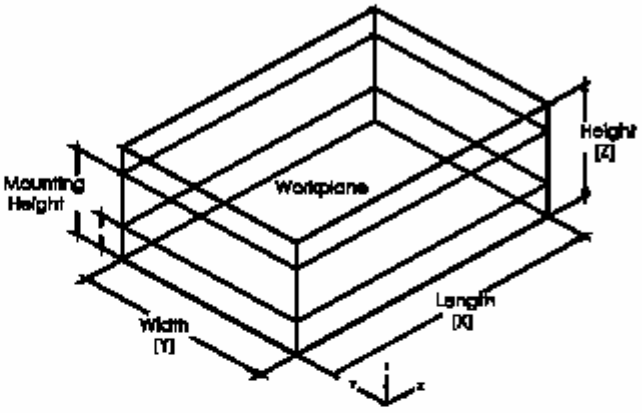
Lumen Method Summary

Project

Title
Number
Company
Designer

Room

Length [X]	29.17	ft
Width [Y]	20.67	ft
Height [Z]	10	ft
RCR	3.10	
Ceiling	80	%
Walls	50	%
Floor	20	%
Workplane Height	2.5	ft

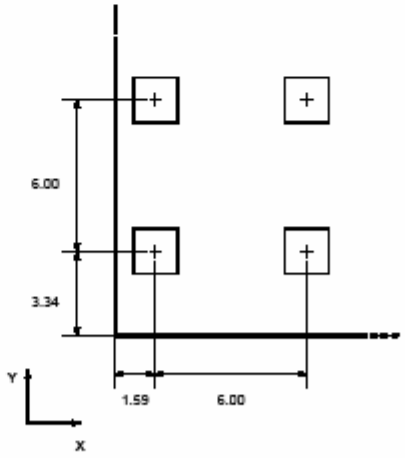


Luminaire

Mounting Height	10 ft
Catalog Number	
Manufacturer	
IES File Name	50G-S22-217-SA12125.ies
Lamp Description	
Number of Lamps	2
Lamp Lumens	1400
Light Loss Factor	0.68
Coefficient of Utilization	0.65

Output

Illuminance	31	fc
Number of Luminaires	15	
Number of Columns [X]	5	
Number of Rows [Y]	3	
Column Spacing [X]	6.00	ft
Row Spacing [Y]	6.00	ft
Column Start [X]	1.59	ft
Row Start [Y]	3.34	ft
Power Density	1.12	Watts/sq. ft



Note: Calculations are based on procedures established by the Illuminating Engineering Society of North America, or standard industry practice.
Visual computes output performance based on input data as provided by, and which is the sole responsibility of, the user.
The Acuity Lighting Group cannot be held responsible for the variations in actual situations which can effect calculated output.

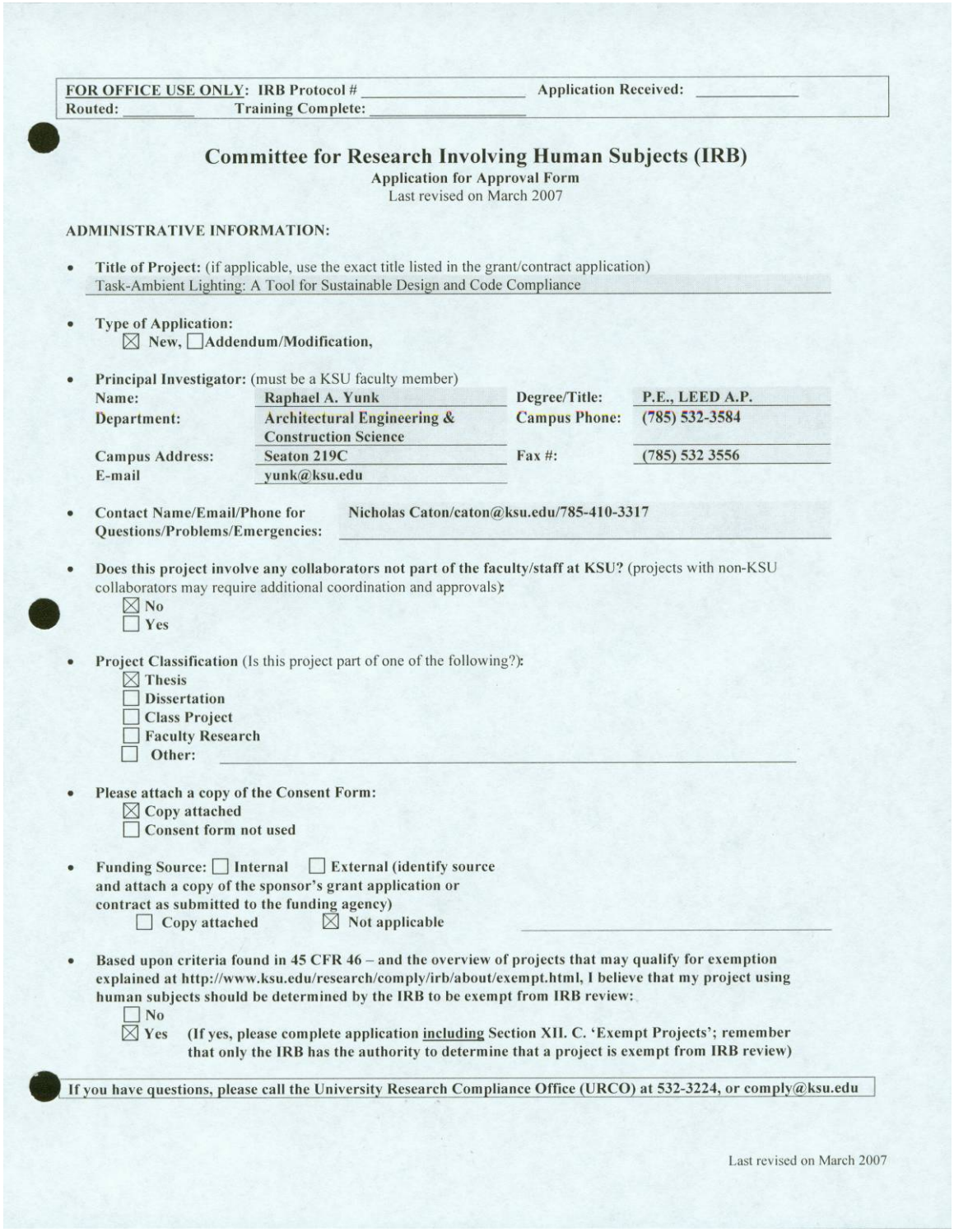
Visual

Appendix F - Committee for Research Involving Human Subjects Documentation

"The Committee on Research Involving Human Subjects serves as the Institutional Review Board (IRB) mandated by federal laws and regulations, and is responsible for oversight of all activities involving research with human subjects." (K-State)

In order to perform any research involving humans, including the survey techniques used for this research, one must submit a number of documents describing the purpose, procedures and necessity for the research before proceeding. The committee's approval, which also requires the completion of online training courses covering the history and need for ethical research, is required before any research begins. This appendix is provided both as documentation that the required approval steps have been taken, as well as a reference for future researchers wishing to pursue similar survey-based studies within the Architectural Engineering Department.

Figure F.1 IRB Application for Approval Form and required attachments (14 pages)



FOR OFFICE USE ONLY: IRB Protocol # _____ Application Received: _____
Routed: _____ Training Complete: _____

Committee for Research Involving Human Subjects (IRB)

Application for Approval Form
Last revised on March 2007

ADMINISTRATIVE INFORMATION:

- **Title of Project:** (if applicable, use the exact title listed in the grant/contract application)
  Task-Ambient Lighting: A Tool for Sustainable Design and Code Compliance

- **Type of Application:**
  ☒ New, ☐ Addendum/Modification,

- **Principal Investigator:** (must be a KSU faculty member)

Name:	**Raphael A. Yunk**	**Degree/Title:**	**P.E., LEED A.P.**
Department:	**Architectural Engineering & Construction Science**	**Campus Phone:**	**(785) 532-3584**
Campus Address:	**Seaton 219C**	**Fax #:**	**(785) 532 3556**
E-mail	**yunk@ksu.edu**		

- **Contact Name/Email/Phone for Questions/Problems/Emergencies:** **Nicholas Caton/caton@ksu.edu/785-410-3317**

- **Does this project involve any collaborators not part of the faculty/staff at KSU?** (projects with non-KSU collaborators may require additional coordination and approvals):
  ☒ No
  ☐ Yes

- **Project Classification** (Is this project part of one of the following?):
  ☒ Thesis
  ☐ Dissertation
  ☐ Class Project
  ☐ Faculty Research
  ☐ Other: _____

- **Please attach a copy of the Consent Form:**
  ☒ Copy attached
  ☐ Consent form not used

- **Funding Source:** ☐ Internal ☐ External (identify source and attach a copy of the sponsor's grant application or contract as submitted to the funding agency)
  ☐ Copy attached ☒ Not applicable

- **Based upon criteria found in 45 CFR 46 – and the overview of projects that may qualify for exemption explained at http://www.ksu.edu/research/comply/irb/about/exempt.html, I believe that my project using human subjects should be determined by the IRB to be exempt from IRB review:**
  ☐ No
  ☒ Yes **(If yes, please complete application including Section XII. C. 'Exempt Projects'; remember that only the IRB has the authority to determine that a project is exempt from IRB review)**

If you have questions, please call the University Research Compliance Office (URCO) at 532-3224, or comply@ksu.edu

Last revised on March 2007

Human Subjects Research Protocol Application Form

The KSU IRB is required by law to ensure that all research involving human subjects is adequately reviewed for specific information and is approved prior to inception of any proposed activity. Consequently, it is important that you answer all questions accurately. If you need help or have questions about how to complete this application, please call the Research Compliance Office at 532-3224, or e-mail us at **comply@ksu.edu**.

Please provide the requested information in the shaded text boxes. The shaded text boxes are designed to accommodate responses within the body of the application. As you type your answers, the text boxes will expand as needed. After completion, print the form and send the original and one photocopy to the Institutional Review Board, Room 203, Fairchild Hall.

Principal Investigator: Raphael A. Yunk
Project Title: Task-Ambient Lighting: A Tool for Sustainable Design and Code Compliance
Date: 3/26/07

NON-TECHNICAL SYNOPSIS (brief narrative description of proposal easily understood by nonscientists):

This is a proposal to perform survey-based research on building lighting layout design. Inefficient fixture layout practices contribute to a significant amount of wasted energy and resources every day. This study will provide lighting design engineers with a tool for increasing the efficiencies of their lighting layouts, while meeting and exceeding the energy codes that govern them.

I. **BACKGROUND** (concise narrative review of the literature and basis for the study):

Energy Codes have recently begun to press lighting systems designers to use less energy. Maintaining the industry accepted IESNA standards for illuminance levels simultaneously is becoming a challenge for many engineers. This report is

II. **PROJECT/STUDY DESCRIPTION** (please provide a concise narrative description of the proposed activity in terms that will allow the IRB or other interested parties to clearly understand what it is that you propose to do that involves human subjects. This description must be in enough detail so that IRB members can make an informed decision about proposal).

In order to illustrate clearly the quantified benefits of the Task-Ambient layout strategy, a physical case study is required. In this study, multiple lighting layouts will be established within a space, and human subjects must perform tasks in that space. Their participation will qualify them to answer in survey format how well the space was lighted, from a human comfort standpoint. This is a very important criteria for any lighting system designer. If the possibility of maintained human comfort is not proven in this manner, the entire study may be considered illegitamate by design professionals.

III. **OBJECTIVE** (briefly state the objective of the research – what you hope to learn from the study):

I hope to establish that average illuminance levels below the published standards, provided by a Task-Ambient design strategy, are still adequate in terms of end-user comfort and productivity, while showing how much energy and costs can be saved in the process.

IV. **DESIGN AND PROCEDURES** (succinctly outline formal plan for study):

A. Location of study: **Seaton Hall, Kansas State Campus**
B. Variables to be studied: **Lighting Illuminance Levels and the Degree of Comfort Associated**
C. Data collection methods: (surveys, instruments, etc– PLEASE ATTACH) **see attachments:**
1. Lighting Level Measurement Procedure
2. Survey Procedure

D. List any factors that might lead to a subject dropping out or withdrawing from a study. These might include, but are not limited to emotional or physical stress, pain, inconvenience, etc.: **Time/Scheduling Constraints**
E. List all biological samples taken: (if any) **N/A**
F. Debriefing procedures for participants: **The first step when the participants have gathered will be to**

go through the entire procedure for that evening, explaining and reviewing fully all parts of the survey. This will include a concise discussion on what research is being performed, and why the volunteers' participation is necessary to complete the research. We will also discuss the confidentiality policies of the university, and the anonymity of the survey being performed. In addition, all steps being taken to secure the participants' anonymity and confidentiality will be clearly presented.

V. **RESEARCH SUBJECTS:**

A. Source: **Kansas State University**

B. Number: **10-15**

C. Characteristics: (list any unique qualifiers desirable for research subject participation) **It is desireable that the research participants have a working knowledge of lighting layout design. Therefore, participants shall be students of the K-State Architectural Engineering program.**

D. Recruitment procedures: (Explain how do you plan to recruit your subjects? Attach any fliers, posters, etc. used in recruitment. If you plan to use any inducements, ie. cash, gifts, prizes, etc., please list them here.) **Research participants will be recruited in person by Nicholas Caton. The volunteers will be recruited from the pool of graduate students in the Architectural Engineering program, the members of the KSU Illuminating Engineering Society (IES) chapter, as well as from current students in the Advance Lighting Systems Design class (ARE 731).**

The only planned incentive/inducement for voluntary participation is the opportunity to experience and learn about lighting system design evaluation, as well as receiving a short educational lecture on the Task-Ambient strategy.

VI. **RISK – PROTECTION – BENEFITS:** The answers for the three questions below are central to human subjects research. You must demonstrate a reasonable balance between anticipated risks to research participants, protection strategies, and anticipated benefits to participants or others.

A. **Risks for Subjects:** (Identify any reasonably foreseeable physical, psychological, or social risks for participants. State that there are "no known risks" if appropriate.)
no known risks

B. **Minimizing Risk:** (Describe specific measures used to minimize or protect subjects from anticipated risks.)
Egress locations are clearly marked, and auxiliary lighting (flashlights) will be availiable, should the power or lighting system in the lighting lab fail.

C. **Benefits:** (Describe any reasonably expected benefits for research participants, a class of participants, or to society as a whole.)
The general nature of the survey group participants will be students interested in learning about lighting system design. By participating, these engineers in training will experience and more deeply understand how light system design solutions may be evaluated and tested for both code compliance and end-user comfort. A short educational lecture, followed by a question and answer based discussion will conclude the evening.

In your opinion, does the research involve **more than minimal risk** to subjects? ("Minimal risk" means that "the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.")

☐ **Yes** ☒ **No**

VII. **CONFIDENTIALITY:** Confidentiality is the formal treatment of information that an individual has disclosed to you in a relationship of trust and with the expectation that it will not be divulged to others without

permission in ways that are inconsistent with the understanding of the original disclosure. Consequently, it is your responsibility to protect information that you gather from human research subjects in a way that is consistent with your agreement with the volunteer and with their expectations. If possible, it is best if research subjects' identity and linkage to information or data remains unknown.

Explain how you are going to protect confidentiality of research subjects and/or data or records. Include plans for maintaining records after completion.

No written or published portions of this Master's report will identify any of the participants by name or other traceable information. If presentation of the data would be clarified by showing individual's survey results, as opposed to averages, then the participants shall only be identified by an alphanumerical label (i.e. A-1, A-2, etc…). Further, the list of participants' names and contact information will be made availiable to anyone not involved in this master's report.

VIII. INFORMED CONSENT: Informed consent is a critical component of human subjects research– it is your responsibility to make sure that any potential subject knows exactly what the project that you are planning is about, and what his/her potential role is. (There may be projects where some forms of "deception" of the subject is necessary for the execution of the study, but it must be carefully justified to and approved by the IRB). A schematic for determining when a waiver or alteration of informed consent may be considered by the IRB is found at http://www.ksu.edu/research/comply/irb/images/slide1.jpg and at http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm#46.116. Even if your proposed activity does qualify for a waiver of informed consent, you must still provide potential participants with basic information that informs them of their rights as subjects, i.e. explanation that the project is research and the purpose of the research, length of study, study procedures, debriefing issues to include anticipated benefits, study and administrative contact information, confidentiality strategy, and the fact that participation is entirely voluntary and can be terminated at any time without penalty, etc. Even if your potential subjects are completely anonymous, you are obliged to provide them (and the IRB) with basic information about your project. See informed consent example on the URCO website at http://www.ksu.edu/research/comply/irb/app.html). It is a federal requirement to maintain informed consent forms for 3 years after the study completion.

Yes	No		**Answer the following questions about the informed consent procedures.**
☒	☐	a.	Are you using a written informed consent form? If "yes," include a copy with this application. If "no" see b.
☐	☒	b.	In accordance with guidance in 45 CFR 46, I am requesting a waiver or alteration of informed consent elements (See Section VII above). If "yes," provide a basis and/or justification for your request.
☒	☐	c.	Are you using the online Consent Form Template provided by the URCO? If "no," does your Informed Consent document has all the minimum required elements of informed consent found in the Consent Form Template? (Please explain)
☒	☐	d.	Are your research subjects anonymous? If they are anonymous, you will not have access to any information that will allow you to determine the identity of the research subjects in your study, or to link research data to a specific individual in any way. Anonymity is a powerful protection for potential research subjects. (An anonymous subject is one whose identity is unknown even to the researcher, or the data or information collected cannot be linked in any way to a specific person).
☒	☐	e.	Are subjects debriefed about the purposes, consequences, and benefits of the research? Debriefing refers to a mechanism for informing the research subjects of the results or conclusions, after the data is collected and analyzed, and the study is over. (If "no" explain why.)

* **It is a requirement that you maintain all signed copies of informed consent documents for at least 3 years**

following the completion of your study. These documents must be available for examination and review by federal compliance officials.

IX. **PROJECT INFORMATION:** (If you answer yes to any of the questions below, you should explain them in one of the paragraphs above)

Yes	No	Does the project involve any of the following?
☐	☒	a. Deception of subjects
☐	☒	b. Shock or other forms of punishment
☐	☒	c. Sexually explicit materials or questions about sexual orientation, sexual experience or sexual abuse
☐	☒	d. Handling of money or other valuable commodities
☐	☒	e. Extraction or use of blood, other bodily fluids, or tissues
☐	☒	f. Questions about any kind of illegal or illicit activity
☐	☒	g. Purposeful creation of anxiety
☐	☒	h. Any procedure that might be viewed as invasion of privacy
☐	☒	i. Physical exercise or stress
☐	☒	j. Administration of substances (food, drugs, etc.) to subjects
☐	☒	k. Any procedure that might place subjects at risk
☐	☒	l. Any form of potential abuse; i.e., psychological, physical, sexual
☒	☐	m. Is there potential for the data from this project to be published in a journal, presented at a conference, etc?
☒	☐	n. Use of surveys or questionnaires for data collection **IF YES, PLEASE ATTACH!!**

X. **SUBJECT INFORMATION:** (If you answer yes to any of the questions below, you should explain them in one of the paragraphs above)

Yes	No	Does the research involve subjects from any of the following categories?
☐	☒	a. Under 18 years of age (these subjects require parental or guardian consent)
☐	☒	b. Over 65 years of age
☐	☒	c. Physically or mentally disabled
☐	☒	d. Economically or educationally disadvantaged
☐	☒	e. Unable to provide their own legal informed consent
☐	☒	f. Pregnant females as target population
☐	☒	g. Victims
☐	☒	h. Subjects in institutions (e.g., prisons, nursing homes, halfway houses)
☐	☒	i. Are research subjects in this activity students recruited from university classes or volunteer pools? If so, do you have a reasonable alternative(s) to participation as a research subject in your project, i.e., another activity such as writing or reading, that would serve to protect students from unfair pressure or coercion to participate in this project? If you answered this question "Yes," explain any alternatives options for class credit for potential human subject volunteers in your study.
☐	☒	j. Are research subjects **audio** taped? If yes, how do you plan to protect the recorded information and mitigate any additional risks?
☐	☒	k. Are research subjects **video** taped? If yes, how do you plan to protect the recorded information and mitigate any additional risks?

XI. **CONFLICT OF INTEREST:** Concerns have been growing that financial interests in research may threaten the safety and rights of human research subjects. Financial interests are not in them selves prohibited and may well be appropriate and legitimate. Not all financial interests cause Conflict of Interest (COI) or harm to human subjects. However, to the extent that financial interests may affect the welfare of human subjects in research, IRB's, institutions, and investigators must consider what actions regarding financial interests may be necessary to protect human subjects.

Please answer the following questions:

Yes	No		
☐	☒	a.	Do you or the institution have any proprietary interest in a potential product of this research, including patents, trademarks, copyrights, or licensing agreements?
☐	☒	b.	Do you have an equity interest in the research sponsor (publicly held or a non-publicly held company)?
☐	☒	c.	Do you receive significant payments of other sorts, eg., grants, equipment, retainers for consultation and/or honoraria from the sponsor of this research?
☐	☒	d.	Do you receive payment per participant or incentive payments?
		e.	If you answered yes on any of the above questions, please provide adequate explanatory information so the IRB can assess any potential COI indicated above.

XII. PROJECT COLLABORATORS:

A. KSU Collaborators – list anyone affiliated with KSU who is collecting or analyzing data: (list all collaborators on the project, including undergraduate and graduate students)

Name:	Department:	Campus Phone:
Nicholas Caton	Architectural Engineering & Construction Science	(785) 539 8948
Robert Nelson	Architectural Engineering & Construction Science	n/a

B. Non-KSU Collaborators: (List all collaborators on your human subjects research project not affiliated with KSU in the spaces below. KSU has negotiated an Assurance with the Office for Human Research Protections (OHRP), the federal office responsible for oversight of research involving human subjects. When research involving human subjects includes collaborators who are not employees or agents of KSU the activities of those unaffiliated individuals may be covered under the KSU Assurance only in accordance with a formal, written agreement of commitment to relevant human subject protection policies and IRB oversight. The Unaffiliated Investigators Agreement can be found and downloaded at (http://www.ksu.edu/research/comply/irb/forms/invagree.pdf). The URCO must have a copy of the Unaffiliated Investigator Agreement on file for each non-KSU collaborator who is not covered by their own IRB and assurance with OHRP. Consequently, it is critical that you identify non-KSU collaborators, and initiate any coordination and/or approval process early, to minimize delays caused by administrative requirements.)

Name:	Organization:	Phone:

Does your non-KSU collaborator's organization have an Assurance with OHRP? (for Federalwide Assurance and Multiple Project Assurance (MPA) listings of other institutions, please reference the OHRP website under Assurance Information at: http://ohrp.osophs.dhhs.gov/polasur.htm).

☐ **No**
☐ **Yes** **If yes, Collaborator's FWA or MPA #** _____

Is your non-KSU collaborator's IRB reviewing this proposal?

☐ **No**
☐ **Yes** **If yes, IRB approval #** _____

C. **Exempt Projects:** 45 CFR 46 identifies six categories of research involving human subjectsthat may be exempt from IRB review. The categories for exemption are listed on the KSU research involving human subjects home page at http://www.ksu.edu/research/comply/irb/about/exempt.html. If you believe that your project qualifies for exemption, please indicate which exemption category applies (1-6). Please remember that only the IRB can make the final determination whether a project is exempt from IRB review, or not.

Exemption Category: 2

XIII. CLINICAL TRIAL ☐**Yes** ☒**No**
(If so, please give product.)

Post Approval Monitoring: The URCO has a Post-Approval Monitoring (PAM) program to help assure that activities are performed in accordance with provisions or procedures approved by the IRB. Accordingly, the URCO staff will arrange a PAM visit as approprate; to assess compliance with approved activities.

If you have questions, please call the University Research Compliance Office (URCO) at 532-3224, or comply@ksu.edu

INVESTIGATOR ASSURANCE FOR RESEARCH INVOLVING HUMAN SUBJECTS

(Print this page separately because it requires a signature by the PI.)

P.I. Name: Raphael A. Yunk

Title of Project: Task-Ambient Lighting: A Tool for Sustainable Design and Code Compliance

XII. ASSURANCES: As the Principal Investigator on this protocol, I provide assurances for the following:

A. **Research Involving Human Subjects:** This project will be performed in the manner described in this proposal, and in accordance with the Federalwide Assurance FWA00000865 approved for Kansas State University available at http://ohrp.osophs.dhhs.gov/polasur.htm#FWA, applicable laws, regulations, and guidelines. Any proposed deviation or modification from the procedures detailed herein must be submitted to the IRB, and be approved by the Committee for Research Involving Human Subjects (IRB) prior to implementation.

B. **Training:** I assure that all personnel working with human subjects described in this protocol are technically competent for the role described for them, and have completed the required IRB training modules found at: http://www.ksu.edu/research/comply/irb/training/index.html. I understand that no proposals will receive final IRB approval until the URCO has documentation of completion of training by all appropriate personnel.

C. **Extramural Funding:** If funded by an extramural source, I assure that this application accurately reflects all procedures involving human subjects as described in the grant/contract proposal to the funding agency. I also assure that I will notify the IRB/URCO, the KSU PreAward Services, and the funding/contract entity if there are modifications or changes made to the protocol after the initial submission to the funding agency.

D. **Study Duration:** I understand that it is the responsibility of the Committee for Research Involving Human Subjects (IRB) to perform continuing reviews of human subjects research as necessary. I also understand that as continuing reviews are conducted, it is my responsibility to provide timely and accurate review or update information when requested, to include notification of the IRB/URCO when my study is changed or completed.

E. **Conflict of Interest:** I assure that I have accurately described (in this application) any potential Conflict of Interest that my collaborators, the University, or I may have in association with this proposed research activity.

F. **Adverse Event Reporting:** I assure that I will promptly report to the IRB / URCO any unanticipated problems involving risks to subjects or others that involve the protocol as approved.

G. **Accuracy:** I assure that the information herein provided to the Committee for Human Subjects Research is to the best of my knowledge complete and accurate.

_____ _____

(Principal Investigator Signature) **(date)**

8

PROCEDURE: Establishing the Lighting Level of a Space

Objectives
Measure the effectiveness of various lighting layouts, measuring both the level of comfort provided, as well as the effects of the lighting layout on accuracy and productivity for an end-user.

Equipment used
- Tape Measure
- Survey
- Digital Camera
- Stopwatch
- Lighting Lab – Seaton 223A – Kansas State University

Conditions to be met
- Paricipants must be debriefed and informed of the purpose and procedures of this survey, as prescribed by the K-State Research Compliance Office
- Participants must have read and signed the Informed Consent Document
- No daylight is present in the room – take measurements only after the sun has set and the sky has darkened.
- Luminaire layouts being evaluated shall be programmed into the lighting lab's various control systems prior to this survey procedure
- All fenestrations in the room will be covered by materials which shall not allow light to pass

Procedure
1. Survey and photograph the space as it exists before any measurements are taken.
2. Turn off all light sources in order to identify sources of light contamination.
3. Eliminate these contaminate light sources by covering their space penetration locations with materials that will completely absorb the light.
4. Record and/or photograph all of the steps taken to eliminate contaminate light sources.
5. Follow the procedure outlined on the attached spreadsheet to determine an estimate of the general illuminance level for the existing lighting solution. This technique can be expected to produce an answer within 10% of the actual general illuminance level, and was found in *Illumination Engineering, 2nd Ed.*
6. Adjust the lighting level using whatever resources are available and document how these changes were made.
7. Repeat this estimation method until the resulting value is within 2 fc of the target illuminance level – which shall be the suggested illuminance value from the current edition of the IESNA Lighting Handbook.
8. Establish a regular grid within the space and document the grid's layout in a manner that may be replicated at a later date. Follow the procedure accompanying the attached regular grid measurements to determine a minimum number of measurement points. This procedure was derived from the text *Lighting for Health and Safety*.
9. Measure the illuminance level, in foot-candles, at each point within the established grid matrix in the space. Use this data to determine the average illuminance level by simply averaging all of the values.

Attachments
- Calculation Spreadsheet (1)

Calculation Spreadsheet

Cells colored GREEN are to be filled in with data.

Data collected by Nick Caton,
Assisted by Robert Nelson
March 02, 2007
Configuration A

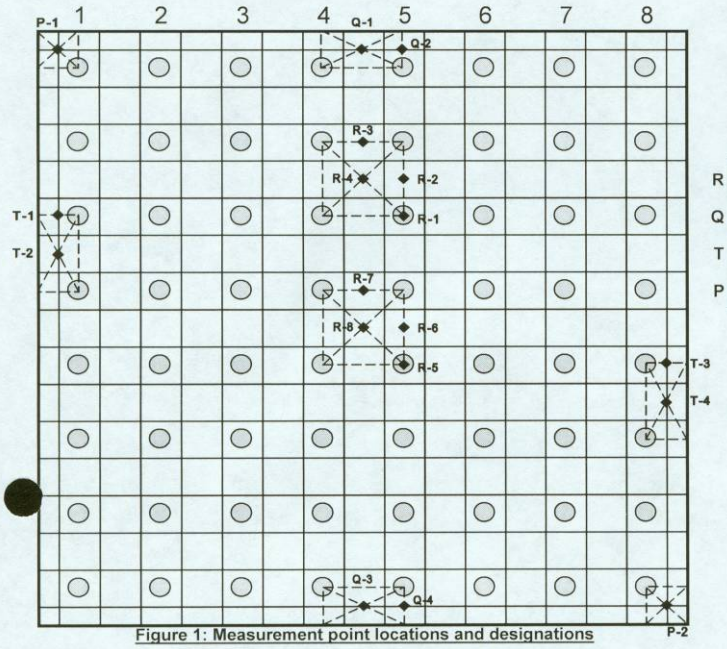


Figure 1: Measurement point locations and designations

Illuminance Readings (fc)

	1	2	3	4	5	6	7	8
R	32.2	36.5	36.4	41.5	43.5	43.6	40.2	41.1
Q	27.5	29.2	14.1	21.0				
T	25.0	25.2	24.2	24.0				
P	21.0	15.7						

Conditions followed for this data collection:

* Measurements are taken 30" AFF.
* No daylight is present in the room.
* Data collected between 6:30 and 8:50 PM
* Luminaires are regularly spaced.
* Luminaires are located symmetrically.
* All fenestrations in the room have been covered by materials which will not allow light to pass

Procedure:

				Notes:
1)	Average all "r" values	R =	39	values in center of space
2)	Average all "q" values	Q =	23	values along top/bottom walls
3)	Average all "t" values	T =	25	values along left/right walls
4)	Average all "p" values	P =	18	values in corners

5) Average Illuminance = $\frac{R(N-1)(M-1) + Q(N-1) + T(M-1) + P}{NM}$

where N = 3 = number of luminaires per row,
and M = 3 = number of rows

Using this equation,
Average Illuminance = **30.1** lm/SF

PROCEDURE: Light Layout Survey and Evaluation

Objectives
Measure the effectiveness of various lighting layouts, measuring both the level of comfort provided, as well as the effects of the lighting layout on accuracy and productivity for an end-user.

Equipment used
- Tape Measure
- Survey
- Digital Camera
- Stopwatch
- Lighting Lab – Seaton 223A – Kansas State University

Conditions to be met
- Paricipants must be debriefed and informed of the purpose and procedures of this survey, as prescribed by the K-State Research Compliance Office
- Participants must have read and signed the Informed Consent Document
- Participants will identify their surveys with a randomly assigned alphanumeric lable (i.e. "A-1)
- No daylight is present in the room – take measurements only after the sun has set and the sky has darkened.
- Luminaire layouts being evaluated shall be programmed into the lighting lab's various control systems prior to this survey procedure
- All fenestrations in the room will be covered by materials which shall not allow light to pass

Procedure
1. Arrive early to arrange the furniture for the participants in the manner prescribed by previous system layout procedures, using a tape measure for accuracy.
2. Photograph the resulting layout of furniture for future verification/comparison to the prior layouts.
3. Turn off all light sources in order to identify sources of light contamination.
4. Eliminate these contaminate light sources by covering their space penetration locations with materials that will completely absorb the light.
5. Record and/or photograph all of the steps taken to eliminate contaminate light sources.
6. Record the attendance of the participants, contact absent members to verify their intentions to not show up. This will prevent data contamination at a later point should they arrive during the survey procedure.
7. Debrief the participants on the methodology and purpose of the research. Cover the anonymity of the survey, and review the survey questions, answering all questions related to their purpose and meaning.
8. Set the room lighting layout to one of the pre-set configurations using the Lighting Lab's system controls
9. Have each participant complete the prescribed tasks (attached) in a timed fashion. Have all participants stop at the timer.
10. Immediately distribute the survey form (attached), and collect.
11. Repeat steps 8 through 10 until all lighting layouts have been evaluated

Attachments
- Tasks (2)
- Survey Form (1)

Task-Ambient Lighting Case-Study
Sign-up Sheet

Name	Phone	E-mail

Date/Time: _____

Location: _Seaton 223A (The lighting lab)__

Categories for Exemption

According to 45 CFR 46, the following categories are EXEMPT from IRB approval. Unless otherwise required by Department or Agency heads, research activites in which the only involvement of human subjects will be in one or more of the following categories are exempt from review by the Committee for Research Involving Human Subjects (IRB). **All** of the project activity must qualify as exempt according to the criteria below for the project to be ruled exempt from IRB review. ***It is the responsibility of the IRB to make the final determination if a project is exempt from IRB review.***

1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as

- research on regular and special education instructional strategies, or
- research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:

- information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and
- any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (2) above, if:

- the human subjects are elected or appointed public officials or candidates for public office; or
- Federal statue(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

5. Research and demonstration projects which are conducted by or subject to the approval of Department or Agency heads, and which are designed to study, evaluate, or otherwise examine:

- Public benefit or service programs;
- procedures for obtaining benefits or services under those programs;
- possible changes in or alternatives to those programs or procedures; or
- possible changes in methods or levels of payment for benefits or services under those programs

6. Taste and food quality evaluation and consumer acceptance studies,

- if wholesome foods without additives are consumed or
- if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture

The above exemption categories <u>do not apply</u> when the research activities include the following:

a. prisoners, fetuses, pregnant women or human in vitro fertilization;
b. the review of medical records if the information is recorded in such a way that subjects can be identified, directly or through identifiers linked to the subjects;
c. survey or interview techniques which include minors (under 18 years of age) as subjects;
d. research involving the observation of the public behavior of minors (under 18 years of age);
e. techniques which expose the subject to discomfort or harassment beyond levels encountered in daily life;
f. the deception of the subjects