EFFECTS OF LIGHTING ON CREATIVE PERFORMANCE

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Creativity is being sought as a competitive edge for businesses as it has become an essential part of work. Previous creativity research focused on the creative person, process, product, and the social environment for creativity; however, recently, increasing attention towards the physical design of the workplace in promoting creative performance has emerged (Dul, Ceylan, & Jaspers, 2011). Many attributes compose the physical environment (e.g. color, lighting, spatial layout, etc.) but not many studies have investigated the relationship between physical environment attributes and creativity to date. From a review of literature, a conceptual framework was created to better understand the effects of physical environment attributes on creative performance and the mediating processes explaining the relationship. This framework identified lacunae in research and was used as a guide for conducting experiments on the effects of lighting on creative performance, in which research was particularly lacking.

A series of experiments utilizing different characteristics of lighting—illuminance levels (Experiment 1), task luminance (Experiment 2), visual privacy (Experiment 3), and color temperature and lighting spectrum (Experiment 4)—investigated the effects of lighting on creative performance as measured by fluency, originality, and elaboration using the Torrance Test of Creative Thinking (TTCT). No significant differences between low and high illuminance levels were found in Experiments 1, 2, and 3, contrary to previous research (Steidle & Werth, 2013). Significant correlations were found among mood ratings (i.e. pleasure and arousal), environmental perceptions, and creative performance suggesting that certain environmental

perceptions may improve creative performance. Experiment 1 and 3 showed that visual privacy improved elaboration scores but no direct effect of lighting on creative performance was demonstrated. Experiment 4 showed a diverse array of individual lighting preferences for creative work, but surprisingly, this self-selected lighting did not affect actual creative performance. Future investigations might usefully focus on other environmental design factors that might improve creative performance.

BIOGRAPHICAL SKETCH

Sung Eun (Susan) Chung received her Bachelor of Arts degree with high honors in interior design at Michigan State University. In the pursuit of her aspirations to understand the relationship between the physical environment and human behavior, and bridge the gap between research and practice in the interior design profession, she then went on to complete her Master of Interior Design degree at the University of Florida. There, Susan's passion for creativity sparked in conjunction with her interests in teamwork and the physical environment. Upon completing her master's thesis on examining the relationship between creativity and interdisciplinary teamwork by profiling individual traits, problem-solving styles, and team process in a real-world setting, Susan further contemplated on the physical environment's role in creativity. At Cornell University's doctorate program in Human Behavior and Design, Susan investigated the relationship between the physical environment and creative performance with interest in mediating processes explaining this relationship and developed a conceptual framework which can be used as a tool for both researchers and designers. Utilizing this conceptual framework, she conducted experiments to investigate the effects of lighting on creative performance. Her research interests continue to lie in uncovering the physical environment's role in creativity and she hopes to apply this knowledge in design education and in design practice.

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to know more of God and to experience more of grace during this chapter in my life has been most fruitful. From this experience I take these words to heart: “Let not the wise man boast in his wisdom, let not the mighty man boast in his might, let not the rich man boast in his riches, but let him who boasts boast in this, that he understands and knows me, that I am the Lord who practices steadfast love, justice, and righteousness in the earth. For in these things I delight, declares the Lord.” [Jeremiah 9:23-24 ESV]

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CHAPTER 1
INTRODUCTION

Creativity has become an essential part of work in various disciplines. Businesses from all sectors consider creativity as a competitive advantage and seek to hire creative individuals and implement creative processes in both management and problem-solving (Amabile & Khaire, 2008). Creativity is both novel and useful, and is fundamental for positive change (Hennessey & Amabile, 2010). The degree of creativity (i.e. incremental creative solutions to monumental breakthroughs) expected in the organization may depend on the nature of the work; however, in general, individual creativity has been linked to organizational creativity, its performance, and survival (Nystrom, 1990; Woodman, Sawyer, & Griffin, 1993). Creativity is not limited to artists and scientists, but is a key requirement for organizational growth (Amabile, 1988; Mumford & Simonton, 1997).

The importance of place in supporting creative work is receiving increasing attention in both the scholarly and practice communities as organizations turn their attention to the design of the physical environment in order to foster creativity in the workplace (Dul, Ceylan & Jaspers, 2011; Moultrie, Nilsson, Dissel, Haner, Janssen & Van der Lugt, 2007). The resurgence of working in the physical office instead of a virtual one was exemplified when Yahoo changed its policy for workplace flexibility to one that potentially facilitates creative interactions within the physical office space, recognizing the importance of face-to-face interactions needed for creating an innovative and collaborative culture (Miller & Rampell, 2013). Innovation laboratories in Europe also emphasize the importance of the physical environment for supporting the creative process and collaborative efforts of employees in the design of spaces (e.g. Haner, 2005). Despite this movement towards designing creative workplaces, little is known about how these physical workplace designs impact creative performance. Most research efforts aimed at

fostering creativity have focused on the social context of creativity in the work environment (e.g. Amabile, Conti, Coon, Lazenby, & Herron, 1996; Hemlin, Allwood, & Martin, 2008; Tesluk, Farr, & Klein, 1997). Only recently has interest in the role of the design of the physical workplace in facilitating creativity received more systematic attention, especially with innovative companies serving as best practices for creative workplace design (e.g. Goolge, Pixar, and IDEO).

Google, Pixar, and IDEO are among the pioneers recognized both for their creative output and for the design of their creative workplace environments. The success of Google, Pixar, and IDEO workplaces is in the combination of their novelty in design and their appropriateness to the organizations' culture – hence, creating a synthesis of person, process, product, and press (or place) for creativity. They are novel in their concept for what a workplace constitutes (e.g. Google offices house numerous amenities such as, play areas, coffee bars, open kitchens, outdoor terraces, food, and themed rooms) and are representative of breaking the norm of typical office spaces (e.g. Pixar office restrooms are located in the atrium where all the departments come together thereby promoting chance encounters that might spark inspiration and collaboration, and IDEO has a DC-3 wing that hangs above the workplace, per request of the employees, symbolizing the playfulness and openness of the company). In addition, Google, Pixar and IDEO all encourage employees to create their own work space to their own satisfaction. For example, the nontraditional physical spaces at IDEO are created by the employees from the belief that free reign over space should be given to the staff, especially in cases where companies depend on their creativity (Kelley, 2001).

A distinct pattern among these examples is that each company's organizational philosophy is illustrated in the design of their physical workplace. For example, Google office

designs represent the company's overarching philosophy in creating the happiest and most productive workplace in the world (Stewart, 2013). When the creativity goal of the organization aligns with the messages that the creative design of the physical environment communicates to the users, the physical environment supports creativity. People who desire creative work have been attracted to these workplaces, suggesting the influence of workplace design on the recruitment and retention of creative individuals (Danko, 2000; Earle, 2003). This connection between creative workplace design and creative individuals may in turn lead to the congruency between the perception of creative places and the performance of places for creativity (e.g. Haner, 2005).

In this thesis, a conceptual framework on the effects of physical environment attributes on creativity that can be used to guide future research and identify lacunae in the research literature is presented. Experiments investigating the relationship between physical environment attributes and creativity were conducted to validate the use of this conceptual framework, to add to the body of knowledge in this field, and to provide designers with guidelines for designing a workplace for creativity.

CHAPTER 2
THE PHYSICAL ENVIRONMENT AND CREATIVITY

Defining Creativity

Creativity is a complex and multifaceted phenomenon. Creativity has been defined as, "the interaction among *aptitude, process, and environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context,*" (Plucker, Beghetto & Dow, 2004, p. 90, emphasis in original). This definition suggests a systemic view of creativity in which the main components of person, process, press (or place), and product interact in generating a creative and tangible outcome. The focus of this chapter is to explore the four main components of creativity and examine creativity frameworks that advocate the inclusion of these, particularly the physical environment.

Frameworks for Describing Creativity

As described above, creativity can be conceptualized as the interplay of four P's—*Person, Process, Product,* and *Press* (or *Place)* (Rhodes, 1961; Runco, 2004). This framework for describing creativity is widely accepted and its components have been used individually and in combination with others for creativity research (Davis, 1999; Mooney, 1963; Torrance, 1988). Characteristics of the creative *person* have been defined in terms of personality traits, cognitive abilities, and biographical traits that combine to influence one's creative potential. Davis (2004) sorted through sources of creative personality traits and descriptions and found sixteen major categories that recurred when characterizing the creative person: aware of creativeness, original, independent, risk-taking, high energy, curious, sense of humor, capacity for fantasy, attracted to complexity or ambiguity, artistic, open-minded, thorough, needs alone time, perceptive, emotional, and ethical. These categories did not include negative traits and not all characteristics apply to all creative people. Relatedly, cognitive abilities in recognizing patterns, making

connections, taking risks, challenging assumptions, taking advantage of chance, and seeing new ways have been suggested to be associated with creativity (Barron, 1988). Biographical traits that are conducive to creativity are those that have been accrued through past experiences in creative involvement (Reis & Renzulli, 1991; Torrance, 1962). Limitations in research on the creative person are based on the complex and multi-faceted nature of creativity and human psyche. Generalizations of creative person characteristics are difficult to make as there are many different forms of creativity and a diverse array of creative people displaying different talents (Davis, 2004; Levi, 2001; MacKinnon, 1978); for example, a creative musician will not necessarily share the characteristics of a creative architect (MacKinnon, 1976).

The creative *process* is commonly thought of as a problem-solving process which follows a sequence of problem solving stages. Although several process models exist, the main idea behind all of these is similar: beginnings that start with finding/defining a problem and gathering information, then proceeding to generating possible solutions and evaluating them in search of the best one, and finally implementing the solution (e.g. Basadur, Runco, & Vega, 2000; Hedge & Lawson, 1979). For example, the Creative Problem Solving (CPS) model guides the creative process through fact-finding, problem-finding, idea-finding, solution-finding (idea evaluation), and acceptance-finding (idea implementation) (Osborn, 1963; Parnes, 1981). A unique feature of this model is that each step of the process incorporates both divergent and convergent thinking. Each step first involves a phase that generates a number of ideas and then moves to select the one with most potential for further exploration. This exercise in shifting from divergent to convergent thinking encourages perceptual changes needed when producing new ideas, and can be thought as a technique or strategy used to facilitate creativity (Guilford, 1986).

The creative *press* includes the social, psychological, and physical environment and is

oftentimes referred to as *place* when describing the physical environment more specifically. Most studies have focused on the social environment of creativity, mainly on the intangible organizational influences such as, organizational culture, climate, and structure (Amabile, 1998; Tesluk et al., 1997). Particularly, organizational climate refers to the attitudes, feelings, and behaviors that characterize an organization through shared perceptions of its members (Ekvall, 1987; Tesluk et al., 1997). Encouragement of creativity, autonomy or freedom, resources, pressures, and organizational impediments to creativity are environmental dimensions identified in creative organizational climates (Amabile et al., 1996). Similarly, Ekvall (1996) describes the creative climate through ten factors: challenge, freedom, idea support, trust or openness, dynamism or liveliness, playfulness or humor, debates, conflicts, risk taking, and idea time. Research has not yet been able to establish a connection between specific physical environment attributes and creativity; however, the physical environment has been identified as an independent factor for creativity in organizations (Dul et al., 2011). Vithayathawornwong, Danko, and Tolbert (2003) suggest that the physical environment is perceived as a support for the psycho-social environment and thus, the physical workplace should be designed for creative climate factors such as freedom and dynamism.

The creative *product* is the judged novelty and appropriateness of the final outcome. These outcomes can be in the form of ideas, concrete products, or solutions and can be assessed differently according to the evaluation criteria set by evaluators or the domain. Novelty is commonly identified by its newness or difference from other ideas, products, or solutions, while appropriateness can only be identified through the context of evaluation. Because of this context dependency, characteristics of creative products are difficult to generalize and rather domain-specific criteria for creative products should be established (Gardner, 1993).

An expansion of the four P's framework was recently proposed through the five A's framework, *Actor, Action, Artifact, Audience, and Affordances,* primarily to add more social meaning to the four P's and to hold true to the social origin of creativity (Glăveanu, 2013). While the four P's describe components for creativity from a cognitive approach from the individual, the five A's comprehend creativity through a socio-cultural approach from a social context. All of the five A's are derived from the four P's with the actor relating to the person, the action relating to the process, the artifact relating to the product, and both the audience and affordances related to press (or place). Holistically, the five A's integrate with each other to explain creativity as, "creative action [emerging] out of actor-audience relations that both produce and are mediated by the generation and use of new artifacts (objects, signs, symbols, etc.) within a physical, social, and cultural environment" (Glăveanu, 2013, pp.71−72). This new framework addresses the interrelations among the components more explicitly and contextualizes creativity by actively incorporating the material or physical environment, which were limitations of the four P's framework.

The inclusion of the material or physical environment in the five A's framework is rooted from acknowledging creativity as a form of action that is embedded in the material world (Glăveanu, 2013). Creative people have been stimulated and inspired by the physical environment yet creativity research has not been able to institute this relationship. Glăveanu's (2013) socio-cultural approach to creativity considers the interrelationship between the physical environment and people through the cultural meanings of physical elements that are constructed by people. The theory of affordances is founded on this relationship between a person and his/her interaction with the surrounding objects in the physical environment. The theory argues that people perceive the physical environment through affordances, or opportunities for action, not

specific qualities (Gibson, 1986). Affordances refer to the perceived and actual properties of an object, especially those that determine how the object is used (Norman, 2002). For example, the roundness property of door knobs signals the user to turn it, while lever-type door handles are meant to be pushed down. The properties perceived by the individual are interpreted and then acted upon, resulting in constant interactions between the person and the physical environment.

Although the five A's framework illustrates a novel conceptualization of creativity that captures its disparate personal and social aspects and better integrates the components of the four P's framework, the complexity of the interrelationship of multiple components makes it difficult to measure or generally define. Research that incorporates the advantages of both frameworks—the clear definitions of the components from the four P's and the systemic interrelations found in the five A's—is needed to get a better grasp of creativity.

Creativity Models

The goal of creativity models is to define and describe what creativity is from a particular perspective. Creativity models that consider all components and interrelations in the phenomenon are somewhat limited in the details of contextual factors, particularly, the role of the physical environment. For example, the interactionist model of creative behavior developed by Woodman and Schoenfeldt (1989) and further explored as a systems model for organizational creativity by Woodman, Sawyer, and Griffin (1993) suggest that individual, group, and organizational characteristics have an impact on the creative process and are influenced by the situation (i.e. environment or context), resulting in the creative product for the organization. In this model, behavior is proposed as a complex interaction of person and situation at each level of the social organization, and in turn, this forms a system in which individuals, groups, and organizational characteristics all impact the creative process and the situation, eventually

resulting in a creative product. The creative situation is defined as the sum total of social and environmental (contextual) influences (e.g. physical environment, task and time constraints) on creative behavior and impacts on individual creativity, which is a function of antecedent conditions, cognitive style and abilities, personality, knowledge, intrinsic motivation, and social and contextual influences, and group creativity, which is an extension of individual creativity with additional group composition, group characteristics, group processes, and contextual influences. Furthermore, organizational creativity is seen as the combination of group creativity and contextual influences in the organization. Although this model explicitly acknowledges the physical environment as a contextual influence at the individual, group, and organizational level for creativity, the model fails to explain what attributes of the physical environment have an effect or what processes underpin the relationship between the physical environment and creative behavior.

Puccio, Murdock, and Mance (2007) proposed a systems model called the *"Creativity Change Model"* to review the sets of variables related to organizational creativity. This model suggested that innovation comes from the result of the interaction among people, the processes they engage in, and the environment (both the psychological and physical setting) in which they work. The interplay of these variables in turn leads to the formation of an intangible or tangible product. In regards to the environment they sum that the general work environment can be supportive or obstructive of the creative process. Similar to Woodman et al.'s (1993) model, this model acknowledges the physical environment as a variable to be considered for creative change however, does not specifically state the attributes of the physical environment that support or obstruct the creative process.

Another systems model proposed by Csikszentmihalyi (1999) examined the intersection

of person, domain, and field in explaining creativity. Here, the domain and the field are perceived as the environment that influences the individual's creative potential. The individual chooses a domain, a cultural or symbolic aspect of the environment, as the area of creative interest and practice. When a creative variation is produced, this is then selected by the field, a social aspect of the environment, to be deemed value for inclusion in the domain. Where the individual chooses to practice the domain is interrelated to the field of acceptance. Csikszentmihalyi (1999) concludes that rather than focusing exclusively on individuals, it makes more sense to focus on communities that the individuals are nurtured in, for it is the community, not the individual, who makes creativity manifest. This model puts more emphasis on the social aspect rather than the physicality of the environment, but sheds light on the difficulty in generalizing aspects of the environment for creativity by suggesting that a physical environment that is conducive to creativity is reliant on the specific domain and field, both based on the social context. Vithayathawornwong et al. (2003) further this notion by explaining the supportive role of the physical environment to the psycho-social environment. The physical environment for creativity may be one that affords a creative climate fit for the particular creativity domain.

Environmental dimensions identified in creative organizational climates are: encouragement of creativity, autonomy or freedom, resources, pressures, and organizational impediments to creativity (Amabile et al., 1996). Hunter, Bedell, and Mumford (2007) reviewed 42 prior studies investigating environmental influences on creativity and innovation. This meta-analysis of studies using climate measures to assess the creative performance found that climate dimensions (i.e. Amabile et al., 1996; Ekvall, 1996) were effective predictors of creative performance. For example, an empirical study on the relationships among the social environment of organizations, employee satisfaction, and perceptions of a creative work environment found

pride in work, freedom, and other personal variables to be related to an innovative climate (Turnipseed, 1994). Identifying social environment interactions within creative knowledge environments will help better understand environmental factors conducive to creativity, and as a result, be able to design environments that promote creativity (Hemlin et al., 2008).

As in the case of the physical environment going unnoticed or the social environment expressed through the perception of the physical environment, it may just be that the effect of the physical environment is not as evident as other factors. Csikszentmihalyi (1996) states that creative individuals disregard their surroundings and claim to solely concentrate on their work but, the consequences from the space and time the individual resides in often go unnoticed. He observed that creative individuals are most likely to change their environment according to the rhythm of their thoughts or habits of their actions. When individuals establish this environment, they are then able to concentrate on pursuing their creative works. On the other hand, he also states that some creative individuals have accounted that the physical environment does have an impact on their thought processes; however, they may simply be unaware of the effect. Only some empirical research studies conducted in laboratory settings have shown that creativity can be impacted by the physical environment (e.g. de Korte, Kuijt, & van der Kleij, 2011; Steidle & Werth, 2013; Vohs, Redden, & Rahinel, 2013). These studies are limited in their measures for creative performance and differ somewhat from real-world workplace environments.

Nonetheless, creativity is still impacted by the environment, including the physical attributes of it. Just as we consider the abundance in research on the impact of the physical environment on human behavior and acknowledge the person-environment relationship, we should do so for the investigation of creative behavior. As has been done with examining other work performances, creative performance in the workplace should be explored within physical

settings. Challenges in advancing research in this field are based on the difficulty in measuring creative performance and the complexity of variables that comprise the physical environment.

Creativity Assessments

Assessing creativity is difficult and most of the common methods used have approached creativity indirectly through skills, behaviors, or traits theoretically linked to creativity rather than the actual outcome (Baer, 2010). The main components mentioned in the definition of creativity illustrate how individual, situational, social, and cultural factors interact to determine the likelihood and magnitude of a creative outcome (Ward & Kolomyts, 2010). Creative outcomes can be assessed by its magnitude, which sets the boundaries for the scope and nature of creativity, and as a whole, provides a more complete picture in conceptualizing creativity (Kozbelt, Beghetto & Runco, 2010). Researchers have identified four magnitudes of creativity that range from everyday creativity (mini-c is from a subjective view and little-c is from an objective view of creativity) to unambiguous examples of creative expression (Big-C creativity) and with professional-level creativity (pro-C creativity) in between the two (Kaufman & Beghetto, 2009; Richards, 2007). The magnitudes of creative products differentiate the population of interest (i.e. amateurs, professionals, experts) which in turn direct the parameters for assessing creativity.

Most psychometric methods in creativity research are based on generalizations of the creative person, process, product, and press and thus, are focused on objectively assessing creativity ranging between little-c and pro-C creativity. They are typically grouped into personality and behavior that correlate with the creative person, creative process, characteristics of creative products, and attributes of creativity-fostering environments (Rhodes, 1961). Instruments intended to measure personality correlates of creative behavior are generally

designed by studying individuals already recognized by their creativity and then determining their common characteristics. After analyzing the results of research in which these and several other related instruments were used, Davis (1992) concluded that personality characteristics of creative people include awareness of their creativity, originality, independence, risk taking, personal energy, curiosity, humor, attraction to complexity and novelty, artistic sense, open-mindedness, need for privacy, and heightened perception. The Adjective Checklist (ACL) developed by Gough (1979) is an example of a psychometric test that measures creative personality traits. The test consists of 300 adjectives from which one selects all the adjectives that best describe their current self. Based on the number of total adjectives checked, the raw score of the number of adjectives selected related to creative personality is converted into the score for creative personality. Domino (1970) further developed another creative personality scale using the ACL to include specific characteristics exemplified through artistic creativity.

Guilford (1968) emphasized the importance of, and distinction from, divergent thinking relative to convergent thinking. In general, divergent thinking tests ask for multiple responses to either figural or verbal prompts, and responses are scored for fluency, flexibility, originality, and elaboration of ideas. Fluency (i.e. associational fluency, ideational fluency) is the ability to produce many ideas, verbal or nonverbal, for an open-ended problem or question. Flexibility is the ability to take different approaches to a problem, think of ideas in different categories, or view a problem from different perspectives. Originality is the uniqueness, nonconformity in thought and action. Elaboration is the important ability to add details to an idea, which includes developing, embellishing, improving, and implementing the idea. The most widely used creativity test, the *Torrance Tests of Creative Thinking* (TTCT; Torrance, 1966) provides outputs for these four measures through a verbal and a figural test which consist of several activities.

Creativity is a complex phenomenon and should always be associated with the context in which it formulates. Although creativity research on the physical environment is currently lacking compared to other creativity components, the increased interest in the component of place and its relationship with creativity, and the concept of creativity always happening in a place provides potential for this research field to grow. In the next chapter, specific physical environment attributes and the effects each has on creative performance examined through empirical research are reviewed.

CHAPTER 3
A REVIEW OF THE EFFECTS OF THE PHYSICAL ENVIRONMENT ON CREATIVITY

Organization of the Physical Environment

The physical environment, like creativity, is a multi-faceted construct and can be understood through the different dimensions that characterize it. It consists of many attributes that interact with each other. To date, several classifications of the physical environment exist. Davis (1984) provided a framework of the physical environment particularly for office settings. He viewed that a physical environment is composed of physical structures, physical stimuli, and symbolic artifacts. Physical structures include the architectural design and physical placement of furnishings in relation to social interaction; physical stimuli are the aspects of the physical setting that impact the user's behavior; and symbolic artifacts are objects that individually or collectively guide the interpretation of the social setting. He suggests that these physical variables have an advantage over psychological or social variables in that they are observable and can be described somewhat accurately.

Similarly, Bitner (1992) classified what he called servicescapes (i.e. environment for service organizations) into three physical dimensions. The first dimension is the ambient environment which includes lighting, temperature, noise, music, and color. He assumed that ambient factors impact the users of the organizational environment especially when they are extreme, when they conflict with user expectations, and when the user needs to spend considerable time in the environment in order for the effects to emerge. The second dimension is the spatial layout and functionality which refers to the way the fixtures, furnishings, and equipment are arranged. The size, shape, spatial relationship, and their ability to function according to the expected level of performance are of importance. The final dimension is the signs, symbols, and artifacts that can be both explicitly and implicitly found as conveying

messages within the physical environment.

The most recent and most relevant categorization of the physical environment for creativity is McCoy's (2005) which identifies five distinctive yet integrated components: spatial organization, architectonic details, views, resources, and ambient conditions. The spatial organization consists of many characteristics which include size, shape, allocation or division of space through furniture configuration and circulation routes, level of enclosure, proxemics, territoriality, flexibility, visual access, and so on. Architectonic details are fixed or stationary aesthetics, ornaments or materials that communicate a sense of identity or purpose through how those elements are used. Views are observable features that can be of the natural or built environment and can be intimate or panoramic. Resources are related to the accessibility and functionality of the environment and can be scarce, finite, nonrenewable resources (i.e. money, time) or expandable, renewable resources (e.g. motivation). Finally, ambient conditions are environmental stimuli, such as illumination, heating, ventilation, and acoustics.

The three frameworks share similarities in how attributes can be classified into certain categories, yet the differences in categorization suggest that the grouping of physical environment attributes may differ according to the purpose of a setting (e.g. office work, service, and creativity). In addition, these frameworks do not depict how the physical attributes in the environment impact creative performance. This missing link of underlying mechanisms, or mediating processes of how the physical environment impacts creativity, is important to investigate as it provides a clearer and stronger connection between the physical environment and creativity, has the potential to explain why creative performance is impacted, and offers insight on what physical environment attributes should be focused on for the design of a space for fostering creativity (Figure 3.1).

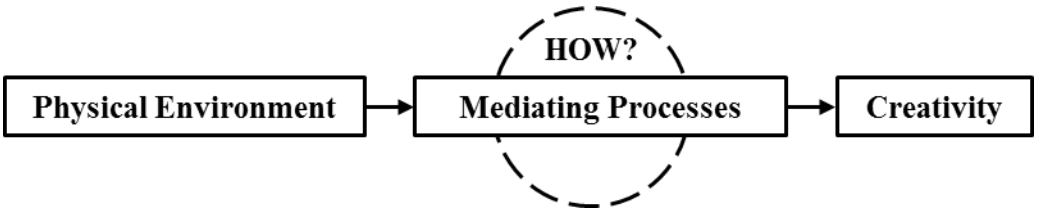


Figure 3.1. Integrated view of the relationship between the physical environment and creativity

Review Methodology

A review of literature spread across various disciplines on the relationship between the physical environment and creativity was conducted by searching databases (i.e. Academic Search Premier, ProQuest, JSTOR, PsycINFO, etc.) using the keywords "creativity" and "physical environment" for full-text, peer-reviewed articles in English. Abstracts were screened to determine the study's relevance. Literature was further expanded by using physical environment attributes (e.g. noise, color, lighting, odor, temperature, size, shape, rectilinearity, space, layout, furniture arrangement, open-plan, window, nature, view, plant, sign, poster, material, wood) as keywords in a joint search, and also by reviewing references cited in relevant articles. Only studies elucidating a clear connection between physical design attributes and creativity were included.

Workspace Size and Shape

Physical space affects the well-being of people, the channels of information, and the availability of knowledge tools, and sets the stage for coherence and continuity, which may contribute to competitive advantages in creativity (Kristensen, 2004). The spatial form of the interior space, defined by the structural size and shape, can be determined by rectilinearity and complexity. McCoy and Evans (2002) analyzed photographs of interior spaces and found that size or rectilinearity of the space had no relation to its creative potential; however, higher visual complexity was perceived to have higher creative potential. Conversely, Ceylan, Dul, and Aytac (2008) found that visual complexity was associated with low creative potential in a modified

version of the McCoy and Evans' (2002) study. In the original study (i.e. McCoy & Evans, 2002), experts conducted a content analysis of the physical elements in the photographed spaces which college students sorted by creative potential; whereas, Ceylan et al. (2008) had office managers rate the overall creative potential as well as evaluate a modified version of the characteristics listed by McCoy and Evans (2002) using a quantifiable method. The differences in sample characteristics and analysis methods may have resulted in mixed findings.

Workspace Layout

Spatial layout or configuration influences social interactions that are necessary for both effective task performance (e.g. creativity) and the satisfaction of social needs in organizations. The physical layout of workplaces can enhance the social process of creativity through interaction patterns (Martens, 2011; Sailer, 2011). Creativity, in particular, takes place in a physical context where the configuration, design and management of space can restrict and support the flow of knowledge and the exchange of ideas, while inducing emotions that facilitate or reduce the enhancement of creativity (Kristensen, 2004; Martens, 2008). Layouts that create pathways for people to get around to different areas of the workplace can be planned to induce spontaneous interaction that is believed to encourage creative idea exchange (Leonard & Swap, 1999). Layouts also facilitate different benefits for different activities: long corridors facilitate a hierarchical organization with people in separated rooms, flat structures afford open space where people can interact at many levels, narrow paths that only allow sequential passages reduce interaction, linear spaces make it difficult for a group to assemble and have discussions, whereas centralized or radial shapes are appropriate for communal space and creativity (Kristensen, 2004).

Layouts can evoke emotions that are identified in the creative process, which can be

related to Ekvall's (1996) dimensions for a creative climate: challenge, freedom, idea support, trust or openness, dynamism or liveliness, playfulness or humor, debates, conflicts, risk-taking, and idea time. Vithayathawornwong et al. (2003) found qualitative evidence that dynamism was the most salient social-psychological condition conducive to creative behavior supported by the physical work environment through layout and spatial arrangements, enclosure of office or workspace, and accessibility. Freedom was another significant dimension which was accomplished by providing a multitude of alternative spaces.

Workplaces that provide opportunities for physical change (i.e. flexibility) through design also support creativity. Csikszentmihalyi (1996) observed that creative individuals are most likely to change their environment according to the rhythm of their thoughts or habits of their actions. The interaction between people and the environment played out by flexibility in spatial arrangement can enable many of the dimensions for a creative climate. When users have the control to design an environment to accommodate their needs for the given task and goal, the process supports dynamism, provides opportunities for idea support, gives a sense of freedom over the environment, and challenges the exploration of the adequate arrangement for the given task and situation (Vithayathawornwong et al., 2003).

Similarly, higher levels of perceived control can influence employees' ability to use their workspace and its adjustable features effectively, and can lead to higher environmental satisfaction and communication (Huang, Robertson, & Chang, 2004). More personal control over the physical workspace and easy access to team or communal places leads to higher perceived group cohesiveness and job satisfaction (Lee & Brand, 2005). However, actual and perceived control should be differentiated in that individuals can become distracted when actual control of the environment is given, thus, reducing work performance (Veitch & Gifford, 1996). Instead,

perceived control symbolizes freedom, trust, and organizational support which may lead to improvement in creative tasks in the long run.

The type of office arrangement (i.e. closed or open-plan) also has a great impact on employee behavior and communication (Ornstein, 1989). Open-plan offices increase communication, rate higher in aesthetics, and have more group sociability among employees than conventional designs (Maher & von Hippel, 2005). Relationships may form according to the spatial proximity of employees, having an effect on communication and employee satisfaction (Oldham & Rotchford, 1983). Layouts can support tasks as well. For example, Lewis and Moultrie's (2005) case study identified that task goals which require collaboration may have advantages when working in a layout that is more open for free-flowing communication or to have workspaces (i.e. desks) that are close to each other for simultaneous idea exchange or to have a large team table or tools to facilitate team discussions.

Conversely, open-plan offices have been linked to increased workplace noise, disturbances, distractions, feelings of crowding, and reduced privacy (e.g. Sundstrom, Herbert, & Brown, 1982; Hedge, 1986; Maher & von Hippel, 2005). The increase in distractions may offer more cues to utilize for creative ideation; however, when attention or concentration is required, the overstimulation from the open environment may hinder cognitive processes and performance. Some studies have found that noise distraction, especially related to the issue of speech privacy, is more bothersome than visual distractions (e.g. Ornstein, 1989; Sundstrom, Town, Rice, Osborn, & Brill, 1994). Even if partitions were placed throughout a space and offered visual privacy, unless they extend from floor to ceiling, those barriers will not be sufficient to block sound, and sound, especially speech sounds, from an unseen source are more distracting. When noise is unpredictable and intelligible (i.e. speech), detrimental effects are found in creative tasks

(Kasof, 1997), particularly in the case of ideational fluency (Kaltsounis, 1973).

Sound, Noise, and Music

Indoor ambient noise can be, in general, a distraction or interruption that inhibits creativity (Martens, 2011). More specifically, noise affects arousal and can either serve as a distractor that inhibits attentional focus and impairs cognitive performance or as an arousing stimulus providing cues to aid task performance. Several laboratory studies have utilized noise to create different arousal levels and test its effect on creativity tasks. Martindale and Greenough (1973) investigated three arousal conditions, described in their study as relaxed, stressed, and with 75dB of white noise, and found that increased arousal (75dB of white noise) improved intellectual performance on a version of the Wechsler Adult Intelligence Scale (WAIS), but inhibited creative performance on the Remote Associates Test (RAT) which measures novelty and divergent thinking. However, noise was only used in their last test condition as an additional stressor and thus it cannot be considered as the sole reason for the observed results. Voss (1977) tested similar conditions (low activation condition having no reference to noise, white noise introduced in a middle activation condition (40dB), and a high activation condition (78dB)) and failed to find any effect on creativity as measured by the RAT and the AC Test (an ideational fluency, spontaneous flexibility, and originality measure), but low and high activation facilitated the fluency component of the AC test. Mehta, Zhu, and Cheema (2012) found an inverted-U relationship between noise level and creative performance where more correct responses in the RAT and more creative ideas in judged idea generation tasks were found in 70dB of various background noise recorded from real-life venues, compared to 50dB and 85dB, and was later found to be associated with higher arousal, more processing difficulty, and a higher construal level. Toplyn and Maguire (1991) found no overall significant effect of the three white noise

levels (60dB, 80dB, 100dB) on performance of Wallach and Kogan tests (Uses and Similarities test for verbal creativity, and Pattern-Meanings and Line-Meanings for visual creativity), although high creative potential participants had significantly more unique responses (z-scores of the Uses tests combined) at the middle arousal level (80dB noise level) than in lower (60dB) or higher level (100dB), suggesting an inverted U-shape relationship between the loudness of white noise and creative performance.

Kasof (1997) found that unpredictable noise had a more damaging effect on judged creativity, as measured by word originality and judged creativity scores of poems written by individuals with high and low creative potential, than predictable noise or no noise. Noise unpredictability and intelligiblility impaired creativity more for individuals who could not screen environmental stimuli. Kaltsounis (1973) tested the effect of four sound conditions (speech, music, industrial sound, and quiet) on a simple creative task (i.e. incomplete figures task) among fifth grade male students. Mean fluency scores went from high to low in the order of music, quiet, industrial sounds, and speech conditions; music, speech, quiet, industrial sounds for flexibility; music, quiet, speech, industrial sounds for originality; quiet, speech, music, industrial sounds for elaboration. Mean performance was highest with music on all creative categories except elaboration; however, the level of significance was not reported. Although the tests were random and the order of sound conditions were counterbalanced, the sample size (N=15) was small and from a very young population that could have been more susceptible to confounding factors such as fatigue.

Physiological effects (galvanic skin response) of auditory stimuli (bursts of 60dB white noise) indicate that individuals with higher creative scores, measured with the RAT and a version of the Alternate Uses Test, were more sensitive to stimuli and had a longer habituation rate

(Martindale, Anderson, Moore, & West, 1996). However, this study identified characteristics of creative individuals, rather than how environmental stimuli can have an impact on creative performance.

Changes in Spatial Settings

Changing different spatial settings, activities and cognitive intensity, and personal preferences can have an impact on how the physical workplace supports creativity (Martens, 2011). For example, open plan offices can facilitate the collaborative phase of the creative process whereas, places that provide moments of relaxation is preferred for creative thinking (Haner, 2005). Kristensen (2004) and Meusburger (2009) emphasized the need for separate spaces for the different stages of the creative process or for certain types of activities as they have different spatial requirements; for example, preparation and elaboration need both communal and private spaces, while incubation and insight are more supported by privacy and seclusion. Penn, Desyllas, and Vaughan (1999) conducted spatial syntax analyses of innovative organizations and identified that centrally located spaces afford unplanned interaction and the rapid transfer of ideas, whereas segregated spaces afford better execution of tasks.

Case studies of innovation laboratories—structures designed purposely to enhance and support creativity—have also suggested different spatial designs according to the needs of each phase of the creative process (i.e. preparation, incubation, insight/illumination, and elaboration/evaluation). Haner (2005) analyzed two cases in which one facility contained a space for convergent thinking phases (i.e. preparation and elaboration/evaluation), equipped with smart furniture, various visualization and interaction devices, and free-formed bright seating, and divergent thinking (i.e. preparation and insight/illumination) spaces located either near the main gathering area of the facility or designed to form a private cocoon-like space with light,

acoustics, projection opportunities, etc. that are individually adjustable. The other case is a facility that required users to physically move from one space to another as they progress through the creative process based on de Bono's (1985) six thinking hats and Wallas' (1926) linear model of creativity. Each space is designed to resemble the specific goal of each phase; for example, the exploration space is white and blank in order for users to fill it in with information. This space, in particular, is supported by equipment for communication, information retrieval, knowledge-sharing and collaboration. In addition to the functional support of the physical environment for creativity, Lewis and Moultrie (2005) also suggested the importance of a 'dislocation' effect in which users diverge from traditional norms and are surrounded with design elements that communicate opportunities that are different from day-to-day activities (e.g. writing on walls, doors utilizing high technology, etc.). Magadley and Birdi (2009) describe this as "getting away from the workplace" in order to think differently, and suggest that creative behavior can be affected by the message that the physical environment communicates to the user.

Materiality and Furnishing Style

Natural elements in the indoor environment have been found to convey messages that may not impact the performance in tasks, but rather impact the emotional perception of the environment. In particular, the amount of wood grain texture and the overall use of natural materials, preferred over synthetic and composite materials, were positively associated with the creative potential of the physical environment (McCoy & Evans, 2002). The restorative quality of nature or the multiple sensory stimuli available in nature, even when interpreted through materiality, may be conducive to creative behavior. Ridoutt, Ball, and Killerby (2002) found that the use of wood led to an overall favorable first impression on interpersonal perception (including creativeness) in offices, and de Korte, Kuijt, and van der Kleij (2011) used wood to

provide an overall impression of psychological safety in the design of a meeting room.

Furnishings are most likely to make up the overall style of the workplace and will convey a message to the users of the space. In de Korte et al.'s study (2011) color, lighting, materials, sitting arrangement, and furniture type were used to convey mood states of arousal and psychological safety for completing a creativity task. The room designed for psychological safety had green colors, armchairs placed in a circle with a low round table, wooden materials, a poster of a natural environment, objects to create a domestic atmosphere and dim lighting. The overall impression of this room was rated to be high in pleasantness and social status. On the other hand, the room designed for arousal had warm, red colors, stools placed in a circle with no table, a poster with complex figures of fractals and bright lighting. This room was rated to be high in originality and complexity. No direct effects were found between the rooms on creativity measures; however, arousal tested by heart rate variability was found to be a possible mediating factor and an interaction effect between the interior and task type indicated that the optimal pairing of these two could enhance creative performance.

Plants, Signs, Symbols, and Artifacts

Interest in the restorative effect of natural environments has translated into interest in whether indoor plants have an effect on task performance and mood. Shibata and Suzuki (2002) found the presence of indoor plants to positively affect association tasks more than sorting tasks, and to have a stronger effect on males than females. In another study by Shibata and Suzuki (2004), positive mood evaluations (i.e. active, confident) of the participants were found in the plant and magazine conditions compared to having no objects, and females performed better on the associations task in these environments. Specifically, plants were evaluated to be calmer and less distracting than magazines, and females performed better in this environment compared to

others, whereas males' task scores were similar in all three conditions.

Physical and social features of work environments influence employees' job satisfaction and well-being. Environmental distractions and poor social climate at work can restrict employees' experiences of creativity by interfering with their concentration on job-related tasks or by increasing unpredictability and uncontrollability, resulting in the belief that the workplace does not support their efforts to be creative (Stokols, Clitheroe, & Zmuidzinas, 2002). However, Vohs, Redden, and Rahinel (2013) found that a disorderly environment (i.e. clutter) stimulated higher scores in the Alternative Uses Task (AUT) by aiding people to break away from tradition and convention than when in an orderly room. Work environment satisfaction was also associated with the extent of the organization's personalization policy (i.e. amount of control over individual workspace), with the amount of personalization found to positively correlate with creativity (Wells, 2000). Personalization allows for individual expression and a very subtle interaction between people and the environment.

Air Quality and Thermal Conditions

Odors have been used as agents for impacting the mood for creative performance. Knasko (1992) compared how pleasant odors (lemon, lavender) and an unpleasant odor (dimethyl sulfide) may selectively activate creativity (measured by the Torrance Test of Creative Thinking (TTCT)), mood, and the report of health symptoms related to Sick Building Syndrome (SBS). Overall, dimethyl sulfide seems to have affected mood and lemon scent was linked with health, but overall, the intensity of odor was perceived to have been too tolerable to have an effect on creativity. Ludvigson and Rottman (1989) found favorable affective reactions when participants were initially exposed to lavender scent; however, this was found to be a temporary effect in the follow-up study and no direct effects were detected on mood. Cognitive functioning

with regards to the arithmetic task was adversely affected by the presence of lavender when first encountered, but could not be found in the second study. Relatedly, ventilation was identified as a characteristic of the physical environment that stimulated creativity (de Alencar & Bruno-Faria, 1997). Willem (2006) found that participants with an increase in outdoor air supply rate (4.5 L/s/p to 18.0 L/s/p) generated more original ideas.

High temperature was unanimously mentioned as a physical attribute that inhibits creativity according to interviews of ten creative leaders in a study conducted by Martens (2011). However, the interviewees did not provide specific temperature values, and the geographical characteristics of the interviewees' environment (i.e. United Kingdom and the Netherlands) may have an impact on their perception of temperature levels. In understanding more detailed effects of thermal conditions, Takahashi, Nagano, and Kato (2007) explored the impact of indoor temperature (23 °C, 28°C and 33°C) on reactive depression and creativity through game performance (Sudoku game), an arithmetic addition task, and a knowledge production task and found changes in temperature only. Performance on the Sudoku game and arithmetic task was best at 28°C and worst at 33°C; however, the effect was smaller for Sudoku than the arithmetic task.

Windows and Views

Windows or access to an exterior view is highly preferred in offices (Boubekri, Hulliv, & Boyer, 1991; Leather, Pyrgas, Lawrence, & Lawrence, 1998; Farley & Veitch, 2010). However, the effects of windows on task performance, whether facilitating or distracting, can depend on the task demands and if the individual has a direct or indirect interaction with the window (Stone & Irvine, 1994). Although Stone and Irvine (1994) found that the presence of windows did not have an effect on creative task performance, when comparing a direct and indirect view of the

window performance was higher with a direct view to some greenery and buildings. According to perceptions of task (filing, computational, creative), windowed rooms contributed more to a dynamic environment as well. Stone (1998) added the presence of a task-relevant poster to the previous study and confirmed that the presence of windows did not affect performance on any of the tasks; however, it increased self-reported motivation. The positive and restorative effect of natural views on performance (e.g. Kaplan, 1995) provides a potential link to creativity; however, empirical studies have not yet explored this relationship. Windows allow daylighting to penetrate into the interior space, bringing in light that is typically brighter and spectrally different than artificial light and varies throughout the day. No studies to date have investigated the relationship between daylighting and creative performance.

Color and Light

Color has been hypothesized to have an effect through arousal, mood, and motivation on creativity-related performance tasks seeking novel and appropriate solutions. In a series of three experiments, Küller, Mikellides, and Janssens (2009) first examined the effect of colorfulness on arousal and mood (i.e. emotional control and physiological state measured by EEG and EKG readings). Strong colors and patterns were perceived as complex; however, slower heart rates were recorded in comparison to the gray neutral room. Differences in hue (red versus blue) resulted in difference in affection level (red > blue), enclosedness (red > blue), potency (blue > red), and perception of social status (blue > red). More delta waves (characterized as a sleepy, drowsy state) were found in the blue condition. However, color's effect on emotional states did not affect performance (story writing task). In their final experiment testing color effects on routine tasks and creative tasks, differences in pleasantness (red > blue) and potency (blue > red) accounted for the differences in mood states, and those with negative mood states reviewed

longer texts and had a larger percentage of errors in the proofreading task in the red room, but also wrote longer essays (creative task).

Mehta and Zhu (2009) conducted a series of six color studies based on the approach and avoidance motivational theory (Elliot & Church, 1997) and its effect on cognitive task performance. Color and motivational state relations (blue associated with approach motivation and red with avoidance motivation) were found in the first study, and their effects on different cognitive task types—red enhanced detail-oriented (memory; proofreading) tasks and blue enhanced creative (fluency and originality; RAT) tasks—were tested and retested in two consecutive studies. Focusing on creative tasks, the fourth study of Mehta and Zhu (2009) found that red color conditions yielded to more practical and appropriate solutions and blue related to more original and novel solutions. This series of studies on the effect of color on performance found that blue enhanced performance on creative tasks when compared to red, however, when participants were asked to choose a color that would support their creative performance more people associated with the color red. Color may be a stimulus in the cognitive processes through emotional and visual channels; however, it is difficult to discern a particular color that creates impact. A conflict between sensory processes and cognitive processes through symbolism may evoke a certain emotion associated with the color, and these meanings and cultural effects (e.g. Adams & Osgood, 1973) should also be interpreted when trying to understand the impact on creativity.

Lighting in general has many psychological and behavioral effects including mood and cognitive performance. From interviews with employees of Brazilian organizations, de Alencar and Bruno-Faria (1997) identified adequate light as a stimulant to creativity and insufficient illumination as an obstacle to creativity; however, specific illuminance levels were not specified.

Veitch and Gifford (1996) utilized lighting conditions to observe the effect of choice and perceived control on intellectual and creativity tasks. They provided three lighting conditions—ambient lighting only (cool-white fluorescent lamps), ambient lighting and supplemental incandescent task lighting, and ambient lighting and compact fluorescent task lighting—that subjects ranked according to preference and were given (or denied) choice for their most-preferred condition and completed various tasks, including a booklet of mixed problems involving logic and creativity (similar to the Uses test). Unfortunately, this study was focused on the effect of control and the specifics of each lighting condition were also not reported.

Knez (1995) tested four cognitive tasks (long-term recall and recognition task, embedded figure task, free recall task, performance appraisal task) in two illuminance levels (dim versus bright) and two color temperatures (warm white versus cool white) at high CRI (Color Rendering Index; Study 1) and then at low CRI (Study 2) to understand lighting effects on performance, mood, and perception of lighting conditions. Problem-solving performance was inhibited in high CRI induced with negative mood (cool white light source for females, warm light for males). Warm white light at 300 lux illuminance and cool white light at 1500 lux illuminance in low CRI was found to be optimal for problem-solving.

In a series of studies, Steidle and Werth (2013) tested dim (150 lux) and bright illuminance (1500 lux) on creative performance measured through insight problem solving and the structured imagination task. The study found that dim illuminance enabled global processing and facilitated freedom from constraints and hence, supported creative performance for both creativity tasks. However, only studies that utilized direct uniform lighting above the work plane in work stations similar to private carrels succeeded in this finding. One study that used a direct/indirect floor luminaire in work stations similar to an open-plan layout did not find an

effect of illuminance on creative performance. The mixed results from this series of studies suggest that although illuminance levels may have an effect on creative performance in insight problem solving and the structured imagination task, the effect from the physical environment may be in combination with other factors and not solely from lighting.

Conceptual Framework for the Physical Environment and Creativity

Due to the complexity of both the physical environment and creativity, an overarching framework that encompasses all settings is needed to organize the relationship and represent possible mechanisms by which the physical setting might facilitate or inhibit creativity. The commonalities of the existing physical environment classifications (i.e. Bitner, 1992; Davis, 1984; McCoy, 2005) and the reviewed literature lead to a conceptual framework that categorizes the physical environment into ambient, spatial, and symbolic attributes (Figure 3.2). Each of the attributes of the physical environment can impact sensory, cognitive, and psychosocial processes associated with creative behavior. Sensory processes are simple behavioral responses from the sensory modalities, cognitive processes include perceptual and intellectual processes that shape behavioral responses to environmental stimuli, and psychosocial processes are emotional and social behavioral responses. All behavior starts with sensation, proceeds through cognition and often culminates in a social behavioral response. These pathways illustrate a systemic view of creative behavior that begins with the person, the person is also influenced by the physical environment and hence, their creative process and behavior that follows. Lines connecting attributes to processes and processes to creativity represent the extent of the relationship between the physical environment and creativity synthesized from the reviewed literature: bold lines represent a definite relationship, thin solid lines represent a probable relationship, and dashed lines represent a possible relationship.

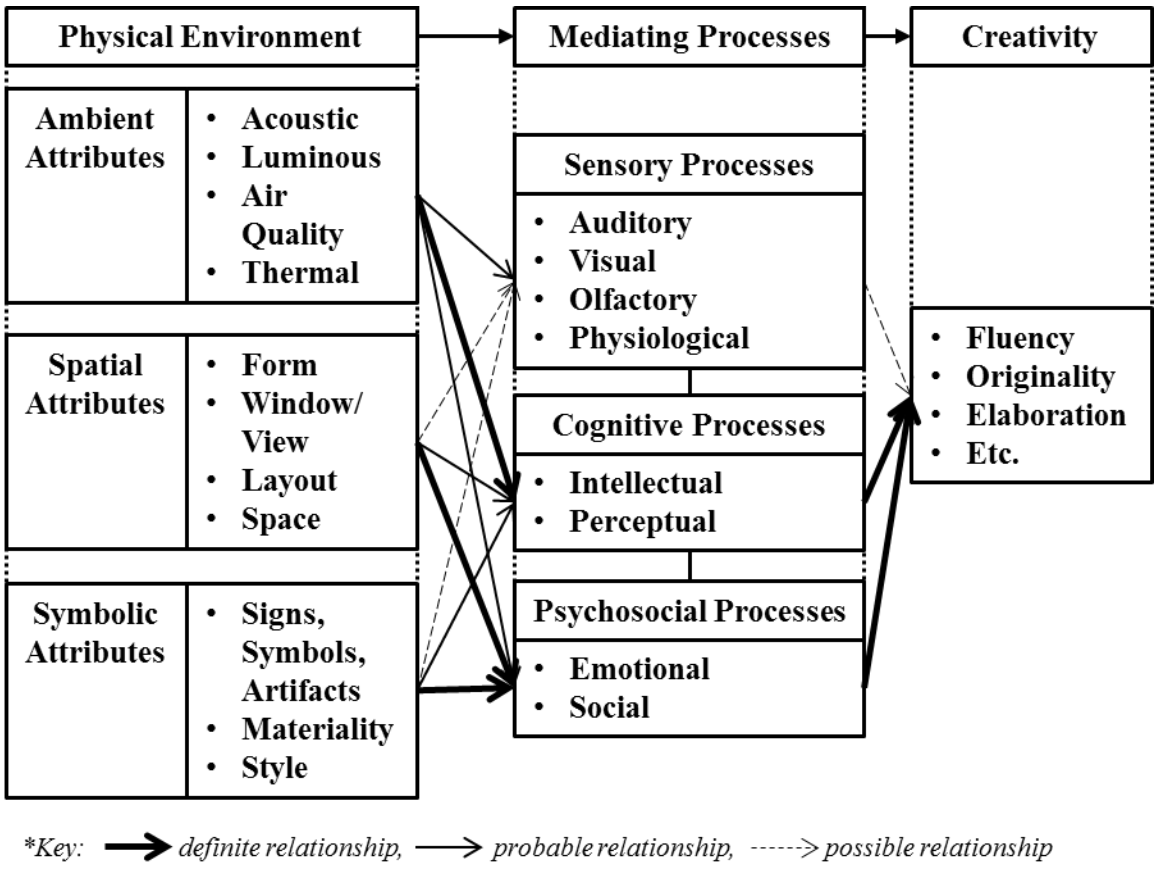


Figure 3.2. Conceptual framework for the relationship between the physical environment and creativity

The proposed framework in general provides a theoretical basis for the physical environment to be included as an influential component for creativity. The translation of the review of studies in the proposed framework identifies gaps and concentration in research for understanding the relationship between physical attributes of the environment and creativity, which are represented in the different line weights connecting physical attributes and mediating processes in Figure 3.2. Gaps are apparent in spatial and symbolic attributes' impact on sensory processes (with the exception of visual senses), spatial and symbolic attributes' impact on intellectual cognitive processes, ambient attributes' impact on perceptual cognitive processes (with the exception of luminous attributes), and ambient attributes' impact on the social aspect of psychosocial processes. Ambient attributes were observed in impacting sensory processes; however, spatial and symbolic attributes were heavily focused on its impact through the visual

sensory system and not through other sensory processes. Studies that looked into spatial layout could be extrapolated to impacting auditory processes (e.g. Ornstein, 1989; Sundstrom et al., 1994); however, studies that directly observed this relationship are also needed. The proposed framework, in general, works as a tool for suggesting areas for future research.

In the future, the framework can be further developed to better understand how specific attributes (e.g. noise, color, spatial layout, plants, etc.) have an impact on different facets of creative behavior (e.g. fluency, originality, etc.). Currently, a limitation for all of the studies reviewed is in the lack of a consistent definition of creativity, the exclusion of mediating processes, or underlying mechanisms, explaining the impact, and the variety of creativity dimensions that have been considered. Different creativity measures have yielded differences in results. Fluency, flexibility, originality, and elaboration have been measured most commonly; however, different studies have used different methods in measuring each of these constructs. An abundant body of research investigating the different physical environment attributes' effects on creative behavior and being consistent in the use of creativity measures is needed in order to cultivate repeated and established findings for this area of creativity research. Furthermore, the use of creativity tasks (i.e. RAT, Uses test, etc.) as dependent variable measures looked into the intellectual impact on cognitive processes and were only found in ambient attribute studies whereas, studies on spatial and most symbolic attributes did not use these objective creativity tasks but rather focused on its perceptual impact by gathering data from surveys or case studies. Research that objectively looks into the impact of spatial and symbolic attributes on cognitive processes is needed.

Additionally, the proposed framework can be utilized as a roadmap for future research and guidelines for designing an environment for creativity. Studies that were experimental used

objective measures for creativity in controlled environments, whereas real-world studies used subjective measures for creativity. Although these studies contribute to the body of knowledge, field studies with objective measures should provide valuable insight towards a better understanding of the relationship between the physical environment and creativity and are needed for further design implications. Objective creativity tasks conducted in office environments that can be analyzed by physical attributes and further compared with other environments may yield results that are more practical. Designers may use the proposed framework to reference particular physical environment attributes that should be considered for the design of the physical workplace. Individuals, groups, and organizations may also benefit from this by referring to the framework to arrange their workspace according to their creativity needs. Additionally, understanding how attributes of the physical environment impact creative behavior and investigating what the underlying mechanisms of the relationship is can become an important guide to the design of workplaces where fostering creativity and innovation is essential.

Extensive research is needed in order to establish a relationship between the physical environment and creativity and to understand how the impact is made. The increasing interest in this research area and the emerging new literature in this field suggest the current effort towards this direction. Creativity research focusing on the physical environment should explicitly state the physical environment attribute or attributes, the mediating processes that underline the relationship, and the creativity dimension being investigated. New findings will add to the proposed framework and continue in the pursuit to better understand the physical environment and how it affects creative behavior in designing for workplaces for creativity.

Challenges in Creative Workplace Research

The demand for creative workplaces is continually increasing as the nature of work calls for new advances and the expectations of the emerging work generation have expanded to the physical environment (Hewlett, Sherbin, & Sumberg, 2009; Kilber, Barclay, & Ohmer, 2014; Martin, 2005; Suleman & Nelson, 2011). For research to advance within creativity, the complexity of the physical environment and the multi-faceted characteristics of creativity need to first be unraveled. In spite of this growing interest in workplaces for creativity, research in this field has not yet been thoroughly investigated. Creativity models acknowledge the physical environment as a component for creativity; however, the specific effects of physical environment attributes and the underlying mechanisms that mediate its relationship with creativity are still unclear. Rigorous investigations of each physical environment attributes effects on particular dimensions of creativity is needed to further build the body of knowledge in this research field.

Proposed Topic of Study

In this review gaps in research investigating the effects of physical environment attributes on creative performance were identified. From the discussion, suggestions for research that include mediating processes that explains the relationship between the two in order for a more holistic approach to creativity were made. In addressing these points mentioned in the review and discussion, the present research will be focused on investigating the effects of lighting on creative performance. Lighting is an important physical environment attribute, yet little is known about its effects on creative performance. Although the effects of lighting in the workplace often have been associated with the "Hawthorne effect," which suggests no effect of lighting on productivity, a recent historical and statistical analysis of archival data sheds light on the experiments appealing that the studies were flawed and the results may have been due to these

shortcomings (Izawa, French, & Hedge, 2011). The effects of lighting in the workplace needs further investigation in which the findings from recent studies (i.e. Steidle & Werth, 2013) suggest that lighting does impact creative performance. The characteristics of lighting and its effects within the interior environment are reviewed in the next chapter.

CHAPTER 4
LIGHTING AND CREATIVE PERFORMANCE

Lighting Characteristics

The human visual system responds to the wavelengths between 380 and 780 nm. Light in this spectral range produces sensations of brightness and color. The photometric measure of lighting includes the electromagnetic radiation emitted by a source, or radiant flux, and luminous flux measured in lumens. While luminous flux is used to quantify the total light output of a light source from all directions, illuminance measures the luminous flux falling on a unit area of a surface. The S.I. unit measurement for illuminance is lumens per square meter (lm/m^2) or lux (lx). Another important measure of lighting is the luminous intensity or luminance, which quantifies the luminous flux in a specified direction. Luminance is the luminous intensity emitted per unit projected area (steradian) of a source in a given direction and its unit measurement is candela per square meter (cd/m^2). The reflectance of a passive surface is the percentage of incident luminance that is emitted from the surface.

The color sensation of light is dependent on its spectral distribution, luminance, and the color of the surroundings. In order to quantify a measure for color, the C.I.E. colorimetry system (the international agreement established by the Commission Internationale de l'Eclairage) uses a mathematical representation of the spectral power distribution of three color matching functions, X, Y, and Z. These values can then be expressed as proportions of their sum (totaling to 1) as x, y, and z, known as the CIE chromaticity coordinates. These coordinates can be plotted on a two-dimensional diagram (using x and y) and this depicts hue and saturation of the color.

Correlated color temperature is another color measure of light sources and is more widely used in practice when characterizing the color of light from a source. The unit for color temperature is the degree Kelvin (K) and light sources typically range from 2,700 to 7,500 K.

The yellowish color appearance of an incandescent lamp is roughly 2,700 K and is described as having a "warm" color temperature while a bluish color appearance is roughly 7,500 K and is described as having a "cool" color temperature. The color temperature describes the color of the light emitted by lamps whereas the color rendering index (CRI) provides information on how the lamp will affect the appearance of the colors of other objects compared to daylight. Other color measures of light such as, color vector maps or color gamut exist; however, they are not widely used lighting measures.

The properties of the light source are essential for understanding lighting characteristics in general; however, this physical stimulus is not the sole determinant of how the human visual system perceives the environment as it is rarely a single element seen in isolation. Humans' perception of the visual world is a combination of the visual stimuli, past experience, and coincidental information (Boyce, 2003). Fundamental attributes of an object that are invariant to lighting conditions are called perceptual constancies. The ability to separate illuminance from reflectance in most lighting conditions pertains to lightness constancy and the ability to identify color in spite of large changes in spectral content of the illuminant is color constancy. Size and shape can also be depicted as constant visual elements in midst of changes in luminous conditions as cues from the surrounding area (e.g. shadows, texture, distance, etc.) makes it possible to determine the objects being viewed.

Lighting characteristics that have an effect on perception are related to luminous intensity distribution and brightness. The direction of light distributed can be direct, indirect, or a combination of both. Direct lighting is when all the light emitted from the lamp is directed downward whereas indirect lighting is when all light is directed upward to a reflective ceiling. Even when luminance is the same, direct lighting is perceived to be brighter than indirect

lighting. Another factor that influences perceived brightness is the breadth of light that is being distributed. A narrow distribution focuses the light on a particular area and less on surrounding areas resulting in the perceived brightness being less than a wide distribution of light. Light installation or lighting design incorporates additional factors such as the location of luminaires which also impacts the perception of objects and space.

Lighting design considers the physical structure and the purpose of the space using different lighting types. Ambient, or general, lighting provides overall uniform lighting in a space and can be achieved using direct lighting, where overhead luminaires provide a downward light distribution, or indirect lighting, where luminaires provide upward light that is reflected from the ceiling, or a combination of both proportionately. The direction and distribution of light impacts our perception of space and objects. The use of indirect lighting reduces video display terminal (VDT) screen reflections (Hedge, 1991; Hedge, Sims, & Becker, 1995), increases the vertical illumination in a space, and when using diffused light it may reduce our sense of visual clarity, depth perception, and sense of orientation (Gordon, 2003). Task lighting is used in task areas that need additional light and can be used to create an energy-effective lighting system (Hedge, 1996). Other lighting techniques used in space are wash lights that provide relatively uniform brightness, usually on a wall but occasionally on a ceiling, and cove lights that are housed in a concave or canted interior corner or molding used to transition from wall to ceiling and shield light sources that distribute light across the ceiling plane (Gordon, 2003).

Although designers always strive for good lighting quality, there is no clear definition or prescription for what this is. A general definition for the application of lighting quality is how well the lighting installation fulfills the objectives and constraints set by the client and the designer (Boyce, 2003). Photometric properties of lighting enable us to measure different

characteristics of lighting; however, it is how these lighting characteristics affect human experience that is most interesting. In design, lighting is usually used to support features within a space rather than being the focal point of the space.

Lighting and Perception

Lighting can influence perception through visual impressions such as clarity, spaciousness, relaxation, privacy, pleasantness, and order. Flynn, Spencer, Martyniuk, and Hendrick (1973) manipulated different light settings in a single-study environment and found consistent responses in spaciousness, perceptual clarity, and pleasantness. Based on the results of this study, Flynn (1992) further suggested lighting design for perceptual clarity should utilize bright lighting and peripheral lighting; for spaciousness it should incorporate peripheral and uniform lighting; and for pleasantness and relaxation it should emphasize peripheral and non-uniform lighting. He also suggested using non-uniform and dim lighting for creating spatial impressions for privacy.

Compound lighting (the use of both general and supplemental lighting) creates non-uniformity and has been found to enhance ratings for pleasantness in the environment (Ballantine, Jack, & Parsons, 2010; Summers & Hebert, 2001) and non-uniform lighting is preferred over the use of only general lighting (Flynn et al., 1973; Han, Ishida, Iguchi, & Iwai, 2006). More specifically, Durak, Olguntürk, Yener, Güvenç, and Gürçınar (2007) found that ratings of pleasantness were higher when cove lighting and wall washing were used compared to general lighting; however, no difference was found between high (500 lx) and low (320 lx) illuminance levels. However, when lighting type was held constant, the rating of pleasantness was higher in high illuminance (1076 lx) than in low illuminance (107.6 lx) (Hendrick, Martyniuk, Spencer, & Flynn, 1977).

Similarly, lighting has been found to affect mood (e.g. Baron, Rea, & Daniels, 1992; McCloughan, Aspinall, & Webb, 1999). The use of warm lighting and accent lighting in retail environments was found to significantly increase pleasure, which was also associated with an increase in perceived coziness and liveliness and a decrease in tenseness (Quartier, Vanrie, & Van Cleempoel, 2014). Küller, Ballal, Laike, Mikellides, and Tonello (2006) found an inverted-U relationship with perceived illuminance and arousal (i.e., level of activity); however, no significant association was found with objective illuminance measures. Kaye and Larson (1992) found more extreme emotional ratings in light that was dimmer or brighter than light levels people were normally accustomed to, suggesting that the difference in lighting quantity is what triggers an emotional response. Arousal theory extends the relationship between lighting and mood with performance: higher illuminance increases arousal, and increased arousal leads to task performance in an inverted-U function (Mehrabian & Russell, 1974; Veitch, 2001).

Lighting and Preference

Lighting perception can also be influenced by individual preference. Butler and Biner (1987) surveyed preferences for illuminance levels in several scenarios and found that these differed according to the behaviors and social situations. They suggested that preferences integrated comfort, aesthetics, and other reactions, which were stronger measures than performance. Biner, Butler, Fischer, and Westergren (1989) further examined this through preferences for illuminance level according to visual and non-visual activities among different social group settings and found the results related to optimal arousal theory. Optimal arousal theory (e.g. Hebb, 1955) proposes that a moderate level of arousal is pleasurable and best for effective behavior for daily activities. Stronger differences in lighting preferences were found among different social situations (e.g., one platonic friend versus a group of platonic friends)

when the activity was more complex; more specifically, subjects preferred much lower lighting for complex activities in the group setting than with only one other friend. Lighting-type preferences also varied among different study areas by college students—incandescent lighting was most preferred in home study areas, and natural daylight was preferred in library and hypothetical office settings (Veitch, Hine, & Gifford, 1993). In general, individual preferences were based on task purposes and situational characteristics, in which studies only commented on preferences in brightness and lighting type and did not report effects on performance.

Lighting and Satisfaction

Satisfying individual preferences may also create a positive mood which then can increase environmental satisfaction and work performance (Baron & Thomley, 1994). Survey data found that people desired control over lighting in the workplace and that workers believed that enhanced lighting quality would improve their mood and work performance (Steelcase, 1999). Empirical studies investigating this claim have consistently found personal control over lighting to improve environmental satisfaction (Boyce, Eklund, & Simpson, 2000; Newsham, Veitch, Arsenault, & Duval, 2004; Veitch & Newsham, 2000). Participants who had control of their light levels in an open-plan office setting according to their preference during the daytime were found to have significantly higher pleasure ratings, lighting satisfaction, and overall environmental satisfaction (Veitch & Newsham, 2000). Lighting level choices selected by individuals varied over a wide range with mean illuminances fluctuating between less than 100 lx to more than 600 lx (Boyce et al., 2000). Newsham, Mancini, Veitch, Marchand, Lei, Charles, and Arsenault (2009) interpreted these differences in lighting preference and the exercise of personal control over lighting to be the individual's effort in creating individualized microclimates. Providing individuals with lighting control also resulted in higher ratings of

lighting quality and comfort (Boyce et al., 2000), and was found to be associated with motivation and improved performance on an attention task (Boyce et al., 2006). Although many studies concur with the connection between lighting control and environmental satisfaction, the effect of personal control on task performance varies. Newsham et al.'s (2009) study only found an effect of lighting control on satisfaction and not for other outcomes such as creative performance in ideation tasks. Veitch and Gifford (1996) found that participants given control over the choice in lighting type performed less well and slower on a creativity task coming up with novel uses for a common object than those who were denied control. They suggest that, although control provides many desirable attributes, having control over the environment may burden the individual to be responsible and make decisions. This may detrimentally affect only creative work and not performances on other tasks.

Lighting and Creative Performance

Research on lighting effects on creative performance can be classified as perceptual or empirical studies. In examining actual work environments, adequate light was identified as a stimulant to creativity and insufficient illumination as an obstacle to creativity based on interviews of Brazilian employees (de Alencar & Bruno-Faria, 1997). This study did not report what employees constituted as adequate or insufficient light, nor were lighting characteristics of the work environment specified to further explain this. Ceylan et al. (2008) analyzed physical workplace environments to examine which attributes contribute to their creative potential and they identified bright lighting, presence of windows, cooler colors, more plants, and lower structural complexity for high-creativity-potential environments among managers, but these results did not accompany any objective measures for what constituted bright lighting. Another study using a similar list of physical environment attributes, but conducted with university

students in a variety of environments, did not yield any significant findings related to lighting (McCoy & Evans, 2002). The incongruence in findings among the studies and the lack of specificity of lighting characteristics suggest that expectations of environments and perceptions of them may differ among individuals.

Few empirical studies have investigated the effects of lighting on creativity and invariably they have not taken detailed measurements of lighting levels and the use of lighting controls. Steidle and Werth (2013) conducted three experiments that manipulated lighting conditions and found that subjects exposed to 150 lx (at 4000K) improved their insight problem-solving and drew more novel ideas for a structured imagination task compared to those exposed to 1500 lx (at 4000K). Steidle and Werth (2013) concluded that dim illuminance enabled global processing and facilitated freedom from constraints and hence, supported creative behavior. However, these conclusions were not consistent in their study when using indirect non-uniform lighting (floor luminaire: 4000K) as they found high perceived freedom from constraints in both the low (150 lx) and high (1500 lx) illuminance settings but no significant effect on creative performance (i.e., insight problem-solving). This suggests that the relationship between perceived freedom from constraints and creative performance is not linear, nor is there a simple relationship between illuminance levels and creativity. The lighting impression from the various light fixtures used in their different studies may have created environmental perceptions other than freedom from constraints, which in turn impacted the creative performance results. Study conditions also differed as the participants in their first study completed tasks on computers in private study carrels, and in their second study participants worked on computers on open individual work surfaces. The discussion of dim illuminance providing participants with perceived freedom from constraints suggested a mediation of the relationship between lighting

and creative performance, but it may not have been solely due to illuminance levels. It could rather have been the visual impressions from lighting and the perception of a combination of attributes in the physical environment (e.g., light distribution, light fixture, workspace, etc.).

Although the Steidle and Werth's (2013) study provides some evidence that dim lighting supports creative performance on insight problem-solving, other effects of lighting beyond simply changing illuminance were not explored. In investigating several lighting characteristics collectively (i.e., illuminance levels, color temperature, and color rendering index), Knez (1995) reported that an interaction between color temperature and illuminance with cool white light at dim illuminance (4200K at 300 lx) and warm white light at bright illuminance (2950K at 1500 lx) in low (55), not high (95), CRI being optimal for problem-solving and also for well-preserved positive mood. However, Nelson, Nilsson, and Johnson (1984) found no lighting effect (100 vs. 300 lx at 6500K) on creative writing performance, which was measured by the number of stories and number of words written. In this case, the difference in illuminance levels may not have been great enough to have had a significant effect. Overall, previous results suggest that with high color temperature, low illuminance conditions will best support performance in a variety of creativity-related tasks.

In addition to studies investigating only lighting effects on creativity, de Korte et al. (2011) conducted a study comparing several room designs for teamwork in which lighting was one of the manipulated physical environment attributes. They found that teams generated more creative ideas for a simple association task in a room designed with bright lighting, warm red colors, stand stool elements placed in a circle, and a poster with complex figures arranged to induce an arousing (or activating) mood. However, for the complex task, more creative ideas were generated in a control condition "neutral" room designed as a traditional meeting room with

moderate lighting, blue, gray, and white colors, a square table and office chairs surrounding it in a U-shape, and plastic materials. Unlike the previously reviewed studies, this study's focus was on how creative performance was affected by the mood created by the design of the whole physical environment rather than a single physical environment attribute, and therefore it is unknown whether a specific attribute contributed to the effects found or whether the combination of attributes interacted to produce the effects. The interaction found between task type and room suggests that different room designs may be appropriate for different tasks. The arousal room may have provided stimuli for the simple task, and the neutral room may have afforded teams fewer distractions to concentrate on the complex task to reach maximum performance.

Overall, previous studies have found lighting to be one of the several physical environment attributes that contributes to creating various spatial impressions via mood and to improving creative performance through different tasks. Although individuals have exercised different preferences for lighting when in different environmental settings and social situations, empirical studies investigating the effect of lighting on creative performance have not yet identified how individuals perceive the physical environment through different lighting conditions and have not yet included lighting preferences for creative work as part of examining the relationship among lighting and perception, preference, and performance for creativity.

CHAPTER 5
A PRELIMINARY STUDY EXPLORING PHYSICAL ENVIRONMENT ATTRIBUTES FOR CREATIVITY

Introduction

The workplace is comprised of many different physical environment attributes. In order to depict attributes that are significant to creating a workplace that fosters creative performance attributes that individuals identify as contributors to creativity in the workplace environment must be identified. Studies examining the physical environment−creativity relationship are few. In addressing the fast-paced demands of creativity, the emerging work generation's perception of the workplace environment is particularly of interest as their view of the workplace will fundamentally change the future of the workplace.

Objectives & Research Questions

The purpose of this preliminary study was to identify physical environment attributes that the emerging work generation perceives to contribute to their creativity in existing workplace environments. Based on previous studies that examined the physical environment holistically (e.g. Ceylan et al., 2008; McCoy & Evans, 2002), this study aims to elucidate which specific physical environment attributes are perceived to credit creativity. Perceptions of the workplace were tested because, based on attribution theory, these interpretations of the environment can be related to workplace behavior (Ivancevich, Konopaske, & Matteson, 2005). This preliminary study explored the significance of the physical environment in relation to creative work by asking the following research questions:

1. How does the emerging work generation describe a creative workplace?
2. What physical environment attributes do they identify in actual workplaces recognized for their creativity? How do they rank the workplaces' creative potential and why?

3. How do they perceive the physical environment in relation to creative work?

Methods

Undergraduate and graduate students in an introductory level course focused on creative problem solving voluntarily participated in a survey on understanding the emerging work generation's perception of the creative workplace. Students taking this course varied in age, expected graduation year, and majoring disciplines. The online survey was distributed to 100 students as a precursor to a special lecture on design and creativity; 86 responded and 68 completed the entire survey, but three were excluded due to a significant amount of data missing. Analysis of 65 participants (gender and age were not reported) were included in the final data analysis. The survey was developed from literature on the creative workplace (e.g. Ekvall, 1999; McCoy & Evans, 2002), and was designed into the following three sections according to the research questions posed (Appendix A).

Characteristics of a Creative Workplace

The first section asked participants to identify descriptors of a creative workplace using an adjective checklist containing 60 items and a 7-point semantic differential scale with 28 items. The descriptors used in this section were derived from synonyms and antonyms of adjectives used in literature to describe a creative workplace. The adjective checklist asked participants to select adjectives that described what they thought a creative workplace was and the semantic differential scale asked for participants to answer to what extent each word pair described what a creative workplace should be. The use of a semantic differential scale enabled individuals to convey their subjective thoughts in regards to the meaning of the construct (in this case, the creative workplace environment), instead of their assessment of how much they believe in it (Robson, 1993). The scales used depicted the three factors that explain the creative workplace—

social, cognitive, and perceptual—derived from creativity models that discuss the environment (e.g. Woodman et al., 1993; Ekvall, 1996; Davis, 2004), ambient environmental factors (Gifford, 2007), and applicable design elements and principles (Pile, 2002). The social factor of the creative environment relates to how people interact with others in producing creative products and how an environment that encourages social interaction supports team creativity; the cognitive factor perceives the environment to be a tool for the creative cognitive process; and the perceptual factor is based on the idea that creativity is enhanced when the individual perceives the environment and has an emotional response to it. The perceptual factors are most likely to be directly related to physical attributes of the environment.

Perception of Creative Individual and Collaborative Workspaces

Three photographs of individual workspaces and three photographs of collaborative workspaces were reviewed separately in order to identify physical environment attributes perceived to contribute to the creativeness of the space. The following questions were asked: 1) rank order a series of three photographs according to how creative you perceive the workplace to be; 2) write three adjectives that describes the workplace; 3) rate the creativity of the space on a scale of 1 (low creativity) to 9 (high creativity); 4) check a list of physical attributes (McCoy & Evans, 2002) that support the creativity of the workplace for the photograph ranked as highest and verbally describe the specific characteristics of it; 5) check the same list of physical attributes that hindered the creativity of the workplace for the photograph ranked as lowest and verbally describe the specific characteristics of it. These photographs were of actual workplaces from organizations recognized for their creativity and were chosen to represent a variety of work environments. The checklists were then followed by a written response for three specific elements in the image that supported (or hindered) the creativity of the workplace.

Attitudes towards Creative Work

The final section of the survey consisted of six agreement statements on the importance of the physical environment for creative performance that were assessed on a 5-point Likert scale. The statements included in this section were on how creative the participant perceived himself or herself to be (i.e. *I am a creative person*), characteristics of the participant in relation to creative work (i.e. *I like to do creative work; I can be creative in any place; My surroundings do not have an impact on my creative behavior*), and perceptions on the relationship between the physical environment and creative work (i.e. *The workplace can foster creativity; Not all workplaces are creative*). These questions were asked to better understand the emerging generation's perception on creativity in general.

Data Analysis

Multivariate statistical software (SPSS v.21) was used to obtain frequencies and descriptive statistics and conduct Friedman tests on the rank data of the individual workspace photographs and the collaborative workspace photographs. A one-way analysis of variance (ANOVA) with repeated measures was conducted to report differences in creativity ratings among the three photos for individual workspaces and three photos for collaborative workspaces.

Results

Adjective Checklist

The ten most frequently identified descriptors and the percentage of participants that checked each of these descriptors for the creative workplace were: active (81.54%), open-minded (81.54%), flexible (80.00%), changeable (70.77%), adaptable (69.23%), lively (69.23%), self-expressive (67.69%), adventurous (63.08%), transformable (61.54%), and versatile (63%). The ten least frequently identified descriptors were: conservative (1.54%), conventional (1.54%),

ordinary (1.54%), predictable (1.54%), slow-paced (1.54%), unchanging (1.54%), cautious (3.08%), inhibited (3.08%), secluded (4.62%), and strenuous (6.15%).

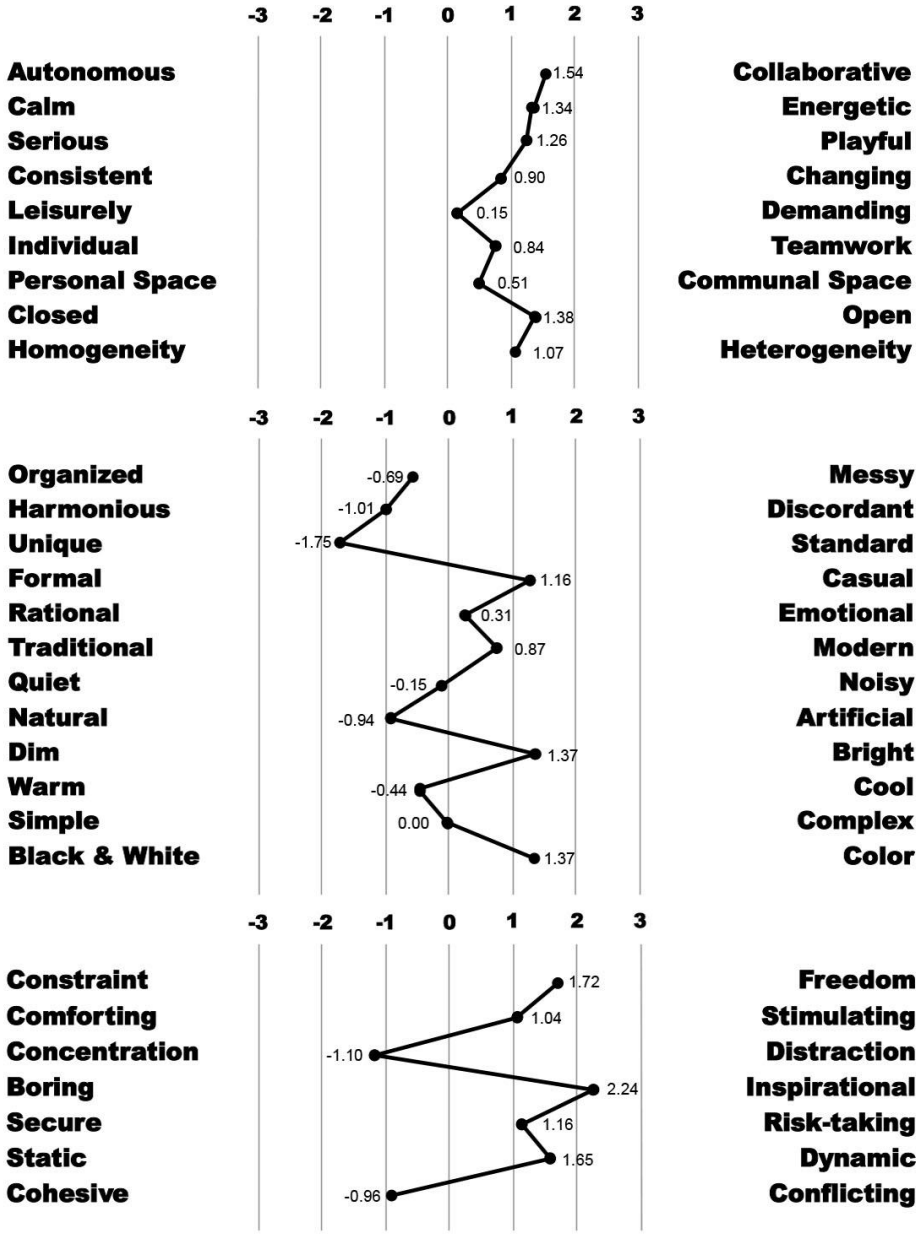


Figure 5.1. Semantic differential scale results for describing the creative workplace

Semantic Differential Scale

Results for the semantic differential can be seen in Figure 5.1. *Inspirational* (opposed to *Boring*), *Unique* (opposed to *Standard*), *Freedom* (opposed to *Constraint*), *Dynamic* (opposed to

Static), and *Collaborative* (opposed to *Autonomous*) had the highest ratings. *Open* (opposed to *Closed*), *Bright* (opposed to *Dim*), *Color* (opposed to *Black and White*), *Energetic* (opposed to *Calm*), *Playful* (opposed to *Serious*), and *Casual* (opposed to *Formal*) also had high ratings. Item pairs that were neutral were: *Simple – Complex, Leisurely – Demanding, Quiet – Noisy, Rational – Emotional, Warm – Cool,* and *Personal Space – Communal Space.*

Photo Survey of Individual Workspaces

Figure 5.2. Individual workspaces in the order of high to low creativity ratings (left to right)

The creativity ratings for each of the individual workspace photos (Figure 5.2) showed that photo A was rated highest with a score of 6.10 (*SD* = 2.02), photo B was rated 5.69 (*SD* = 1.89), and photo C was rated 2.79 (*SD* = 1.86). A repeated measures ANOVA found that creativity ratings were significantly different among the three individual workspace photos ($F(2, 98) = 35.07$, $p < .001$). Bonferroni post-hoc tests indicated that the creativity rating for photo C (2.78 ± 0.28) was significantly lower than that of photo A (5.94 ± 0.30, $p < .001$) and photo B (5.58 ± 0.28, $p < .001$); however, there was no significant difference between photo A and B ($p = 1.000$). The Friedman test indicated a statistically significant difference in ranking the photos according to perceived creativeness, $\chi^2(2) = 48.86$, $p < .001$. Post-hoc analysis with Wilcoxon signed-rank tests with a Bonferroni correction applied was conducted resulting in a significant level set at $p = .017$. There was a statistically significant difference in ranking between the photo A and C ($Z = -5.24$, $p < .001$), and between photo B and C ($Z = -5.40$, $p < .001$), but not between

photo A and B ($Z = -0.21$, $p = .83$). Photo A was ranked first by 28 participants, second by 31, and third by 6 according to how creative the workplace was perceived to be, whereas, photo B was ranked first by 30 participants, second by 29, and third by 6.

A repeated measures ANOVA found that the agreement on the desire to go to the workspace to do creative work was significantly different among the three individual workspace photos ($F(2, 122) = 52.05$, $p < .001$). Bonferroni post-hoc tests indicated that participants desired to go to the workspace of photo A (3.55 ± 0.14) and photo B (3.76 ± 0.14) significantly more than the workspace of photo C (1.97 ± 0.14, $p < .001$) for creative work; however, there was no significant difference between photo A and B ($p = .800$).

For photo A, aesthetic interest (71% of respondents), furniture (71%), light quality (69%), materiality (68%), texture (66%), visual details (64%), quantity of light (56%), and color (54%) were frequently chosen as support attributes. In the qualitative response, participants thought this workspace to be visually interesting overall, had a warm atmosphere, and appreciated the use of natural materials. For photo B, quantity of light (88% of respondents), quality of light (78%), structural shape (63%), materiality (58%), and aesthetic interest (55%) were the most frequently selected attributes that were found to support the creativity of the workspace. Qualitative responses for specific supportive attributes were focused on the chalkboard, the size and the amount of space available, and the visual detail of the beams. For photo C, furniture arrangement (84% of respondents), furniture (69%), quality of light (69%), structural shape (69%), and [lack of] aesthetic interest (52%) were selected most frequently as hindering attributes. Participants that ranked photo C to be the least creative workplace described the layout, lack of work space, and homogenous design as attributes that hindered the creativity of the space.

Photo Survey of Collaborative Workspaces

The creativity ratings for each of the collaborative workspace photos (Figure 5.3) showed that photo A was rated highest with a score of 6.86 (*SD* = 1.71), photo B was rated 6.37 (*SD* = 2.25), and photo C was rated 4.92 (*SD* = 1.95). A repeated measures ANOVA found that creativity ratings were significantly different among the three collaborative workspace photos ($F(2,80) = 10.52$, $p < .001$). Bonferroni post-hoc tests indicated that the creativity rating for photo C (5.00 ± 0.29) was significantly lower than that of photo A (6.76 ± 0.27, $p < .001$) and photo B (6.39 ± 0.35, $p = .007$); however, there was no significant difference between photo A and B ($p = .996$). The Friedman test indicated a statistically significant difference in ranking the photos according to perceived creativeness, $\chi^2(2) = 30.62$, $p < .001$. Post-hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied resulting in a significant level set at $p < .017$. There was a statistically significant difference in ranking between photo A and C ($Z = -5.30$, $p < .001$), and between the photo B and C ($Z = -3.11$, $p < .001$). No significant difference was found between photo A and B ($Z = -2.34$, $p = .019$). Photo A was ranked first by 33 participants, second by 28, and third by 4 according to how creative the workplace was perceived to be, whereas, photo B was ranked first by 25 participants, second by 21, and third by 19.

Figure 5.3. Collaborative workspaces in the order of high to low creativity ratings (left to right)

A repeated measures ANOVA found that the agreement on the desire to go to the

workspace to do creative work was significantly different among the three individual workspace photos ($F(2, 118) = 52.05$, $p = .005$). Bonferroni post-hoc tests indicated that participants desired to go to the workspace of photo A (3.93 ± 0.14) significantly more than the workspace of photo B (3.40 ± 0.16, $p = .019$) and photo C (3.30 ± 0.13, $p = .015$) for creative work; however, there was no significant difference between photo B and C ($p = 1.000$).

For photo A, quality of light (88%), furniture (86%), quantity of light (73%), furniture arrangement (71%), aesthetic interest (53%), and materiality (51%) were the most frequently chosen physical environment attributes that supported creativity. The large whiteboard and the furniture (boat seating) were commented on the most when asked for specific attributes that supported the creativity of the workspace. For photo B, aesthetic interest (76% of respondents), texture (76%), materiality (64%), color (62%), structural shape (62%), and visual details (60%) were the most frequently selected physical environment attributes that supported the creativity of the workspace, and the unique ceiling design and the use of wood were top elements that were used to specify supportive attributes. Conversely, about half of the respondents selected furniture arrangement (53%) and structural shape (50%) as hindering attributes, explaining that the restrictive layout and the clutter of the ceiling were elements that hindered the creativity of the workspace. For photo C, quality of light (62% of respondents), furniture arrangement (55%), and color (51%) were most frequently selected as physical environment attributes that hindered the creativity of the space. More specifically, the lack of color and aesthetic interest, and the lack of light (natural and in general) were commented on the most.

Characteristics of the Emerging Work Generation in relation to Creativity

Creativity was sought to be important in general and in relation to future work (Table 5.1). The workplace was also considered important as participants agreed that the workplace can

foster creativity and they did not agree that they could be creative in any place.

Table 5.1. Mean Scores and Standard Deviations for Attitudes towards Creativity

	M (*SD*)		M (*SD*)
Creative Person	3.89 (0.90)	Workplace Fosters Creativity	4.45 (0.56)
Like Creative Work	4.34 (0.82)	Not all Workplaces are Creative	4.37 (0.60)
Creativity is Important	4.38 (0.77)	No Impact from Surroundings	1.82 (0.73)
Creative work in Future	4.49 (0.69)	Creative in Any Place	2.78 (0.98)
Creativity impacts Job Decision	4.06 (0.80)		

Discussion

Perception Reflects Characteristics of the Emerging Work Generation

The results of this study indicate that the perception of the environment reflects characteristics of the emerging work generation. For example, *freedom* was one of the top characteristics of a creative workplace identified by the semantic differential scale, and at the same time is one of the main characteristics that describes the emerging work generation as they prefer freedom in everything they do (Tapscott, 2009). This may include the freedom to self-express through the environment or the freedom to change their surroundings according to their needs. *Self-expressive* and *changeable* were also adjectives among the top 10 most identified in the adjective checklist. Similarly, the adjectives *flexible*, *adaptable*, and *versatile* can also support this generation's need for freedom. Prensky (2009) explains this need through the neuroplasticity, or the brain's characteristic for constant reorganization, of the generation.

This generation is also perceived as the collaboration and relationship generation (Tapscott, 2009), and thus, the majority of this study's participants identified adjectives that describe just that: *collaborative*. Their preference for a *lively* and *energetic* workplace also reflects this. Even in the individual workspace photos, a good number of qualitative responses were on collaborative opportunities in which the workspace could offer. For example, when

describing the chalkboard, or whiteboard, as a physical environment attribute that supported the creativeness of the space, participants had commented on how it could be used to "share ideas" and "communicate with others." In addition, when workspaces were commented on its size, space, or layout (i.e. furniture arrangement), they oftentimes were on whether it could accommodate collaboration. However, neutral items from the semantic differential scale (i.e. *quiet – noisy* and *personal space – communal space*) suggest a balance between individual and collaborative space. The creative process requires both individual and team efforts, and therefore, workplaces should provide spaces that can accommodate one or the other, in which users have access to both (Haner, 2005).

Results also verify that this generation mostly appeals to the visual senses. True to the qualities of being visual learners, the most commonly checked physical environment attributes in this study were aesthetic interest, light, and color. However, this may be a result of using photo images rather than actual workplace settings. In spite of methodological limitations, these visual attributes can represent the first impression of the workplace. As a generation that seeks a collaborative, positive and creative work culture, the first impression of the workplace may provide a glimpse of what the work culture may be in the organization. Through narrative inquiry, Danko (2000) found that workplace design may impact recruitment, retention, and corporate competitiveness. Designing a workplace that is perceived to be creative may be the first step in creating a creative work culture that attracts this emerging work generation and motivates them further in doing creative work.

Differences in Perception

The ranking of images according to their creativeness reflected differences in individual perceptions, and even perhaps in individual preferences. For individual workspaces, in particular,

the first and second ranked workspaces were very close, and the creativity ratings for the workplace environments were also similar. This may be due to similar environmental qualities among the first and second-ranked workspaces, yet some differences in style. In the case of the individual workspace that was rated as the least creative workspace, the environmental qualities may have differed from the other two workspaces; however, there were still a number of participants that had ranked it as what they perceived to be the most creative workspace. Individual perceptions, or preferences, in environments can vary; however, the comments on the physical environment attributes were quite consistent. For example, for the individual workspace that was rated with the lowest score, participants that ranked it as the least creative workspace thought the uniformity of the space and furniture arrangement was homogeneous and boring. They also thought the use of color was not visually appealing. On the other hand, participants that ranked the same space as the most creative workplace thought the furniture arrangement was supportive for work and that the use of color helped make the space to be creative. One explanation for this difference may be from the diversity of disciplines among the participants. Different disciplines or fields have different definitions and perceptions of creativity and this may reflect how they perceive the creativeness of the physical workplace as well. In addition, different fields may require different physical environment attributes that support their [creative] work.

Physical Environment Attributes for Future Studies

The results of this exploratory study suggest the importance of lighting among the many attributes of the physical environment. Quantity and quality of light were selected as attributes perceived to support or hinder the creativity in the workspaces reviewed. Lighting is a design attribute that can create different impressions of the physical environment (e.g. Flynn et al.,

1973). Among the various attributes of the physical environment, lighting plays an essential role in the design of built environments as the many characteristics of lighting (e.g., illuminance/luminance levels, color temperature, chromaticity, etc.) can be manipulated to create different impressions within a space and support or inhibit visual and cognitive performance. The literature reviewed on the physical environment attributes related to creative performance indicates only a few studies that examined lighting effects on creative performance. The lack of studies on the relationship between lighting and creative performance to date, and the importance lighting has on one's perception of the physical environment suggest that lighting is a significant physical attribute that needs to be further investigated to define its role in supporting (or hindering) the physical workplace environment for creative performance.

In this thesis, several experiments are proposed to test the effects of lighting on creative performance and investigate how this impact may be made (i.e. mediating processes). Based on this preliminary study discovering both light quantity and light quality as significant physical environment attributes identified to contribute to the creativity of a workplace, this thesis looks at various lighting characteristics such as, illuminance levels, task luminance, and color (both color temperature and spectrum). Lighting affords the spatial impression of privacy, among others (Flynn et al., 1973), and is a physical environment attribute that can oftentimes be controlled personally in the work environment. In addition to having the potential to influence how we perceive a space, lighting has been found to impact mood, both pleasure and arousal (e.g. Baron et al., 1992), and therefore, both environmental perceptions and mood are hypothesized to be the mediating processes explaining the relationship between lighting and creativity (Figure 5.4).

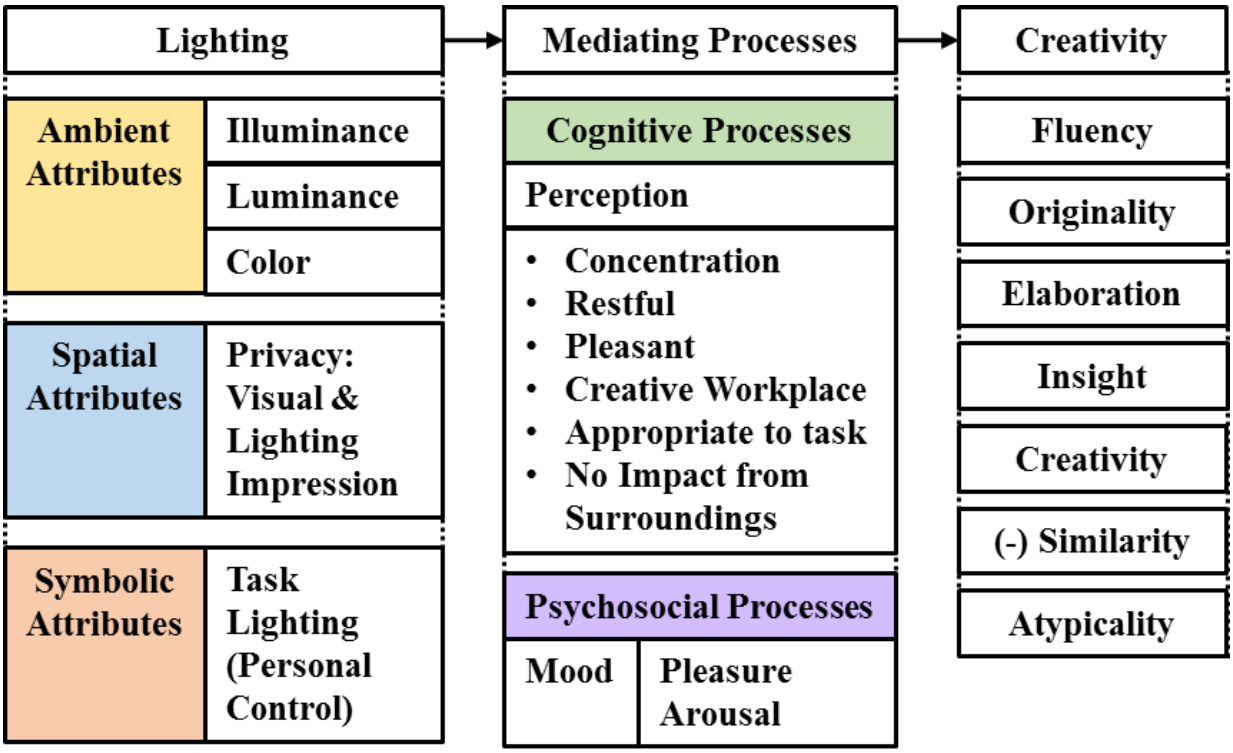


Figure 5.4. Research model for thesis

CHAPTER 6
EXPERIMENT 1: EFFECTS OF ILLUMINANCE LEVELS ON CREATIVE PERFORMANCE

Introduction

A fundamental characteristic of lighting is the illuminance level. The manipulation of illuminance level alone can dramatically change the impressions of a space and the user's emotional response to it (i.e. mood)—improved mood was found in high illuminance levels than in low illuminance levels (e.g. Daurat et al., 1993; Hendrick et al., 1977). Arousal theory also proposes an inverted-U function in which low or high illuminances decrease arousal, but optimal illuminance increases arousal and increased arousal in turn leads to better task performance (Veitch, 2001). Teams generated more creative ideas for a simple association task in a high arousal environment designed with bright lighting (de Korte, Kuijt, & van der Kleij, 2011); however, illuminance levels were not specified and it is unknown whether this was at the optimal illuminance level for increased arousal or whether other physical attributes used to invoke arousal could have been responsible for the effect on creative performance. The effect of lighting alone on mood and creative performance has not been thoroughly investigated. Unrelated to mood, Steidle and Werth (2013) found dim illuminance (150 lx) to be more conducive to creative performance on solving problems with insight and in a structural imagination drawing task than bright illuminance (1500 lx), which conflicts with predictions from arousal theory. Their results indicated that freedom from constraints mediated the relationship between illuminance levels and creative performance.

Objectives & Hypotheses

The purpose of experiment 1 was to further investigate the relationship between lighting and creative performance by examining the effects of illuminance level on creative performance

with environmental perception and mood as the mediating processes explaining the relationship (Figure 6.1). It was hypothesized that illuminance levels will be positively correlated with environmental perceptions, mood (pleasure and arousal), and creative performance. High illuminance will be associated with improved pleasure and arousal than low illuminance, and improved pleasure and arousal in turn will lead to better creative performance scores.

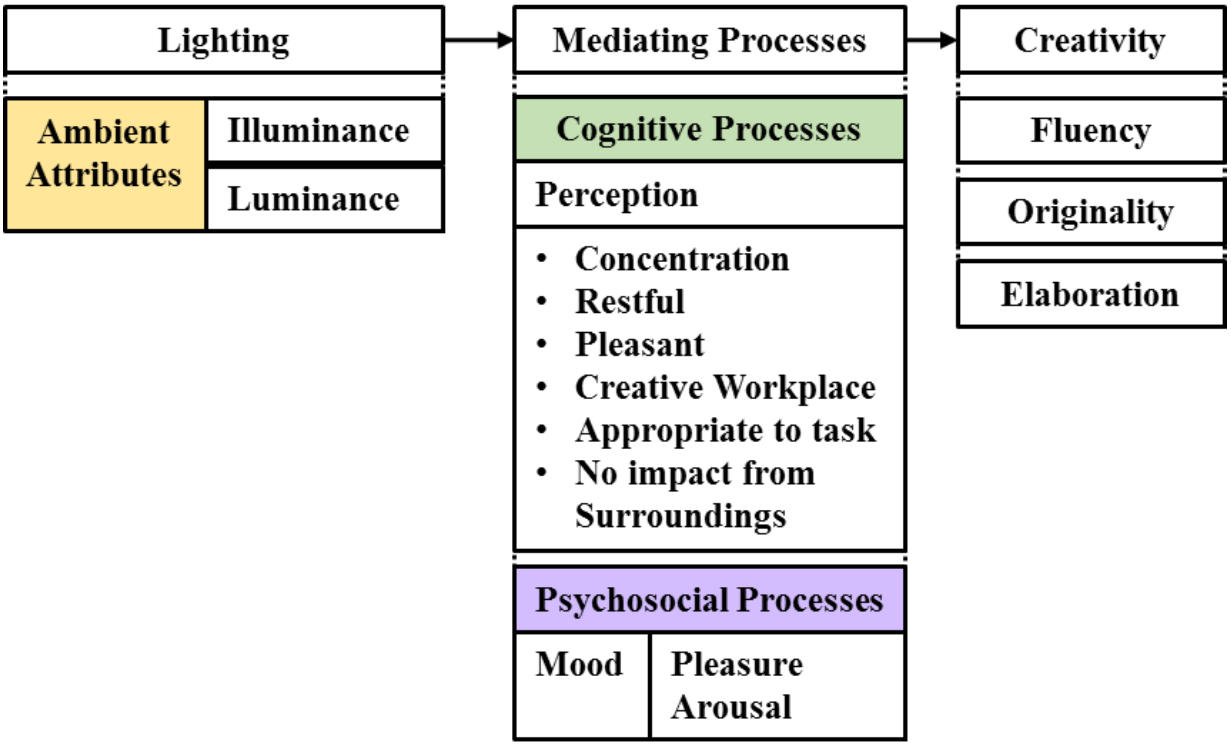


Figure 6.1. Research model for experiment 1

Methods

Design

This experiment compared two lighting conditions that differed only in their illuminance level. Forty-eight undergraduate and graduate students (6 males and 42 females) were recruited from classes related to the fields of ergonomics, environmental psychology and interior design, and participants received extra credit as applicable. Participants' ages ranged from 18 to 28 years with a mean age of 20.60 (*SD* = 2.43) and they were randomly assigned to the experimental

conditions.

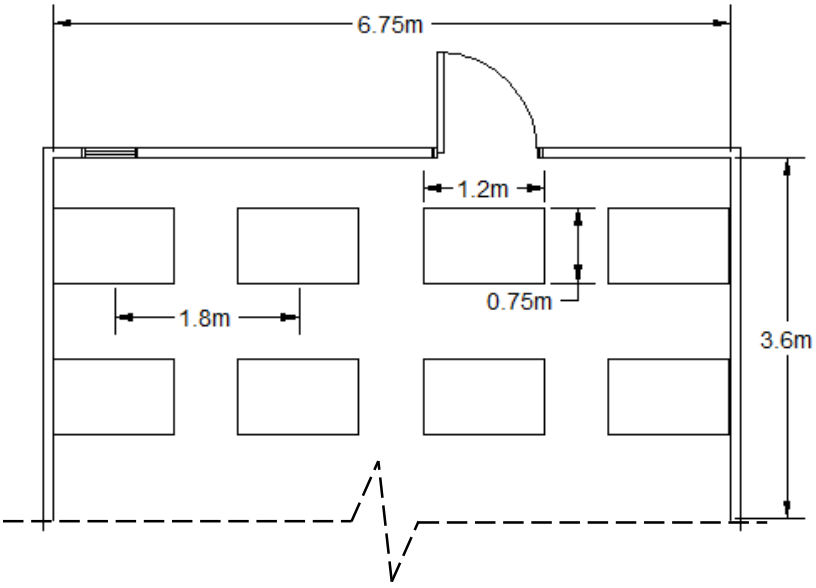


Figure 6.2. Experiment room layout

Setting

The experiment was conducted in the Human Factors and Ergonomics Laboratory climate chamber at Cornell University with all test conditions held constant at 22˚C, 50% RH, and air velocity of 0.24m/s. The space was 6.75m × 3.6m with a ceiling height of 2.4m. Eight identical tables (Fixtures Furniture Roam with 0.9m^2 surface area, 0.74m table height, height adjustable legs, and casters) and chairs (Blu Dot Chair Chair with 0.48m seat height) were arranged in two rows and were spaced uniformly (Figure 6.2). General lighting consisted of recessed ceiling luminaires containing three linear fluorescent tubes (F32T8 with color temperature of 3500K and a CRI of 75) with an acrylic diffuser. Each row of four recessed ceiling luminaires was controlled separately (Lutron GRX-4504) and was dimmable from 0% to 100%. Lighting was adjusted to 15% for low illuminance and 100% for high illuminance 30 minutes prior to the experiment to secure full brightness of the bulbs. Illuminance was measured using a light meter (TES-1336A) and task work surface luminance with a photometer (Cal-spot

400) aimed at a consistent point of the informed consent paper form placed at the center of each table surface for each lighting condition.

Measures and Task Instruments

Creative performance. Creative performance was measured using the Torrance Test of Creativity Thinking Figural Form A, Activity 3 (TTCT; Torrance, 1974). This measure is widely used in testing creativity (Davis, 1997; Lissitz & Willhoft, 1985) and the figural form overcomes language constraints. Participants were asked to draw as many objects or pictures from pairs of straight lines given in the booklet. Participants were encouraged to try and think of things that no one else would (i.e. originality), to make as many different figures as possible (i.e. fluency), and to make them complete (i.e. elaboration). Based on the solutions, the researcher scored fluency by counting the number of ideas, originality by adding the number of ideas that other participants had not generated and the ratings of originality for each picture on a scale of 0 to 2, and elaboration by rating each picture on a scale of 0 to 2 based on the amount of detail given to complete each idea and the name for the idea.

Mood. Mood was measured using the Semantic Differential Measures of Emotional State or Characteristic (Trait) Emotions (SDME; Mehrabian & Russell, 1974) pleasure and arousal factors. Both pleasure and arousal factors have six sub-dimensions: *Happy-Unhappy, Pleased-Annoyed, Satisfied-Unsatisfied, Contented-Melancholic, Hopeful-Despairing,* and *Relaxed-Bored* for Pleasure; *Stimulated-Relaxed, Excited-Calm, Frenzied-Sluggish, Jittery-Dull, Wide Awake-Sleepy,* and *Aroused-Unaroused* for Arousal. The order of scales was randomized and three dimensions for each factor were reversed for both the pre-task and post-task survey used. Numerical scales (+4 to -4) were used to score the sub-dimensions and the ratings for pleasure and arousal were calculated as the mean score of their respective sub-dimensions.

Individual characteristics. Creative personality was assessed using the Adjective Check List (ACL; Gough & Heilbrun, 1983), a standardized self-report instrument in which participants select adjectives that best describe their actual self from a list of 300 personality attributes to profile a wide range of human behaviors. As this study used a figural activity, the creativity scale (ACL-Cr) developed by Domino (1970) for design-based research was used. To see whether time-of-day would have an effect on the study results, the Morningness-Eveningness Questionnaire (MEQ; Horne & Östberg, 1976) was used to measure the sleep-wake patterns and preferences for various activities in work and rest. The results of this self-report classify individuals into five different types ranging from morning-type to evening-type, with neither-type as the neutral category. The Rating Scale for Mental Effort (RSME) was administered to assess how much mental effort was perceived in completing the creative performance task.

Environmental perception. A self-constructed environment survey consisted of a series of statements on the study environment (i.e. lighting, color, furniture arrangement, etc.) and the overall atmosphere. These 5-point Likert-type agreement statements were developed to survey participants' general perceptions of the environment which included those on lighting, other ambient attributes, task support, and additional attributes desired. This survey also included the section on attitudes towards creative work from the survey used in the preliminary study and demographic questions. The measures included in this study can be found in Appendix B.

Procedure

Data was collected during two sessions (spring and fall) which were conducted in late afternoon (3-5pm) over several weekends. Participants chose their seats upon entering the environment and were briefly introduced to the study and its procedure, which was also outlined in the informed consent form. Upon agreement, each survey was administered with brief oral

instructions that complemented the written instructions. Participants in each condition were given the paper-based measures in the order of: pre-task mood survey (SDME), Adjective Check List (ACL), Morningness-Eveningness Questionnaire (MEQ), creative performance measure (TTCT), rating scale for mental effort (RSME), environment survey, and post-task mood survey (SDME). Specific instructions were given prior to the creative performance task, as it was timed. Participants were in the environment for approximately 45 minutes in total. The research protocol was approved by the Institutional Review Board at Cornell University.

Data Analysis

All data analyses were conducted using multivariate statistical software (SPSS v.21). Independent samples t-test was used to compare variables between the two lighting conditions. Linear mixed models were used to compare the two lighting conditions on pleasure and arousal ratings across time (i.e. change from pre-task to post-task ratings). Pearson correlations across environmental perceptions, mood ratings, and creative performance measures were used to examine possible relationships among the variables.

Results

No differences in sample characteristics (i.e. age, gender, grade, morningness-eveningness type, and creative personality scores) were found between participants in the two lighting conditions. The manipulation of low and high illuminance levels was successful as they were significantly different from each other in illuminance ($t(46) = -21.28$, $p < .001$) and in luminance ($t(46) = -19.68$, $p < .001$). The average illuminance level for the low illuminance condition was 167.92 lx ($SD = 48.53$) and the high illuminance condition averaged to 2052.71 lx ($SD = 431.18$) (see Figure 6.3). The average task luminance for the low illuminance condition was 28.54 cd/m^2 ($SD = 7.33$) and the high illuminance condition averaged to 377.87 cd/m^2 ($SD =$

86.65). Participants' self-reported perception of lighting conditions also indicated that the low illuminance was indeed dim ($t(46) = 8.86$, $p < .001$) and the high illuminance was bright ($t(46) = -4.27$, $p < .001$). Participants in the low illuminance condition reported a higher desire for additional lighting than those in the high illuminance condition ($t(46) = 5.23$, $p < .001$). Participants in the high illuminance condition reported a higher desire to lower the light levels compared to those in the low illuminance condition ($t(46) = -2.42$, $p = .020$).

Figure 6.3. Low illuminance (left) and high illuminance (right) conditions

Illuminance and Environmental Perceptions

No differences in perceptions of the non-lighting specific physical environment attributes or overall perceptions of the study environment were found except for participants' in the low illuminance condition agreeing more strongly that the surroundings had no impact on them ($t(46) = 2.32$, $p = .025$).

Effects of Illuminance on Mood and Creative Performance

No differences in pre-task pleasure or arousal ratings were found between the two lighting conditions. Participants in the low illuminance condition (M = 0.25, SD = 1.24) had significantly higher post-task arousal ratings than those in the high illuminance condition (M = -0.59, SD = 1.33, $t(46) = 2.26$, p = .029). The linear mixed model indicated a significant interaction effect between lighting and time ($F(1, 46) = 7.50$, p = .009) in which arousal ratings decreased slightly over time in the high illuminance condition but increased in the low illuminance condition (Figure 6.4).

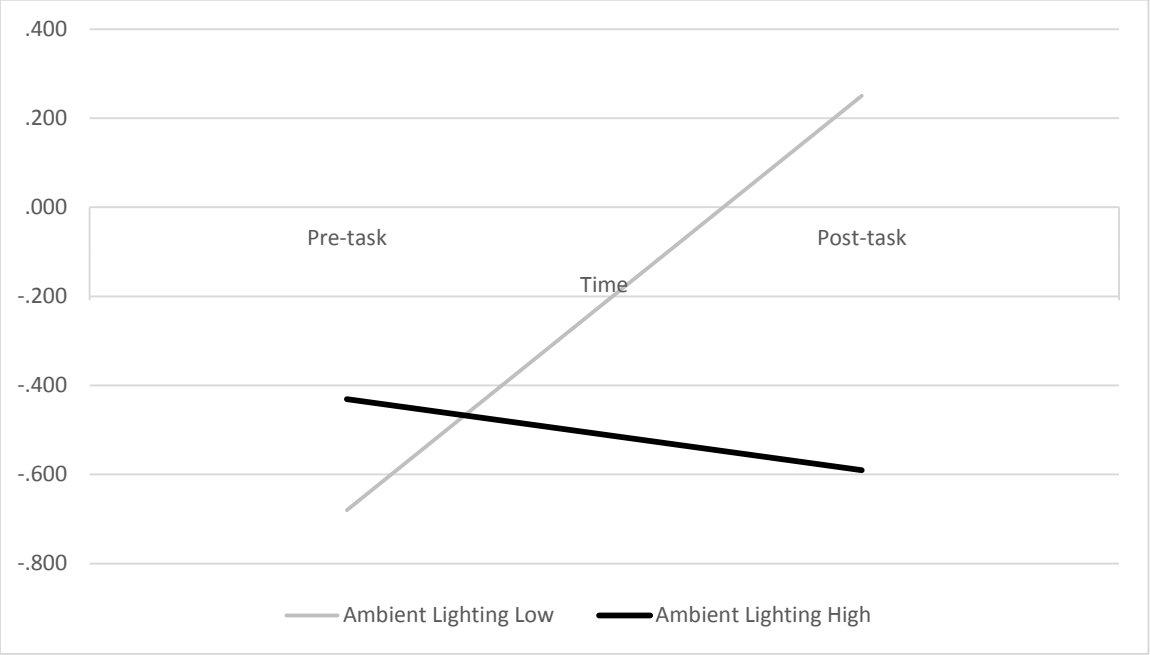


Figure 6.4. Interaction effect between illuminance level and time on arousal

Mean scores for creative performance scores on the TTCT test (i.e. fluency, originality, elaboration, and overall scores) were higher in the low illuminance condition than the high illuminance condition (Table 6.1); however, no significant differences were found.

Relationship among Environmental Perception, Mood, and Creative Performance

Pre-task arousal ratings were negatively correlated with perceiving the environment as

restful (r = -.361, p = .012) and pre-task pleasure ratings were positively correlated with perceiving the air quality to be good in the environment (r = .342, p = .017). Pleasure ratings at the end of the study period were correlated with perceiving the environment as restful (r = .396, p = .005).

Table 6.1. Mean Scores and Standard Deviations for Creativity Measures by Condition

	Creativity Measures			
Illuminance	Fluency	Originality	Elaboration	TTCT
Low	10.67 (5.35)	4.92 (3.37)	6.38 (3.87)	21.96 (9.85)
High	9.75 (4.64)	4.88 (3.29)	6.21 (3.73)	20.83 (8.81)

Relationship between Attitude towards Creative Work and Creative Performance

Significant correlations were found between originality scores and agreeing creativity was important (r = .306, p = .034) and originality scores and agreeing they could be creative in any place (r = .345, p = .016).

Discussion

Contrary to the research hypothesis, the findings for this experiment indicate that illuminance in the range tested does not have a direct effect on mood or creative performance; however, an interaction effect of illuminance and time showed increased arousal in the low illuminance condition, and participants in the low illuminance perceived their surroundings to not have an impact on them (see Figure 6.5 for summary of findings). Creative performance scores were found to be more closely tied to attitudes towards creativity rather than perceptions of the environment. Although fluency scores were significantly correlated with originality scores and originality scores were significantly correlated with elaboration scores, only originality scores were found to be related to creativity-related attitudes—agreement on the importance of creativity (r = .306, p = .034) and being creative in any place (r = .345, p = .016). Certain

environmental perceptions were associated with mood, but not creative performance.

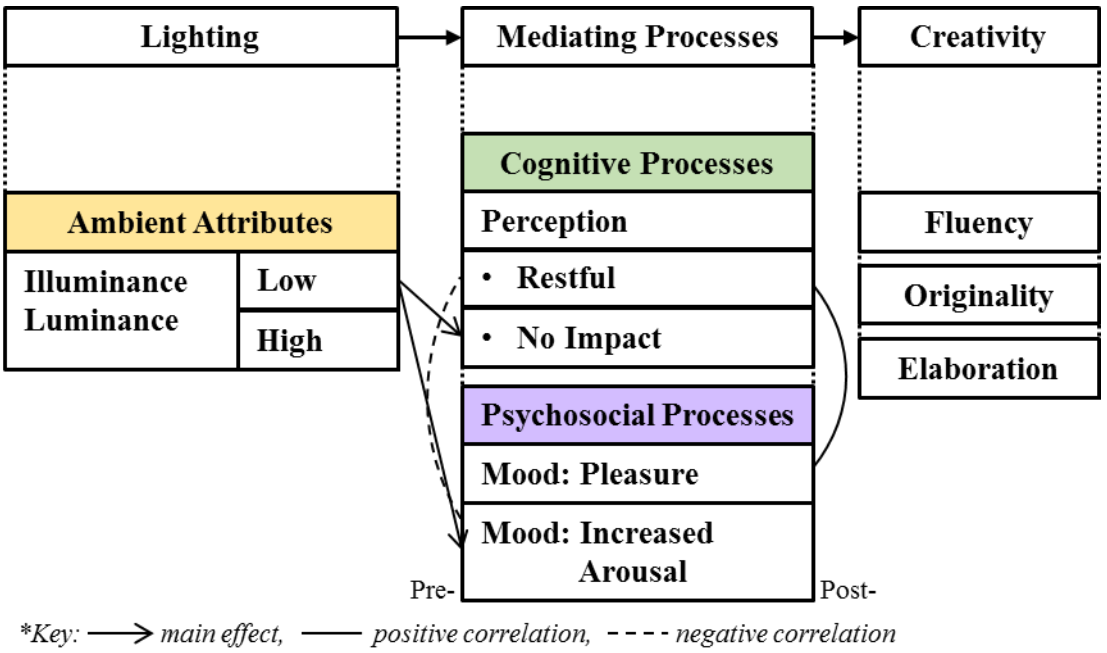


Figure 6.5. Summary diagram of experiment 1 results

The results did not confirm the findings of Steidle and Werth's (2013) study that dim illuminance enhances creativity. The present experiment's low illuminance condition (≈ 168 lx) and the high illuminance condition (≈ 2053 lx), although over 500 lx greater, was comparable with Steidle and Werth's (2013) low illuminance condition (150 lx) and high illuminance condition (1500 lx). The duration the participants were in the experimental condition before the creative performance task (12-15 min.) in the present experiment was also comparable to that of Steidle and Werth's (2013) study (15 min.). However, Steidle and Werth (2013) used computer tasks whereas the present experiment used paper tasks. Screen appearance improves when ambient illuminance is lowered and hence, the screen brightness coming from the computer screen in Steidle and Werth's (2013) study may have added to the illuminance and had an effect rather than the reported direct effect of horizontal illuminance. Although Steidle and Werth (2013) report vertical illuminance which measures the amount of light arriving at the eye, it does

not account for the light reflected from the surface. Conversely, task luminance measuring the light reflected from the paper used during the task was recorded in the present experiment. The task luminance in the low illuminance condition for the present experiment was about 7.5% of that in the high illuminance condition, whereas the vertical illuminance in the dim illuminance condition for Steidle and Werth's (2013) study was 9% of that in the bright illuminance condition. Despite the similarities, the illuminance effect on creative performance was not replicated in the present experiment.

Another difference was in the tasks used to measure creative performance. This study used the TTCT to acquire measures for different facets of creativity—fluency, originality, and elaboration—whereas, Steidle and Werth's (2013) study used the structured imagination task (i.e. drawing aliens) to measure overall creativity, similarity to earth creatures, and atypicality of features. Their measures seem to focus on originality, yet from several different viewpoints that are very specific in evaluation. Steidle and Werth's (2013) study also measured performance on creative insight problem-solving (verbal, spatial, mathematical). Insight problems have a single correct answer to them which is more related to convergent thinking than to divergent thinking which is associated with the TTCT. Although Steidle and Werth's (2013) study found that illuminance had an effect on creativity through originality in ideas and insightful problem solving, this may not generalize to other creativity measures.

Although this experiment failed to find a significant relationship between illuminance and creative performance, it did find that participants in the low illuminance condition reported increased arousal over time and that they perceived the environment to not have an impact on them. This perception of the physical environment's role to not have an impact on participants may be related to the mediating effect found in Steidle and Werth's (2013) study where they

proposed the perception of freedom from constraints as the underlying mechanism between illuminance and creativity, suggesting that dim illuminance affords this freedom from constraints which in turn allows for cognitive flexibility that results in creative outcomes. Perceived freedom from constraints could in turn be an extension of having no distractions from surrounding elements. Additionally, spatial impressions created by lighting that relate to perceived freedom from constraints are privacy and pleasantness. The use of non-uniform lighting to create spaces for privacy or pleasantness (Flynn, 1992) may be associated with perceptions related to freedom from constraints and in turn improve creative performance. To create an environment with non-uniform lighting while increasing task luminance, the next experiment uses the same background illuminance levels (low and high) as experiment 1 and adds the use of task lighting.

CHAPTER 7
EXPERIMENT 2: EFFECTS OF ILLUMINANCE LEVELS ON CREATIVE PERFORMANCE USING TASK LIGHTING

Introduction

Experiment 1 failed to confirm the results of Steidle and Werth's (2013) study that low illuminance improves creative performance. However, experiment 1 used paper tasks so when illuminance was low, the task luminance was also low, whereas Steidle and Werth (2013) used computer tasks, so when ambient illuminance was low, light emitted from the screen may have been brighter which could have had an effect. Experiment 2 proposes to use task lighting in combination with general lighting to increase task luminance, and also to create non-uniformity in lighting distribution. This non-uniformity has been associated with spatial impressions of privacy and pleasantness (Flynn et al., 1973; Flynn, 1992). Task lighting is also considered as an important physical element in workplaces as it provides additional light to needed visual tasks and has been found to conserve energy (McKennan & Parry, 1984). Task lighting also provides workers with personal control, or perceived control, over their work environment (Veitch & Gifford, 1996) which also improves environmental satisfaction (e.g. Newsham et al., 2009). Compound lighting, or the use of multiple light sources, has been found to be evaluated as more interesting and pleasant than general lighting alone (Ballantine, Jack, & Parsons, 2010; Summers & Hebert, 2001). People also preferred the combination of different lighting over the use of general lighting only (Flynn et al., 1973; Han, Ishida, Iguchi, & Iwai, 2006).

Experiment 1 showed that illuminance levels using general lighting did not affect creative performance (i.e. fluency, originality, and elaboration). The present experiment continues to investigate the effects of illuminance levels on mood and creative performance through lighting created by the combination of general and task lighting, which increases task luminance. The

experiment also investigated effects of this type of lighting on mood and environmental perceptions.

Objectives & Hypotheses

Experiment 2 tested the effects of task luminance and illuminance levels and non-uniform lighting on creative performance using task lighting, and proposed environmental perception and mood as the mediating processes explaining the relationship (Figure 7.1). From previous research, it was hypothesized that non-uniform dim lighting will be rated as more pleasant, and that low illuminance with task lighting will result in improved pleasure and arousal ratings than in high illuminance with task lighting. Additionally, the presence of task lighting allows for personal control and will affect environmental perceptions and mood. These environmental perceptions and mood will impact the effects of illuminance on creative performance.

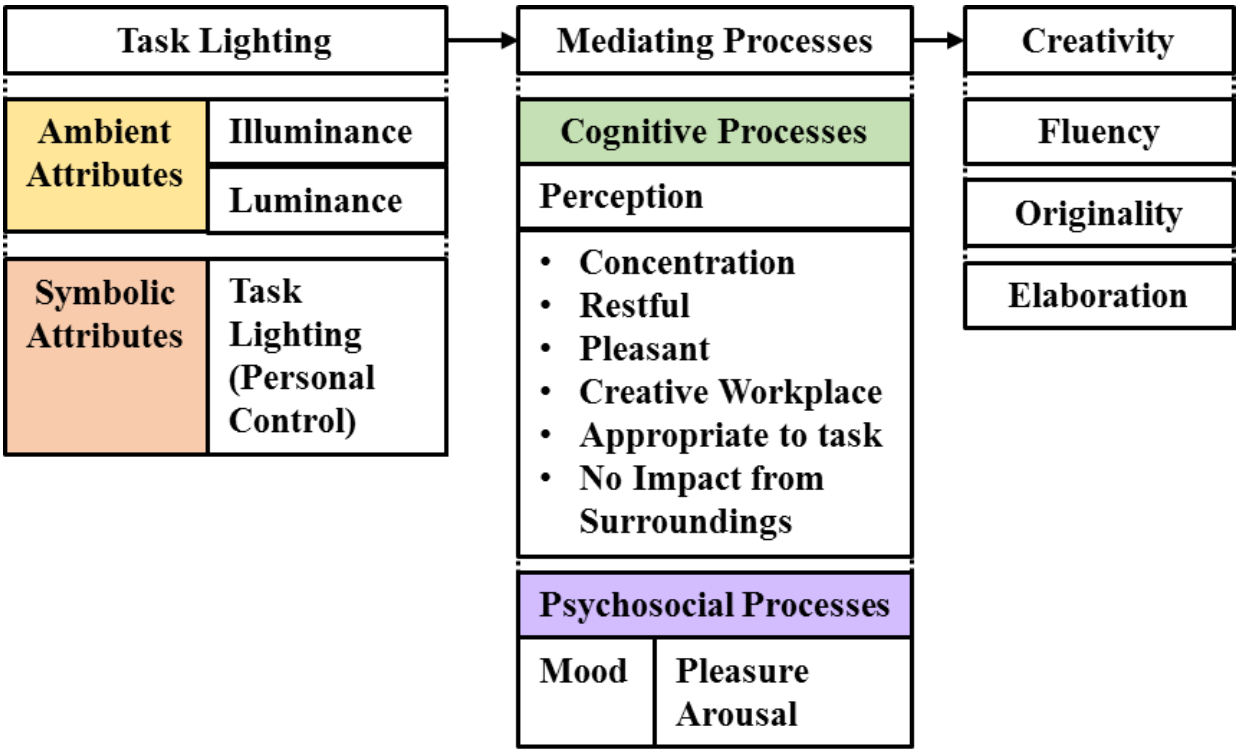


Figure 7.1. Research model for experiment 2

Methods

Design

This study used task lighting in conjunction with general lighting (low vs. high illuminance) to test the hypotheses. Forty-eight undergraduate and graduate students (17 males and 31 females) were recruited from classes related to the fields of ergonomics, environmental psychology and interior design, and participants received extra credit as applicable. Participants' ages ranged from 18 to 42 years with a mean age of 22.04 (*SD* = 4.69) were randomly assigned to the two experimental conditions.

Setting

The experiment was conducted in the same laboratory as experiment 1 with temperature, humidity, and air velocity held constant at 22˚C, 50% RH, and 0.24m/s. The layout of the space and the furnishings used were identical to experiment 1. The general lighting system and layout was also identical to experiment 1—general lighting was adjusted to 15% for low illuminance and 100% for high illuminance using the Lutron GRX-4504 dimmable system 30 minutes prior to the experiment to secure full brightness of the bulbs. A task light (Humanscale Element 790 lamp with a correlated color temperature of neutral white 3500K and a CRI of 85) was placed at the far left corner of each table and turned on 5 minutes prior to the experiment (Figure 7.2). Illuminance was measured using a light meter (TES-1336A) and task work surface luminance was measured with a photometer (Cal-spot 400) aimed at a consistent point of the informed consent paper form placed at the center of each table surface for each lighting condition.

Measures and Task Instruments

The measures used in this study are identical to those in experiment 1 (see Appendix B).

Procedure

The study procedure was also identical to that of experiment 1. Participants in each condition were given the paper-based measures in the order of: pre-task mood survey (SDME), Adjective Check List (ACL), Morningness-Eveningness Questionnaire (MEQ), creative performance measure (TTCT), rating scale for mental effort (RSME), environment survey, and post-task mood survey (SDME). Specific instructions were given prior to the creative performance task, as it was timed. Participants were in the environment for approximately 45 minutes in total. The research protocol was approved by the Institutional Review Board at Cornell University.

Figure 7.2. Low illuminance with task lighting (left) and high illuminance with task lighting (right)

Data Analysis

Data analyses from experiments 1 and 2 were concatenated and analyzed using multivariate statistical software (SPSS v.21).

Results

No differences in sample characteristics (i.e. age, gender, grade, morningness-eveningness type, and creative personality scores) were found among participants in the two lighting conditions. The manipulation of the two lighting conditions was successful as they were significantly different from each other in illuminance ($t(46) = -14.46$, $p < .001$) and in luminance ($t(46) = -21.33$, $p < .001$). The average illuminance level for the low illuminance task lighting condition averaged to 1532.55 lx (*SD* = 54.63) and the high illuminance task lighting condition averaged to 3435.67 lx (*SD* = 119.79). The average task luminance for the low illuminance condition was 174.95 cd/m^2 (*SD* = 12.23) and the high illuminance condition averaged to 551.53 cd/m^2 (*SD* = 84.64). Participants' self-reported perception of lighting conditions also indicated that the low illuminance was indeed dim ($t(46) = 4.25$, $p < .001$) and the high illuminance was bright ($t(46) = -3.14$, $p = .003$). Participants in the high illuminance condition reported a higher desire to lower the light levels than those in the low illuminance condition ($t(46) = -4.07$, $p < .001$).

Effects of Illuminance on Environmental Perceptions, Mood, and Creative Performance

No significant differences in perceptions of the specific physical environment attributes or overall perceptions of the experiment environment were found. No differences in pre-/post-task pleasure or arousal ratings were found between the two lighting conditions. The linear mixed model indicated no significant effects of time on pleasure and arousal ratings. Mean scores for creative performance scores on the TTCT test (i.e. fluency, originality, elaboration, and overall scores) were not significantly different between the high illuminance condition and the low illuminance condition (Table 7.1).

Table 7.1. Mean Scores and Standard Deviations for Creativity Measures by Condition

	Creativity Measures			
Illuminance	Fluency	Originality	Elaboration	TTCT
Low	9.13 (4.45)	4.38 (3.21)	5.13 (3.97)	18.63 (8.19)
High	10.42 (3.96)	4.88 (3.62)	5.83 (3.75)	21.13(9.12)

Relationship among Environmental Perception, Mood, and Creative Performance

Pre-task pleasure ratings were positively correlated with perceiving the environment as restful (r = .415, p = .003) and pleasant (r = .373, p = .009), and negatively correlated with perceiving the environment to be cold (r = -.338, p = .019). Post-task pleasure ratings were also correlated with perceiving the environment as restful (r = .370, p = .01) and pleasant (r = .544, p < .001), with the addition of perceiving the environment to have a positive affect (r = .363, p = .011) and to be appropriate for the task (r = .345, p = .016). Conducive layout (r = .330, p = .023) and comfortable chair (r = .322, p = .026) were also correlated with post-task pleasure ratings. Post-task arousal ratings were correlated with perceiving the environment as pleasant (r = .352, p = .014), having a positive affect (r = .441, p = .002), and being appropriate for the task (r = .312, p = .031).

Mood ratings and certain environmental perceptions were found to be correlated with different dimensions measured for creative performance. Both post-task pleasure ratings and post-task arousal ratings were correlated with elaboration scores (r = .273, p = .007 and r = .224, p = .028 respectively). Environmental perceptions of concentration were related to fluency scores (r = .415, p = .003) and overall TTCT scores (r = .307, p = .034). Perceiving no impact from surroundings were correlated with low originality scores (r = -.293, p = .044). A summary of these findings are illustrated in Figure 7.3.

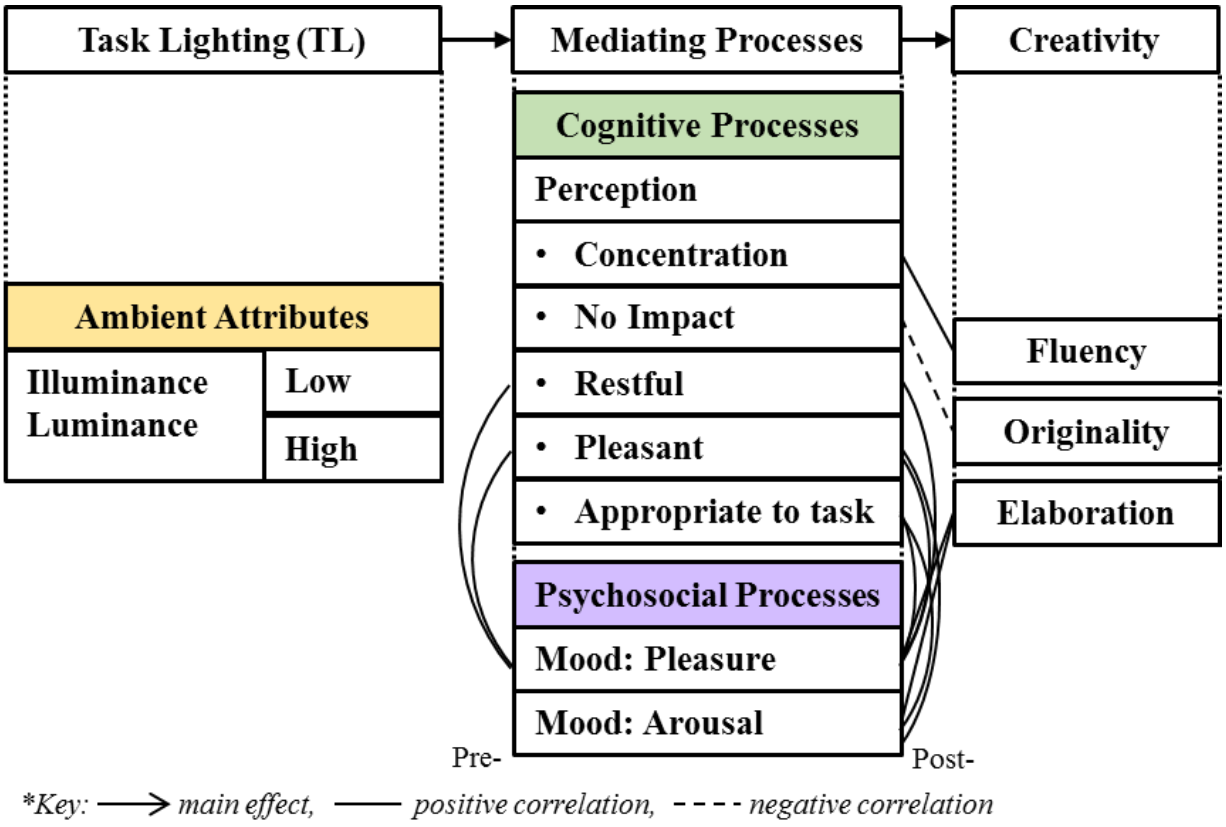


Figure 7.3. Summary diagram of experiment 2 results

Relationship between Attitude towards Creative Work and Creative Performance

Significant correlations were found between elaboration scores and liking creative work (r = .290, p = .046), and elaboration scores and agreeing they could be creative in any place (r = .304, p = .035). Those who agreed on being a creative person were significantly correlated with having higher originality (r = .290, p = .046), elaboration (r = .355, p = .013), and overall TTCT scores (r = .395, p = .005).

Comparison Analysis with Experiment 1: Effects of Task Lighting

In order to investigate whether task lighting has an effect on creative performance, data from experiment 1 was compiled with experiment 2. The measures and methods used in both studies are identical, with the exception of using task lighting in experiment 2. Linear mixed modeling was used to analyze the compiled data from the experiments as a 2 (low vs. high

illuminance) × 2 (with vs. without task lighting) between subjects design. No main effects of general illuminance or the use of task lighting were found on creative performance scores. There were main effects of task lighting on perceiving the environment as pleasant ($F(1, 92) = 5.724$, $p = .019$) and as a place for creative work ($F(1, 58) = 6.761$, $p = .012$) in which lighting conditions with task lighting were rated higher than those without task lighting. There was also a main effect of general illuminance on perceiving the surroundings to have no impact on the participants ($F(1, 79) = 6.416$, $p = .013$) in which ratings were higher in low illuminance conditions than in high illuminance conditions.

According to the mixed model with general lighting, task lighting, and time as fixed factors, there was a main effect of task lighting on pleasure ratings ($F(1, 182) = 9.829$, $p = .002$) in which participants in the experimental conditions with task lighting rated pleasure to be higher than those in experimental conditions without task lighting. More specifically, pleasure was rated highest in the low illuminance with task lighting condition and lowest in the low illuminance without task lighting condition. The low illuminance with task lighting condition had significantly higher pleasure ratings compared to the high and low illuminance conditions without task lighting. The linear mixed model also indicated an interaction effect between ambient lighting and time on arousal ratings ($F(1, 108) = 5.724$, $p = .013$). Conditions with general lighting set at a low illuminance had lower initial arousal ratings compared to high illuminance conditions however, arousal ratings increased over time in low illuminance and decreased over time in high illuminance.

Pre-task pleasure ratings were associated with perceptions of the environment being restful ($r = .290$, $p = .004$) and pleasant ($r = .330$, $p = .001$). Good air quality and not feeling cold were also related to pre-task pleasure ratings ($r = .234$, $p = .022$ and $r = .220$, $p = .031$

respectively). Post-task pleasure ratings were related to perceiving the environment as being restful (r = .380, p < .001), having a positive affect (r = .318, p = .002), being pleasant (r = .424, p < .001), being appropriate for the task (r = .211, p = .039), agreeing the chair to be comfortable (r = .317, p = .002), and being of good air quality (r = .219, p = .033). Pre-task arousal ratings were correlated with not being restful (r = -.313, p = .002) and not feeling cold (r = -.209, p = .041).

The perception of concentration correlated with fluency scores (r = .244, p = .016) and post-task pleasure ratings correlated with elaboration scores (r = .347, p = .001). Figure 7.4 summarizes these findings.

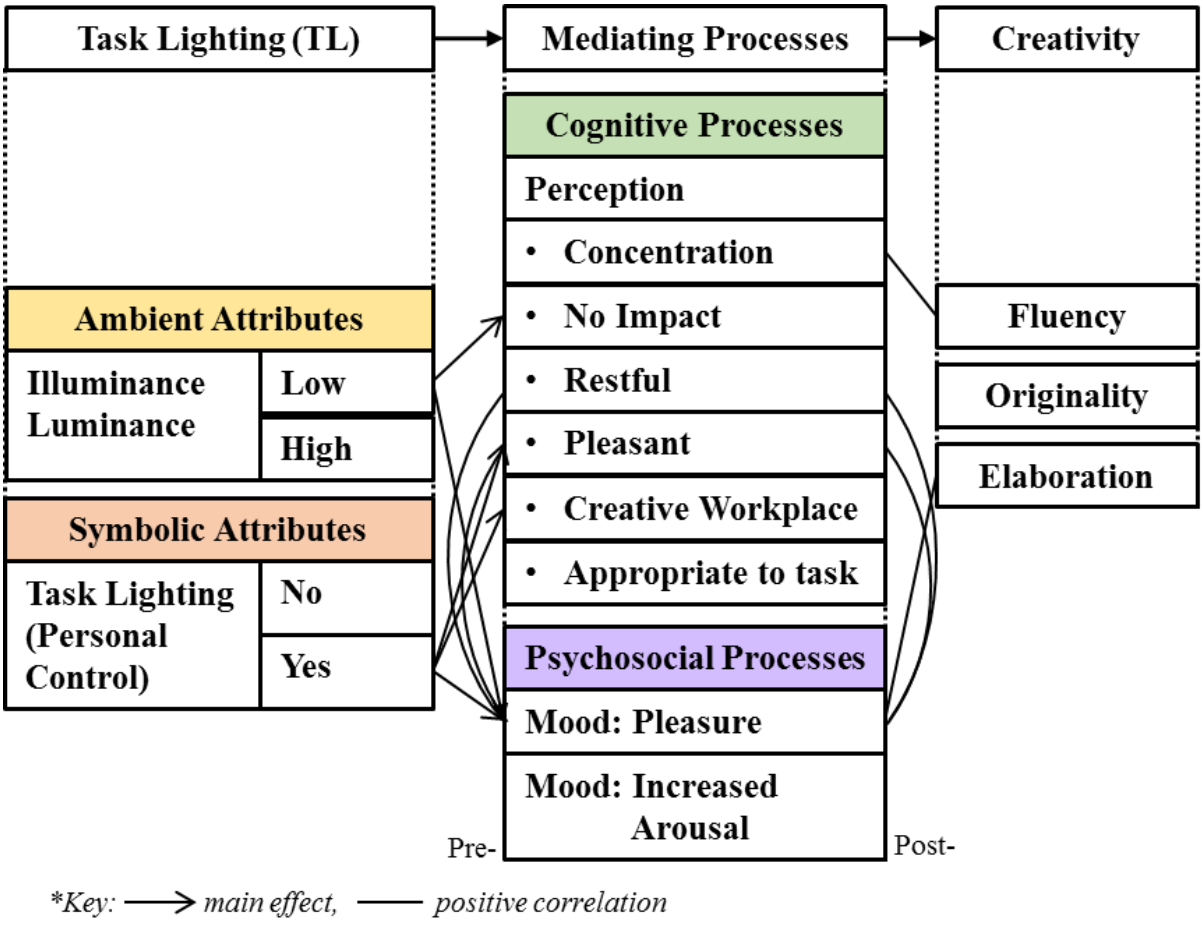


Figure 7.4. Summary diagram of data analysis from experiment 1 and 2

Discussion

The findings for this experiment confirmed that illuminance did not have an effect on mood or creative performance, even with the use of task lighting, again contrary to what was found in the Steidle and Werth's (2013) study. The task luminance increased the overall horizontal illuminance for both conditions (≈1533 lx for low illuminance and ≈3436 lx for high illuminance) and the task luminance in the low illuminance condition was 31.9% of that in the high illuminance condition. The horizontal illuminance was much higher than Steidle and Werth's (2013) study and the high illuminance levels may have hindered the processes towards creative performance suggested by the inverted-U function between illuminance and task performance (Veitch, 2001).

The present experiment did find that certain environmental perceptions were significantly correlated with pleasure and arousal ratings and with creative performance. Improved pleasure and arousal ratings recorded at the end of the study were related to high elaboration scores. Perceiving the study environment as a place for concentration was correlated with high fluency and overall TTCT scores. Having no impact from surroundings was related to low originality scores, which was contrary to what was expected from the discussion of experiment 1. Although low illuminance was not found to be related to perceiving no impact from surroundings in the present experiment, based on Steidle and Werth's (2013) findings that perceived freedom from constraints led to improved creative performance, originality scores were expected to improve when perceiving to have no impact from surroundings. Perceiving to be free from constraints and perceiving to have no impact from surroundings may be measuring different aspects of perception.

When combining data from experiment 1, post-task pleasure ratings were again

associated with high elaboration scores and the environmental perception on concentration with high fluency scores. This consistency suggests that, regardless of particular lighting settings, when people feel more pleasurable, they may invest more time and effort in elaborating more on the details of an idea and when the environment affords people with concentration, an uninterrupted flow of ideas may result.

Additionally, task lighting was found to have an effect on pleasure ratings measured over time. The low illuminance with task lighting condition was rated highest for pleasure and was visually the most distinctive among the lighting conditions. Although no inquiry was made to discern the affordances provided through low illuminance with task lighting, this setting is commonly seen in offices in which literature has explained to provide workers with perceived personal control and space (Veitch & Gifford, 1996). The microclimate set for the individual using task lighting to focus on the workstation rather than the surrounding environment may have stimulated the perception of concentration which in turn related to high fluency scores. In addition, the emotional response of pleasure in low general illuminance may have offered means to elaborate more.

Another explanation to why experiment 2 failed to confirm Steidle and Werth's (2013) findings may be that the effects were not from task luminance, but from other factors. Steidle and Werth (2013) suggested that the feeling of freedom from constraints was the mediating factor between illuminance and creativity and they proposed that dim illuminance suggested being free from constraints which allowed for cognitive flexibility for creative outcomes. Another way to frame freedom from constraints could be through privacy or having control over a space rather than perceiving it to be under external control. The study environment for Steidle and Werth's (2013) study shows each participant had their own workstation with a visual barrier between

participants and a layout similar to a study carrel which provides a greater sense of privacy. However, in experiments 1 and 2 the participants were in an open environment. It may have been that the privacy of the environment afforded the feeling of being free from constraints or privacy in combination with dim illuminance had this effect. In experiment 2, fluency was found to be correlated with perceiving the environment as a place for concentration which also could be related to the findings for Steidle and Werth's (2013) study. When the physical environment affords the individual their own environment where they can concentrate and be in their own world with no external constraints, then creativity can happen. However, since this was not found in the results for experiments 1 and 2, particular physical environment attributes that contribute to perceived concentration in the environment may be the key to this relationship. Low illuminance may just be a supportive attribute that combines with other physical environment attributes to create an effective impact on creative performance. The next experiment was conducted to investigate the effect of privacy created with visual barriers in combination of illuminance on creative performance.

CHAPTER 8
EXPERIMENT 3: EFFECTS OF ILLUMINANCE LEVELS ON CREATIVE PERFORMANCE IN SPACES WITH VISUAL PRIVACY

Introduction

Open-plan layouts in offices have reaped many benefits (e.g. collaboration and communication), however are criticized for the distractions in the environment and the lack of privacy. A solution proposed to address these issues in the workplace was to use cubicles which provided workers with personal space and visual privacy. Spatial impressions for privacy can also be enhanced through the use of dim lighting (Flynn, 1992). The previously investigated studies suggest that perceived concentration in the environment improves creative performance in fluency measured by the TTCT. Similarly, dim lighting was found to influence perceived freedom from constraints and result in higher creative performance in drawing creatures imagined to be encountered on another planet (i.e. structured imagination task) and in solving problems with insight (Steidle & Werth, 2013). Experiment 3 examines the intersection between spatial and ambient attributes, namely privacy screens and lighting, to see whether a workspace utilizing both attributes have effects on mood and creative performance.

Objectives & Hypotheses

Experiment 3 tested the effects of lighting and visual privacy on creative performance. The combination of lighting and visual privacy may affect environmental perceptions, pleasure and arousal ratings, and creative performance scores. Experiment 3 hypothesized that having visual privacy in low illuminance will enhance individuals' pleasure and arousal ratings and result in higher creative performance scores compared to having visual privacy in high illuminance (Figure 8.1). In addition, experiment 3 also added the insight problems task (Dow & Mayer, 2004) and the structural imagination task (Ward, 1994) used in Steidle and Werth's

(2013) study, in an attempt to replicate characteristics of their study and their results.

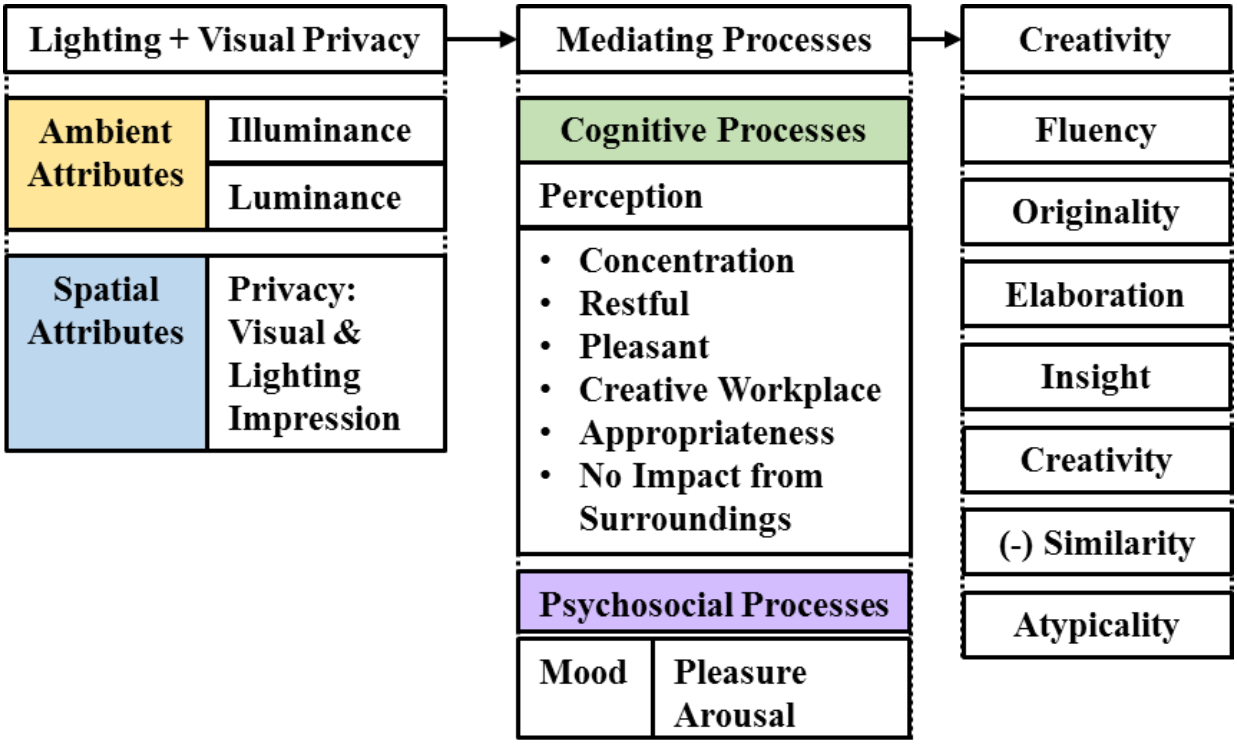


Figure 8.1. Research model for experiment 3

Methods

Design

Experiment 3 compared two lighting conditions (low vs. high illuminance) with workstations that had visual privacy to test the hypotheses. Forty-eight undergraduate and graduate students (13 males and 35 females) with a mean age of 20.54 (*SD* = 2.78) were recruited from a research participant pool and were compensated with ten dollars in cash. Participants were randomly assigned to the two experimental lighting conditions.

Setting

The setting was identical to experiments 1 and 2 with the exception that each workstation had a white cardboard screen surrounding the front and sides of the work surface (0.61m in height) to create visual privacy (Figure 8.2). The low and high illuminance conditions were set

using the same general illuminance levels as in experiment 1, which are comparable to those used by Steidle and Werth (2013).

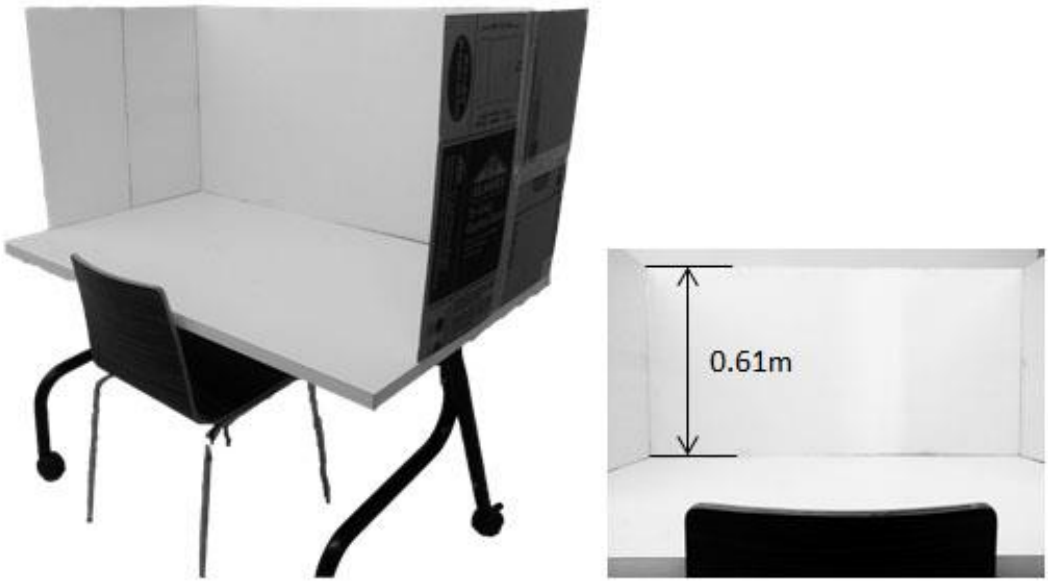


Figure 8.2. Workstation with privacy screen

Measures and Task Instruments

Mood, creative personality, and environmental perception were measured using identical instruments from experiments 1 and 2. In addition to the TTCT creative performance task used in the previous study, insight problems and the structural imagination task were used to measure creative performance. Participants were given two minutes to solve each of the four insight problems used in Steidle and Werth's (2013) study and they were scored according to the number of problems correctly solved. Two verbal ("window washer" and "doesn't want it"), a spatial ("the candle problem"), and a mathematical insight problem ("2 dollar bill") from the collection of insight problems by Dow and Mayer (2004) were used. Seven minutes were given for the structured imagination task was scored according to the method used in Maddux and Galinsky's study (2009) with measures of overall creativity, similarity to earth creatures, and atypicality of features. Overall creativity was measured on a scale of 1 (not creative at all) to 5

(extremely creative) and similarity to earth creatures were scored according to how similar the drawings were to existing earth creatures and the extent to how much earth creatures were considered with a scale from 1 (not at all) to 5 (very strongly). Atypicality of features was coded as a count variable which was scored by determining whether the creatures drawn were lacking sensory organs (1) or body features (1), had atypical numbers of sensory organs (1) or body features (1), had an uncommon configuration of these sensory organs (1) or body features (1), had an uncommon function of these sensory organs (1) or body features (1), or had an uncommon ability (1). Reliability was obtained from two independent coders (α = .76, .91, and .88 for the respective measures) and the average of the ratings were obtained for each participant's score (Maddux & Galinsky, 2009). The same insight problems and structured imagination task used in Steidle and Werth's study (2013) were included in this study in order to acquire a more precise comparison (see Appendix C for these measures).

Procedure

Data was collected during late afternoon (3-5pm) consistent with the time frame for experiment 2. Participants chose their seats upon entering the environment and were briefly introduced to the study and its procedure outlined in the informed consent form. Upon agreement, each survey was administered with brief instructions. Participants in each condition were given paper-based measures in the order of: pre-task mood survey (SDME), Adjective Check List (ACL), creative performance task (TTCT), two insight problems, the structured imagination task, two insight problems, environment survey, and post-task mood survey (SDME). Specific instructions were given prior to the creative performance tasks, as they were timed. Participants were in the environment for approximately 50 minutes in total. The research protocol was approved by the Institutional Review Board at Cornell University.

Data Analysis

All data analyses were conducted using multivariate statistical software (SPSS v.21) and were comparable to those of experiments 1 and 2.

Results

No differences in age, gender, academic level (i.e. grade), or creative personality (ACL-Cr) were found among the participants in the two lighting conditions. No significant correlations were found among creative personality, TTCT scores (i.e. fluency, originality, elaboration, and overall scores), insight problem solving scores, and structured imagination task scores (i.e. overall creativity, similarity to earth creatures, and atypicality of features).

The manipulation of the two lighting conditions was successful as they were significantly different from each other in illuminance ($t(46) = -28.64$, $p < .001$) and in luminance ($t(46) = -21.33$, $p < .001$). The average illuminance level for the low illuminance task lighting condition averaged to 173.42 lx ($SD = 49.57$) and the high illuminance task lighting condition averaged to 2103.42 lx ($SD = 326.42$). Participants' self-reported perception of lighting conditions also indicated that the low illuminance was indeed dim ($t(46) = 6.27$, $p < .001$) and the high illuminance was bright ($t(46) = -7.89$, $p < .001$). Participants in the high illuminance condition had a stronger desire to lower the light levels than those in the low illuminance condition ($t(46) = -5.21$, $p < .001$). Participants in the low illuminance condition had a stronger desire for additional lighting ($t(46) = 3.52$, $p = .001$).

Illuminance Effects on Environmental Perception, Mood, and Creative Performance

Significant differences between the two lighting conditions were found in perceiving the study environment with low illuminance as restful ($t(46) = 2.57$, $p = .014$) and as a place for concentration ($t(46) = 2.23$, $p = .031$). No significant differences were found between the two

lighting conditions in mood ratings or creative performance measures. No time effects were found for pleasure and arousal ratings. There were marginal significant differences between the two lighting conditions on originality scores, overall TTCT scores, and the number of insight problems solved. The high illuminance condition had higher mean scores for all TTCT measures and overall creativity and atypicality of features in the structured imagination task; however, the low illuminance condition had higher insight problem-solving scores and similarity to earth creatures in the structured imagination task (Table 8.1). Significant correlations were only found within measures of the TTCT and the structured imagination task, but not among all three creative performance tasks (Table 8.2).

Table 8.1. Mean Scores and Standard Deviations for Creativity Measures by Condition

	Creativity Measures			
	TTCT			
Illuminance	Fluency	Originality	Elaboration	TTCT
Low	8.67 (3.71)	4.88 (2.56)	3.25 (1.42)	16.79 (4.61)
High	9.29 (3.77)	6.54 (3.45)	4.50 (3.20)	20.33 (7.71)
	Creativity Measures (cont.)			
	Insight Problems	Structured Imagination Task		
Illuminance	Insight	Creativity	Similarity	Atypicality
Low	1.71 (0.81)	2.69 (1.00)	3.02 (1.37)	3.27 (1.37)
High	1.21 (0.98)	3.17 (0.94)	2.69 (1.29)	3.73 (1.33)

Table 8.2. Correlation Matrix for Illuminance and Creativity Measures

	Fluency	Orig.	Elab.	TTCT	Insight	Creativ.	Sim.
Originality	.440**						
Elaboration	-.156	.343*					
TTCT	.719**	.861**	.463**				
Insight	.090	-.100	-.121	-.044			
Creativity	.011	.172	.124	.137	.189		
Similarity	-.169	-.285*	.080	-.201	-.049	-.599**	
Atypicality	.070	.111	.099	.131	.205	.723**	-.571**

* $p < .05$

** $p < .01$

Relationship among Mood, Creative Performance, and Environmental Perception

Significant correlations were found between pre-/post-task pleasure ratings and

perceiving the experimental environment as being restful (r = .508, p < .001 and r = .449, p = .001 respectively), having a positive effect on performance (r = .448, p = .001 and r = .408, p = .004 respectively), being pleasant (r = .445, p = .002 and r = .593, p < .001 respectively), and being a place for concentration (r = .374, p = .009 and r = .372, p = .009 respectively). Pre-task pleasure ratings were also correlated with drawing creatures similar to those seen on earth and drawing less atypical features in the structured imagination task (r = .340, p = .018 and r = -.317, p = .028 respectively). Additionally, post-task pleasure ratings were correlated with perceiving the study environment as being appropriate for tasks (r = .432, p = .002). Pre-task arousal ratings were significantly correlated with perceiving the study environment as having a positive effect on performance (r = .292, p = .044). Post-task arousal ratings were correlated with elaboration scores (r = .351, p = .014).

Regardless of lighting condition, participants who agreed that the study environment was pleasant, had a positive effect on performance, and was appropriate for the task was significantly correlated with drawing creatures that were similar to those seen on earth in the structured imagination task (r = .378, p = .008; r = .343, p = .017; and r = .342, p = .017 respectively). Participants that did not perceive the environment to be pleasant had higher scores for overall creativity in the structured imagination task (r = -.309, p = .033). Participants who agreed the study environment was appropriate for the task and was a place for concentration correlated with insight problem solving scores (r = .363, p = .011 and r = .357, p = .013 respectively). High overall TTCT scores correlated with feeling cold in the study environment (r = .302, p = .037). Summary of findings are illustrated in Figure 8.3.

Comparison Analysis with Experiment 1: Effects of Visual Privacy

In order to further investigate whether visual privacy had an effect on creative

performance, the data from the low and high illuminance conditions using general overhead lighting from experiment 1 was compared with the data for experiment 3. Only TTCT scores were compared for creative performance as experiment 1 did not use the other creativity tasks. The combined data was considered as a 2×2 between subjects design with two lighting conditions (low vs. high illuminance) and two visual privacy conditions (with vs. without).

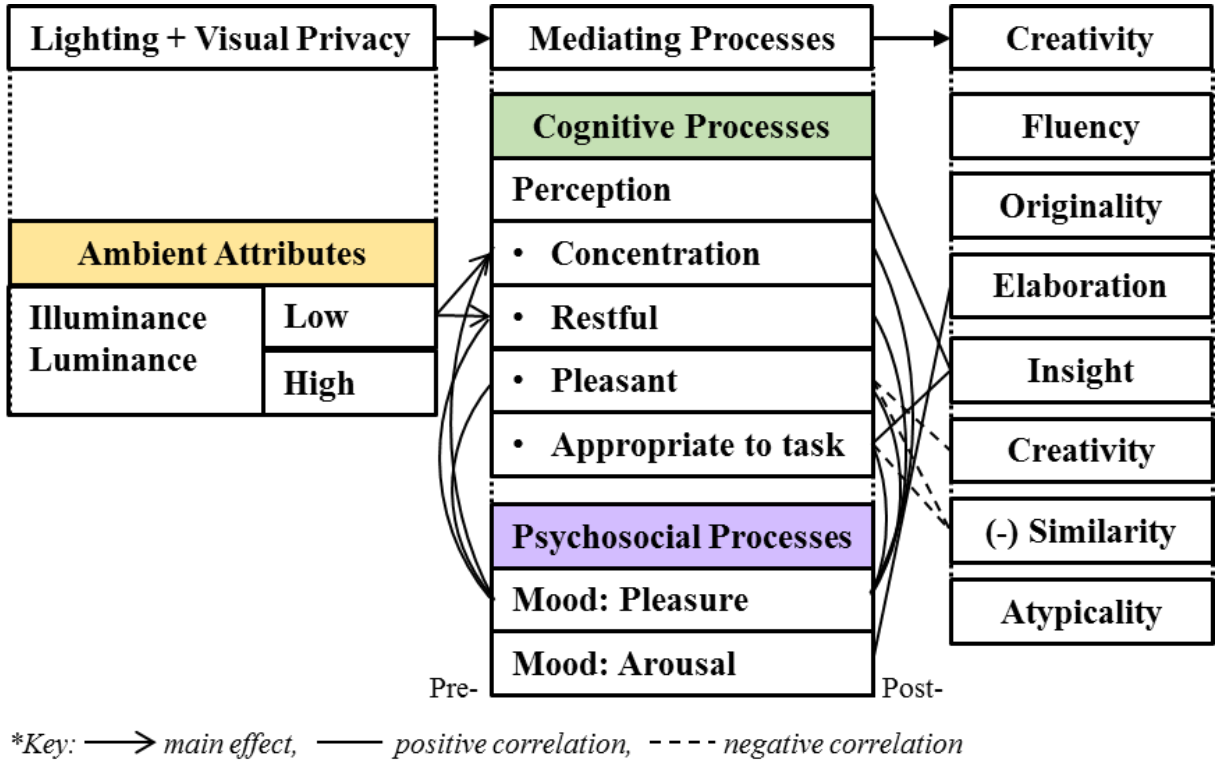


Figure 8.3. Summary diagram of experiment 3 results

There were no significant main effects of lighting and privacy on fluency, originality, or overall TTCT scores. There was a significant main effect of privacy on elaboration scores ($F(1, 92) = 13.63$, $p < .001$) in which participants without visual privacy ($M = 6.29$, $SD = 0.46$) had higher scores than those with visual privacy($M = 3.86$, $SD = 0.46$). No significant interaction effects of lighting and privacy were found for any of the creative performance scores.

There was a significant main effect of lighting on environmental perception of feeling more restful in the low illuminance conditions ($M = 3.42$, $SD = 0.18$) than the high illuminance

conditions (M = 2.88, SD = 0.18; F(1, 92) = 4.76, p = .032). There was a significant main effect of lighting on environmental perception of the study environment being a place for concentration (F(1, 92) = 7.56, p = .007) in which participants in low illuminance conditions (M = 3.19, SD = 0.15) agreed more strongly that the study environment was a place for concentration than those in high illuminance conditions (M = 2.58, SD = 0.15). There was a significant main effect of lighting on the environmental perception that the participant had no impact from their surroundings (F(1, 92) = 4.33, p = .040) in which participants in low illuminance conditions (M = 2.58, SD = 0.16) agreed more strongly than those in high illuminance conditions (M = 2.13, SD = 0.16). There was a significant main effect of privacy on the environmental perception that the experimental environment was a place for creative work (F(1, 92) = 7.05, p = .009) in which participants disagreed more strongly in conditions without visual privacy (M = 1.58, SD = 0.13) than those with (M = 2.08, SD = 0.13). A significant interaction effect of lighting and privacy was found for the change in arousal ratings over time (F(1, 92) = 5.15, p = .026) in which the low illuminance without visual privacy was the only study condition where participants reported increased arousal ratings over time.

Significant correlations between creative performance scores and several environmental perceptions were also found. Higher fluency scores were found among participants who perceived the study environment's layout to be conducive to the work (r = .201, p = .049). Originality scores correlated with perceptions on the lighting in the study environment. Participants with lower originality scores reported the study environment to be dim (r = .208, p = .042) and participants with higher originality scores reported the desire to lower the lights (r = .205, p = .045) and the study environment to be too bright (r = .277, p = .006).

No significant correlations were found between mood ratings and creative performance

scores. Significant correlations were found among mood ratings and environmental perceptions of the study environment. Participants that reported lower pleasure ratings had a stronger desire to lower the lights in the environment at the beginning of the experiment (r = .276, p = .006). Higher pleasure ratings were correlated with the study environment being restful (pre-task: r = .328, p = .001; post-task: r = .420, p < .001), having a positive effect on performance (pre-task: r = .317, p = .002; post-task: r = .327, p = .001), being pleasant (pre-task: r = .333, p = .001; post-task: r = .441, p < .001), being appropriate for the tasks (pre-task: r = .207, p = .043; post-task: r = .249, p = .015), having good air quality (pre-task: r = .295, p = .004; post-task: r = .252, p = .013), and being a place for concentration (pre-task: r = .254, p = .013; post-task: r = .236, p = .020). Lower arousal ratings at the beginning of the experiment were correlated with the study environment being restful (r = .250, p = .014). Figure 8.4 summarizes these findings.

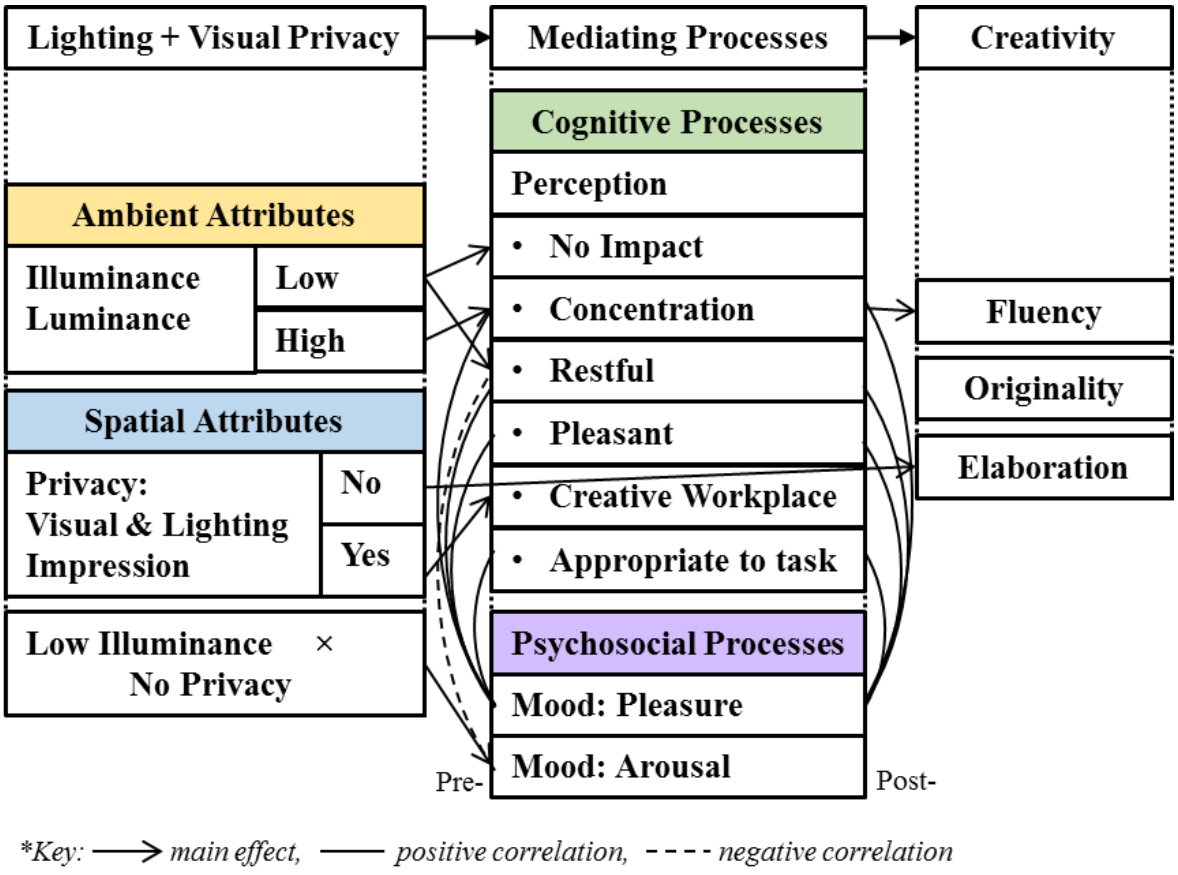


Figure 8.4. Summary diagram of data analysis from experiment 1 and 3

Discussion

Environments for Specific Creativity Dimensions

Higher mean scores for insight problem-solving were found in the low illuminance (M = 1.71, SD = 0.81) than in the high illuminance condition (M = 1.21, SD = 0.98), which is consistent with the finding from the Steidle and Werth (2013) study (low illuminance: M = 2.26, SD = 0.89; high illuminance: M = 1.77, SD = 0.85). However, only marginal significance was found in comparing the low and high illuminance conditions in this experiment which may have been due to a smaller sample size (n=24 per condition in present experiment, n=38 per condition in Steidle and Werth (2013) study). Conversely, higher mean scores for the TTCT measures and structured imagination measures were found in the high illuminance condition compared to the low illuminance condition. This difference in creative performance score outcomes between the low and high illuminance conditions and finding no significant correlations among the measures suggest that the three creative performance tasks were measuring different dimensions of creativity. This also suggests that different creativity dimensions may require different physical environmental conditions for successful performance. Participants with higher scores for insight problem-solving agreed that the experimental environment was appropriate for the task in only the low illuminance condition and not in the high illuminance condition, also confirming that certain environments are perceived to be more appropriate for the given task.

One difference to note between experiment 1, 2, and 3 is in the lighting conditions where TTCT scores were higher. The comparison of experiments 1 and 2 showed higher scores in the low and high illuminance conditions without task lighting whereas the comparison of experiments 1 and 3 showed higher scores in the high illuminance condition that had visual privacy. Although further exploration is needed to compare these studies, some suggestions can

be made. The setting for experiments 1 and 2 did not have visual privacy and was designed as an open-plan layout whereas experiment 3 was arranged in the identical layout but with visual privacy provided at each workstation. For experiment 1, the openness in the layout may have provided the stimulation needed for the TTCT task so the illuminance level may not have had an effect. Conversely, the task lighting in experiment 2 may have provided more focus on the workstation rather than the surroundings and may have hindered the flow of stimuli needed for the task. When the workstation already provided a private individual environment (i.e. experiment 3), illuminance may have had an effect in which high levels provided the stimulation needed. This may have been different for the insight problems as the thought mechanism is different from the TTCT and structured imagination task. The TTCT task is said to be modeled for divergent thinking (Plucker, 1998) and coming to a single answer for the insight problems may be more from convergent thinking. To converge into a single point is parallel with focus or concentration that can be designed within an environment through an individual private space with low illuminance.

Effects of Lighting on Environmental Perception and Effects of Privacy on Elaboration

The combined data analysis comparing the effects of illuminance levels in combination with visual privacy suggests that privacy and lighting separately have stronger effects on environmental perception. Low illuminance is associated with restfulness, concentration and no distractions, and privacy is associated with creative work. Although visual privacy was associated with perceiving the environment as a place for creative work, higher elaboration scores were found to be influenced by the absence of visual privacy. The data from experiment 3 suggest that this is related to post-task arousal ratings. When arousal persists for a certain amount of time, people may have the cognitive endurance to pay attention to details and elaborate on

ideas. Further inquiry of which attributes afford certain environmental perceptions and a thorough investigation of how environmental perceptions affect the performance of different creativity dimensions is needed. However, in summary, none of the results from experiments 1, 2, and 3 replicated those reported by Steidle and Werth (2013). This persistent incongruence in results may be that cultural factors played some unknown role: Steidle and Werth conducted their research in Germany, whereas the current experiments were conducted in the U.S.A. It is possible that some other difference might account for the failure to replicate Steidle and Werth's (2013) results, such as their use of computer tasks compared with the use of paper tasks in experiments 1, 2, and 3. Alternate explanations for the difference in findings may be that the results reported by Steidle and Werth (2013) are not generalizable or perhaps the results of some unknown artifact. The next experiment investigates the effects of different lighting characteristics and several factors related to control and privacy on creative performance.

CHAPTER 9
EXPERIMENT 4: EFFECTS OF LIGHTING QUALITY AND PREFERENCE ON CREATIVE PERFORMANCE

Introduction

Contrary to expectations, results from experiments 1, 2, and 3 show that illuminance does not appear to significantly affect creative performance. However, lighting has many characteristics other than illuminance levels. An interaction effect of color temperature and illuminance level on problem-solving performance has been found (Knez, 1995), suggesting that other lighting characteristics combine in having an effect on cognition. Studies investigating the effects of color on creative performance have found that the color blue used on study materials enhanced creative performance for fluency, originality, and RAT performance compared to red, and also that blue and red were associated with approach and avoidance motivation respectively (Mehta & Zhu, 2009). Studies show that having lighting control is associated with motivation and in turn, improved performance on an attention task (Boyce et al., 2006). Conversely, Veitch and Gifford (1996) found that control over choosing lighting type was detrimental for complex tasks such as creativity tasks, and results from experiments 1 and 2 here showed no effect of controllable task lighting on creativity measures. Nevertheless, when it comes to environmental control, satisfying individual preferences has been found to enhance mood, satisfaction, and work performance (Baron et al., 1994; Steelcase, 1999).

Other research has shown that natural daylight is highly preferred for work in offices (e.g. Veitch et al., 1993), but lighting preferences also depend on the task and the social situation (e.g. Biner et al., 1989). Studies have not yet investigated how lighting color preferences affect creative work. Consequently, experiment 4 investigates the effects of color and the possible interactive effects between illuminance levels, color temperature, and lighting control on

creativity-related tasks.

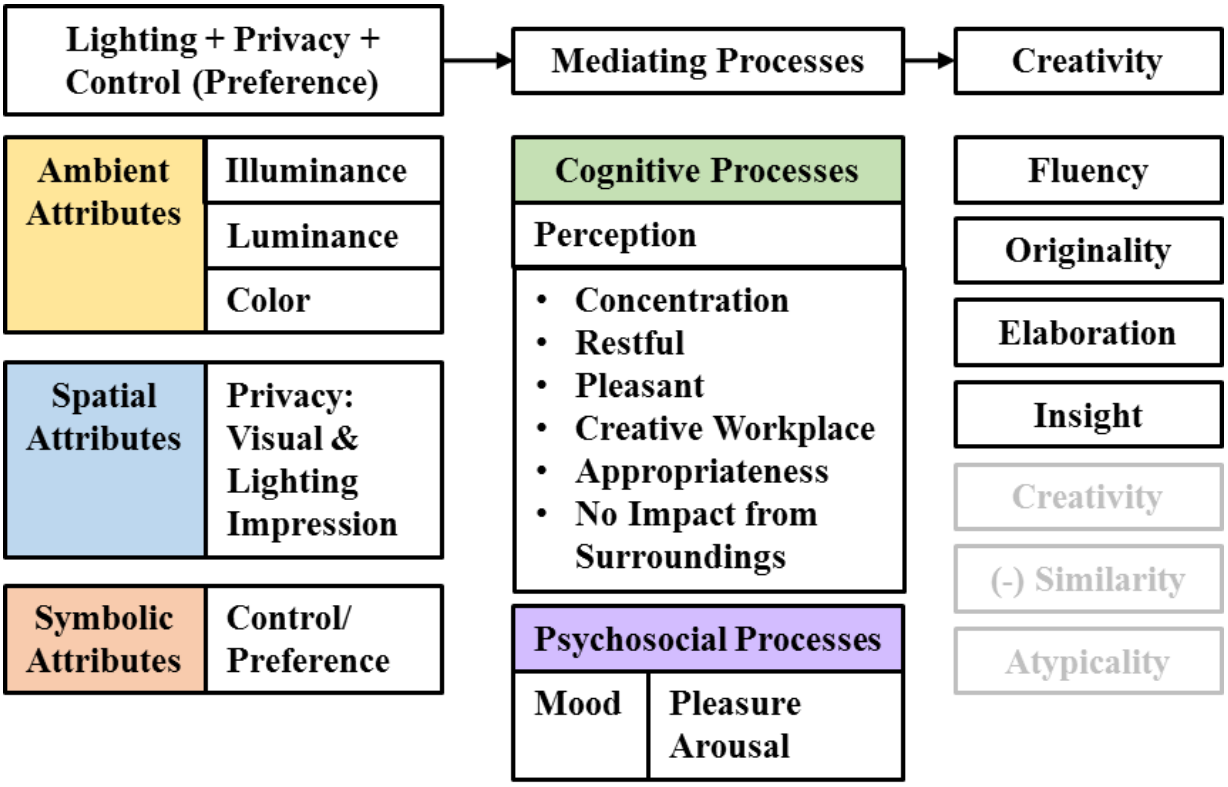


Figure 9.1. Research model for experiment 4

Objectives & Research Questions

Experiment 4 investigates the effects of lighting preferences (color and illuminance) on creative work. It also investigates the relationship between these lighting characteristics and creative performance, with environmental perceptions and mood hypothesized as the processes that impact this relationship (Figure 9.1). The following research questions were asked for this study:

1. What are the characteristics of lighting preferences for creative work?
2. Do lighting preferences have an effect on mood (i.e., pleasure and arousal) and creative performance?
3. How do lighting preferences change perceptions of the environment?
4. Does perception of the environment have an effect on mood and creative performance?

5. Does mood have an effect on creative performance?
6. What are other physical environment attributes preferred for creative work environments?

Methods

Design and Setting

This experiment used a within-subjects design for two lighting conditions: a control condition and a preference condition in which participants manipulated the lighting in the study room. The control condition used the "concentration" light recipe prescribed using spectrum-controllable light emitting diodes (LEDs) (Philips HUE system) tuned with a combination of color and brightness supposed to help focus and remain alert, and the preference condition was set according to participant's preferred lighting for creative work controlled by using a smart phone app (Philips HUE). Philips HUE is a personal wireless lighting system that can control shades of white from warm to cold color temperatures and provide a full spectrum of color (reported 16 million colors) through an app that controls multiple lamps (up to 50) running on a smart phone or tablet. This experiment used five A19 LED bulbs with various lumen outputs at different color temperatures (typically 600 lumens each at 4000K) and providing a color rendering index ranging over 80 from 2000 to 4000K.

The experiment was conducted in the Usability Laboratory at Cornell University designed to mimic a typical office space (Figure 9.2). The windowless room is 2.43m × 3.84m with a ceiling height of 2.26m. Participants were seated at a table (Fixtures Furniture Roam with $0.9m^2$ surface area, 0.74m table height, height adjustable legs, and casters) and chair (Humanscale Freedom task chair with 0.43m seat height). A floor luminaire (Intertek HX-F0049) holding five Philips HUE A19 bulbs was used as the sole lighting source for the windowless room. Initially the lamps were grouped together in the Philips HUE app to maintain a consistent

light spectrum and color temperature emitted in the room. The lamps were unshielded so that they discharged the pure light characteristics of the Philips HUE lighting, the room has white walls and the light fixture was placed in front of the work area to minimize shadows on the task surface. Illuminance was measured using a light meter (TES-1336A), task work surface luminance with a photometer (Cal-spot 400), and chromaticity with a chromameter (Minolta Chroma Meter xy-1) at a consistent point of the informed consent paper form placed at the center of the table surface for each condition.

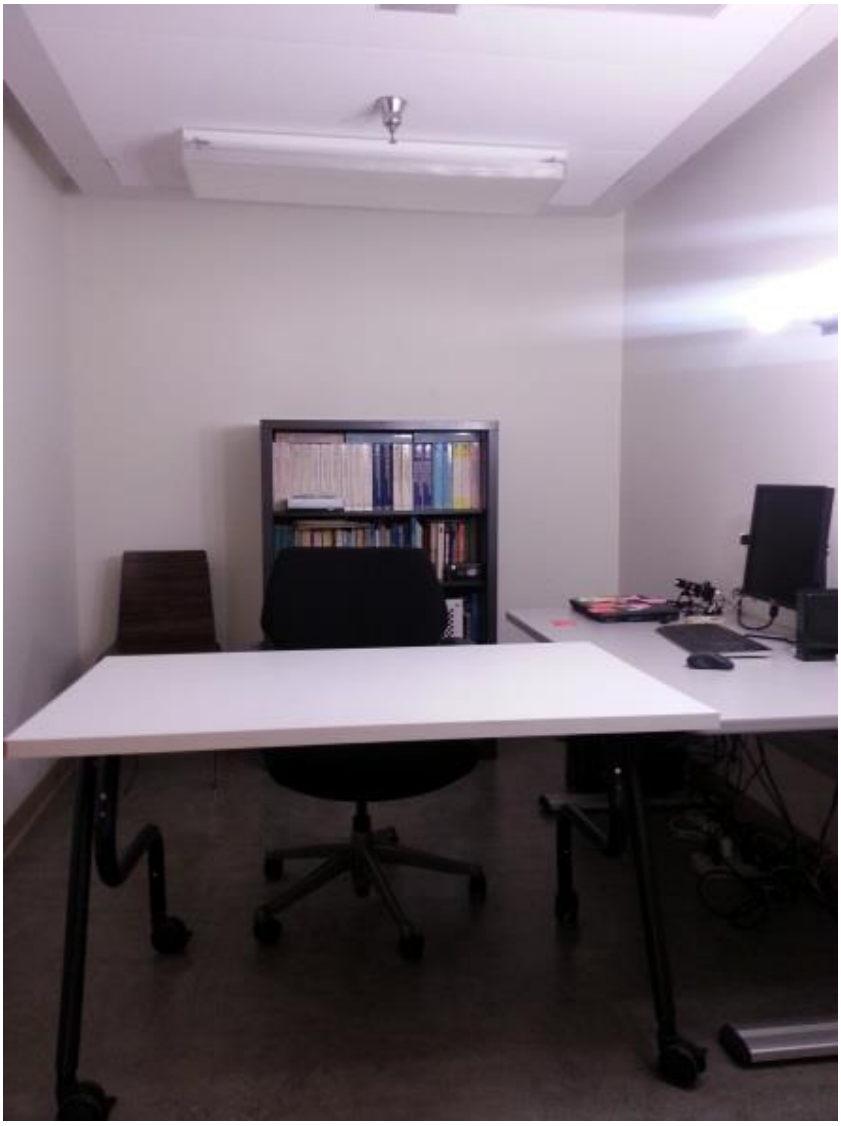


Figure 9.2. Experiment room

Participants

Twenty-five undergraduate and graduate students volunteered to participate through the university's psychology experiment participant pool and were compensated with $15 US. Among the 25 participants, one participant was excluded due to misunderstanding the creativity task. Twenty-four participants were included in the final data analysis: 6 males and 18 females, with a mean age of 20.54 (*SD* = 1.74). Participants were randomly assigned to an order of conditions that was counterbalanced to prevent order/practice effects.

Measures and Task Instruments

Mood. The mood dimensions of pleasure and arousal were measured by the Semantic Differential Measures of Emotional State or Characteristic (Trait) Emotions (SDME) (Mehrabian & Russell, 1974) used in the previous studies.

Creative performance. Creative performance was measured using a figural task, a drawing task, and a series of insight problems. The Torrance Test of Creativity Thinking (TTCT) Figural Activity 3 (Torrance, 1974) which challenges participants to come up with as many objects or pictures from pairs of straight lines (Form A) or circles (Form B) given in the booklet. Participants were encouraged to try and think of things that no one else would (i.e., originality), to make as many different figures as possible (i.e., fluency), and to make the figures complete (i.e., elaboration). The sum of fluency, originality, and elaboration scores was coded as the overall TTCT score.

The TTCT focuses on idea generation, whereas insight problems challenge participants to find one creative solution to a given problem by seeing the problem in a new and insightful way. Two verbal, one spatial, and one mathematical insight problem from the collection by Dow and Mayer (2004) were randomly selected to administer in each experiment condition. The control

condition used the four insight problems used in experiment 3. Additionally, the "two strings" (spatial), "water lily" (mathematical), "pocket," and "light switch" (verbal) problems were selected for the preference condition. Participants were given two minutes to solve each problem. The total number of correct answers was calculated as the overall insight score, with a range of 0 to 4.

The structured imagination task (Ward, 1994) challenges participants to draw in seven minutes an animal they would meet when visiting a planet in another galaxy very different from earth. Creativity was rated using the procedure proposed by Maddux and Galinsky (2009), coding for overall creativity, similarity to earth creatures, and atypicality of features. Reliability was obtained from two independent coders (α = .82, .86, and .93 for the respective measures) and the average of the ratings were obtained for each participant's score. Although this task was a creativity task, this was not repeated in both conditions due to practice effects, and instead was used as a filler task and a reference for creativity. These additional measures can be found in Appendix D.

Individual characteristics. Creative personality was assessed using the Adjective Check List (ACL) (Gough & Heilbrun, 1983), a standardized self-report instrument in which participants select adjectives that best describe their actual self from a list of 300 personality attributes to profile a wide range of human behaviors. As this study used figural and drawing activities, the scale (ACL-Cr) developed by Domino (1970) for design-based creativity was used.

Environmental perception. A self-constructed environment survey consisting of a series of questions on general participant perception of the study environment (i.e., lighting, color, furniture arrangement, etc.) and the overall atmosphere was assessed using five-point Likert-type agreement scales. Open-ended questions were included asking participants' perception of the

environment, lighting preferences for creative work, and a description of their creative work environment.

Procedure

Data were collected during the afternoon (1 to 6pm) over several weeks. Participants were seated at the table and briefly introduced to the study and its procedure, which was outlined in the informed consent form. Upon agreement, during the control condition, participants were given paper-based measures in the order of pre-task mood survey (SDME), Adjective Check List (ACL), two insight problems, creative performance measure (TTCT-Form A), two insight problems, environment survey, and post-task mood survey (SDME). The order of measures in the preference condition was similar: pre-task mood survey (SDME), structural imagination task, two insight problems, creative performance measure (TTCT-Form B), two insight problems, environment survey, and post-task mood survey (SDME). Specific instructions were given prior to the creative performance tasks, as they were timed. Participants were in the environment for approximately 60 minutes total. The research protocol was approved by the Institutional Review Board at Cornell University.

Data Analysis

Data analyses were conducted using multivariate statistical software (SPSS v.21). The Pearson correlations method was used to examine relationships among lighting characteristics, mood (i.e., pleasure and arousal), and creative performance scores (i.e., insight and TTCT), as well as relationships among environmental perceptions, mood, and creative performance. Paired t-tests were used to examine differences between the control and preference lighting conditions in lighting characteristics, environmental perceptions, mood, and creative performance scores. Linear multi-level modeling was used to investigate differences in pleasure and arousal ratings

over time (i.e., pre-/post-task) in each condition. Content analysis of qualitative responses from open-ended questions in the environment survey was conducted to find emerging themes within each question. Prominent themes were then coded as categorical data, and t-tests were run to examine differences among the themed groups.

Results

No significant differences were found among the creativity tasks according to the time and order of conditions. The control condition using the Philips HUE "concentration" light recipe was measured at 295 lux and approximately 3500K. Participants in the control condition agreed, on average, that the environment was of good air quality, was quiet for creative work, and had appropriate furniture arrangement for individual creative work, and they preferred to have some daylight in the room (Table 9.1).

Table 9.1. Mean Scores and Standard Deviations for Environmental Perceptions of Control Condition

		Mean (SD)			Mean (SD)
Lighting	Dim	1.71 (1.00)	Furniture/ Objects	Chair Uncomfortable	1.79 (0.88)
	Desires Lower Light	2.50 (1.35)		Layout	4.00 (1.06)
	Prefers Brighter Light	2.25 (1.03)		Plants	3.71 (1.12)
	Needs Task Lighting	2.38 (1.01)	Atmosphere	Pleasant	3.50 (0.89)
	Prefers Warmer Light	3.25 (1.23)		Restful	3.29 (1.27)
	Needs Daylight	4.04 (1.16)		Positive Attitude	3.13 (0.95)
Ambient	Needs more Color	3.13 (1.04)		Appropriate for task	2.29 (0.86)
	Quiet	4.12 (0.95)		Creative Work	3.17 (1.05)
	Air Quality	4.13 (0.95)		Concentration	4.13 (0.68)
	Cold	2.22 (1.20)		No Impact	2.42 (1.18)

According to the qualitative responses from the environment survey, participants perceived the control condition to be bright, focused, and a place for concentration. Participants who responded positively (33.3%) described the space as being secluded, being quiet, and having minimum to no distractions. Conversely, participants who disagreed (42.7%) or were not sure

(25.0%) of the study room being a place for creative work commented on it being a typical office space that was empty, dull with no inspiration, and in need of more distractions.

Lighting Preferences for Creative Work

Themes found among the qualitative responses for preference in lighting for creative work were on light level (dim, moderate, and bright), color temperature (warm or cool), uniformity (in distribution), its relation to vision (e.g., glare), and natural lighting. Of the 18 participants that commented on light levels, three preferred dim lighting, six preferred moderate lighting, and nine preferred bright lighting. Six participants commented on color temperature—four preferred warmer hues and two preferred cooler hues. Two participants referred to wanting uniform distribution of light across the entire room with no dark shadows, three participants commented on visibility (i.e., wanting enough light to see, not too bright to look into, less glaring), and one participant preferred light that did not give headaches. Five participants specifically commented on preferring natural light from outside.

The actual lighting conditions that participants chose for creative work for the preference condition varied (Figure 9.3), ranging from illuminance levels of 40 to 292 lx, task luminance of 7.5 to 64.4 cd/m^2, and color temperatures of 1660K to over 40000K (Figure 9.4). Significant differences in illuminance ($t(23) = 5.913$, $p < .001$), luminance ($t(23) = 6.158$, $p < .001$), and color temperature ($t(23) = -2.461$, $p = .022$) were found between the control and preference condition but not for chromaticity. Participants selected lighting that was dimmer and, on average, a higher color temperature than the control condition.

Figure 9.3. Lighting preferences set by participants

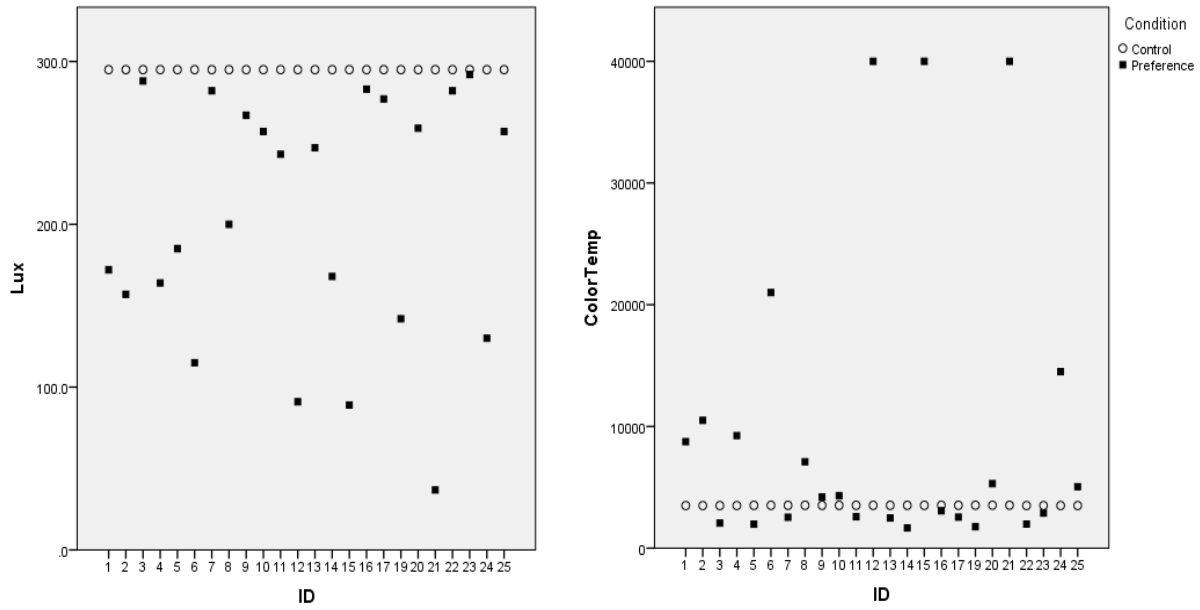


Figure 9.4. Illuminance levels and color temperature preferences set by participants

Effects of Lighting Preference on Mood and Creative Performance

A significant difference in means for pre-task pleasure ratings was found between the control and preference condition ($t(23) = -2.669$, $p = .014$), in which pleasure ratings were higher in the preference condition (Table 9.2) than the control condition ($M = 0.95$; $SD = 1.33$). Particularly, significant negative correlations were found among illuminance levels and pre-task pleasure ratings ($r = -.438$, $p = .032$), as well as illuminance and post-task arousal ratings ($r = -.495$, $p = .014$) in the preference condition. Similar correlations were found for luminance (pre-task pleasure: $r = -.429$, $p = .037$; post-task arousal: $r = -.495$, $p = .014$).

Table 9.2. Mean Scores and Standard Deviations for Pleasure and Arousal Ratings by Condition

	Control		Preference	
	Pre-task	Post-task	Pre-task	Post-task
Pleasure	0.95 (1.33)	1.08 (1.10)	1.77 (0.81)	1.62 (1.31)
Arousal	-0.13 (1.24)	0.18 (1.24)	-0.19 (1.07)	-0.34 (1.11)

For creative performance, participants did not have significantly higher insight and TTCT

mean scores in the preference condition than in the control condition (Table 9.3).

Table 9.3. Mean Scores and Standard Deviations for Creativity Measures by Condition and Creative Workplace Agreement

			Place for Creative Work			
	Condition		Yes		No	
	Control	Preference	Control	Preference	Control	Preference
Insight	1.25 (1.07)	1.67 (1.09)	1.75 (1.04)	2.13 (0.99)	1.00 (1.03)	1.44 (1.09)
TTCT	17.92 (6.73)	19.46 (8.79)	14.00 (3.42)	14.88 (5.79)	19.88 (7.19)	21.75 (9.28)
Fluency	10.42 (4.15)	10.46 (5.73)	7.00 (2.20)	6.13 (3.14)	12.13 (3.85)	12.63 (5.54)
Originality	5.17 (2.28)	6.54 (3.90)	4.63 (1.85)	6.13 (3.52)	5.44 (2.48)	6.75 (4.17)
Elaboration	2.33 (2.12)	2.46 (1.50)	2.38 (1.77)	2.63 (1.92)	2.31 (2.33)	2.38 (1.31)

Differences in Environmental Perception through Lighting

Lighting preference had an effect on environmental perceptions when comparing the two lighting conditions. Participants in the preference condition agreed more strongly that the environment was restful ($t(23) = 3.916$, $p = .001$), was appropriate for the tasks ($t(23) = 7.224$, $p < .001$), was pleasant ($t(23) = 4.653$, $p < .001$) and gave them a positive attitude toward it ($t(23) = 6.191$, $p < .001$), compared to the control condition. According to the responses to the open-ended questions, many participants (66.7%) explicitly commented that the environment for the preference condition was relaxing and calm. Based on the written responses, differences in perceptions of the environment for the two conditions also suggest that participants perceived the preference condition environment to be more positive than the control condition. For example, one participant perceived the control condition to be small, but the preference condition to be spacious, and similarly one participant commented that the control condition felt empty, but noted that the preference condition had plenty of space, although both were conducted in the same room. In addition, a participant perceived the control condition to be plain, but the preference condition as interesting.

Relationship among Environmental Perception, Mood, and Creative Performance

Certain environmental perception items were particularly related to the pleasure and arousal measures. Overall, pre-task pleasure ratings positively correlated with perceiving the environment as being a place for creative work ($r = .403$, $p = .005$), being pleasant ($r = .436$, $p = .002$), being restful ($r = .445$, $p = .002$), and providing a positive attitude for creative work ($r = .429$, $p = .002$). Post-task pleasure ratings positively correlated with the latter two (restful: $r = .401$, $p = .005$; positive attitude: $r = .289$, $p = .047$). More specifically, these correlations were found in the preference condition but not in the control condition. Pre-task pleasure ratings in the preference condition positively correlated with perceiving the environment as being a place for creative work ($r = .473$, $p = .020$), being restful ($r = .576$, $p = .003$), providing a positive attitude for creative work ($r = .568$, $p = .004$), and being appropriate for the tasks ($r = .511$, $p = .011$). Additionally, pre-task arousal ratings negatively correlated with the environment being restful ($r = -.431$, $p = .036$) and being a place for concentration ($r = -.573$, $p = .003$).

These environmental perception items were also found to relate to creative performance scores. Overall TTCT scores and fluency scores negatively correlated with perceiving the environment as being a place for creative work ($r = -.367$, $p = .010$ and $r = -.508$, $p < .001$ respectively) and being a place for concentration ($r = -.386$, $p = .002$ and $r = -.432$, $p = .002$ respectively). Originality scores negatively correlated with perceiving the environment as being set for concentration ($r = -.386$, $p = .007$), and elaboration scores positively correlated with perceiving the environment as being restful ($r = .321$, $p = .026$).

The relationship between environmental perception and creativity performance scores differed slightly between the two conditions. In the control condition, insight scores were negatively correlated with perceiving the environment as appropriate for the tasks ($r = -.460$, p

= .024); however, they were positively correlated with perceiving the environment as a place for concentration (r = .492, p = .015). Elaboration scores were negatively correlated with perceiving the environment as appropriate for the tasks (r = -.462, p = .023). In the preference condition, overall TTCT scores were negatively correlated with perceiving the environment as being appropriate for the tasks (r = -.537, p = .007), as providing a positive attitude toward creative work (r = -.431, p = .036), as being a place for concentration (r = -.628, p = .001), and as being a place for creative work (r = -.571, p = .004). More specifically, fluency scores were correlated with all the items mentioned above: perceiving the environment as being appropriate for the tasks (r = -.581, p = .003), as providing a positive attitude toward creative work (r = -.463, p = .023), as being a place for concentration (r = -.588, p = .003), and as being a place for creative work (r = -.658, p < .001). Originality scores were negatively correlated with perceiving the environment as being appropriate for the tasks (r = -.405, p = .049) and being a place for concentration (r = -.477, p = .018).

Participants were categorized into two groups according to whether they perceived the experiment environment in the control condition to be a creative place or not. Those who stated in their written responses that the experiment environment was a creative place had higher insight scores but lower TTCT scores—especially in fluency scores—than the participants who disagreed that the study environment was a creative place (see Table 9.3). There were no significant differences between the two groups in age, gender, grade, or lighting preferences, nor in pleasure or arousal ratings. In explaining why or why not the environment was a creative place, most participants explained that the lack of distractions supported it being a creative place, whereas lack of inspiration was the reason for it not being a creative place. Taking these comments into consideration, participants were categorized into three groups according to their

perception of the environment: no inspiration, distraction, or other comments. Differences among these groups were found when comparing their creative performance scores in the control condition. The group that did not specifically comment on the environment having no distractions or no inspiration (i.e., neutral) had significantly higher TTCT scores ($F(2,21) = 4.359$, $p = .026$), especially in fluency ($F(2,21) = 7.216$, $p = .004$), than the group that commented on the environment not having distractions. There were no significant differences among these groups in individual characteristics, lighting preferences, or mood ratings.

Effects of Mood on Creative Performance

Overall, pre-task arousal ratings were positively correlated with TTCT scores ($r = .337$, $p = .019$) and particularly with originality scores ($r = .336$, $p = .020$). This relationship was also found in the preference condition: significant positive correlations were found between pre-task arousal ratings and TTCT scores ($r = .418$, $p = .042$), particularly with originality scores ($r = .426$, $p = .038$). However, no correlations were found between mood ratings and creative performance scores in the control condition. These results are summarized in Figure 9.5.

Preferred Physical Environment for Creative Work

Common themes found in participants' description of where they went for creative work were related to nature, access to resources, and support for individual work or mood/comfort. Seventeen participants (70.8% of participants) mentioned aspects of nature or connection with it. For example, several participants described their creative workplace to be outside, in sunlight, or having access to natural daylight (i.e., window). Some were specific as to having trees, fresh air, or birds chirping, or being by a lake or watching the sunset. Thirteen participants (54.2% of participants) described their creative workplace as containing resources that were accessible to them or having inspiration for ideas. Resources were described as necessities, amenities, and

supplies, and in some cases were specifically mentioned by means of people around them or food. In asking what made the environment creative and how the environment supported creativity, most participants mentioned affordances related to individual work or mood. Support for individual work was mentioned (70.8% of participants) through the environment providing a space for focus or concentration and being a space without distractions. Some participants also commented on the environment allowing them to be free from distraction, other responsibilities, or stress. The creative workplace also provided opportunities that supported positive mood (54.2% of participants). Mood-related affordances included comments on feeling relaxed, restful, and comfortable.

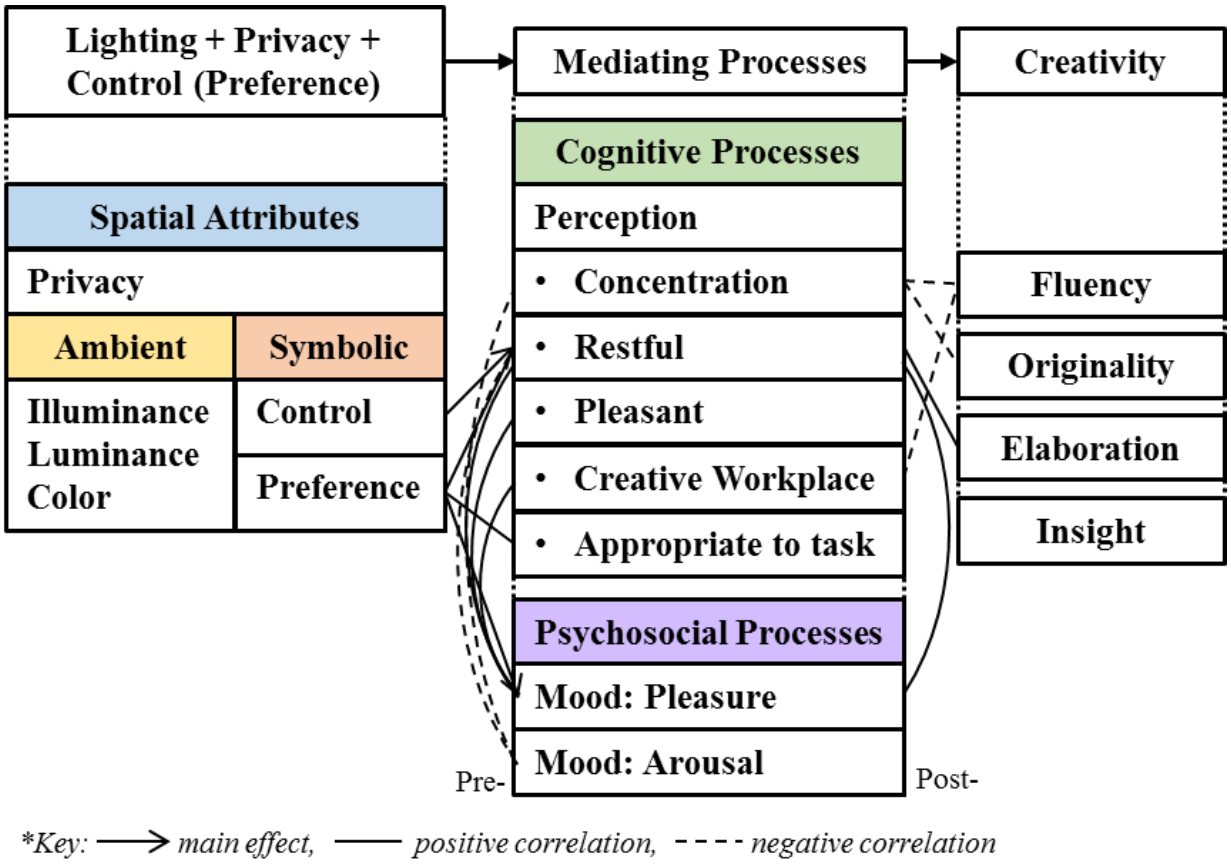


Figure 9.5. Summary diagram of experiment 4 results

Observations

The setting for this study was designed to be similar to that found in an actual office

workspace. Some existing equipment (e.g. computer with monitor, CPU, and keyboard, bookcase with books, post-its, and a roll of tape, etc.) were kept in the experimental environment to create an office-effect. Participants were facing the door when completing the tasks for this study (see Figure 9.1 for office layout and artifacts). In looking over the ideas for the TTCT figural forms, there was some evidence of participants screening the environment for ideas (Figure 9.6).

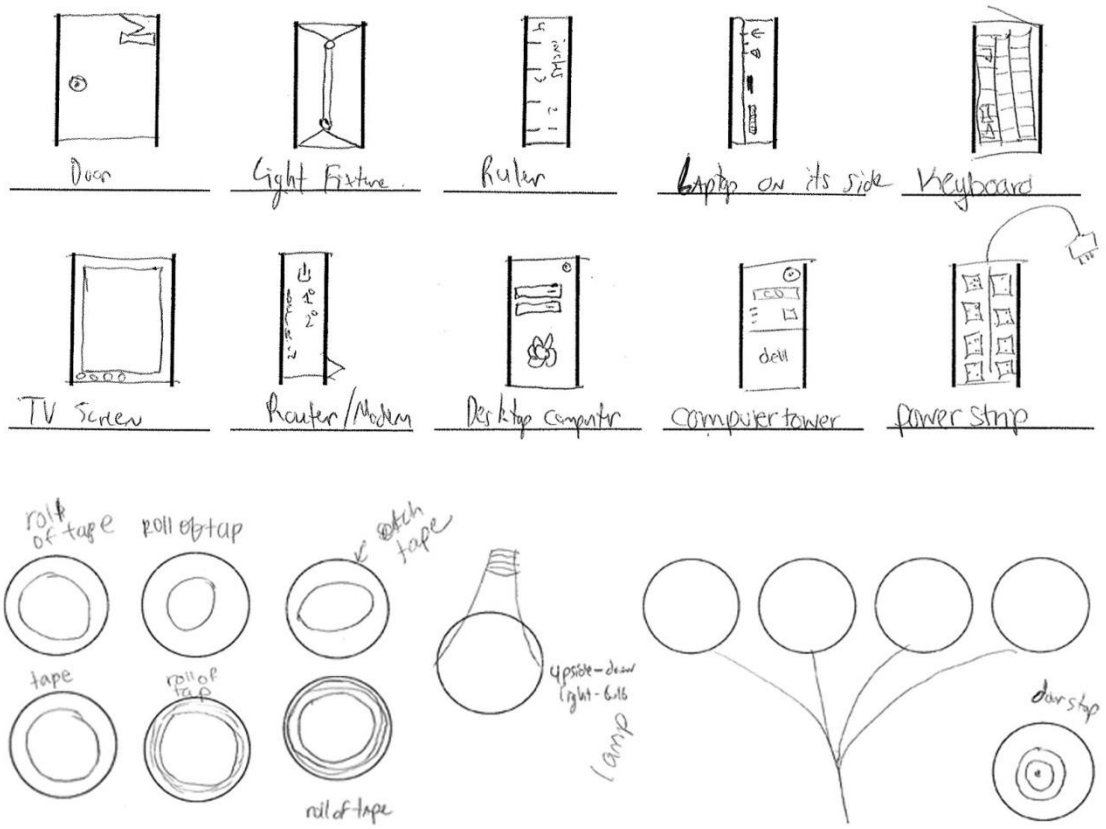


Figure 9.6. Examples of TTCT results that related to objects in study environment

Additional Explorative Analysis

An analysis of data from experiments 1, 3, and 4 was conducted to further investigate the effects of privacy on elaboration scores as found in experiment 3. Only low illuminance conditions from experiments 1 and 3 were included as these illuminance levels were similar to

that of the control condition for experiment 4. The data set from experiment 1 was determined as the condition with no privacy, experiment 3 as the condition with semi-private settings, and experiment 4 as the condition with individual privacy. One-way ANOVA found a significant difference among the three degrees of privacy in which elaboration scores were significantly higher in the no privacy condition (M = 6.38, SD = 3.87) compared to the semi-private (M = 3.25, SD = 1.42) and private conditions (M = 2.33, SD = 2.12; $F(2,69) = 15.069$, $p < .001$). There were no significant differences between the semi-private and private conditions on elaboration.

Discussion

Perceptual Differences

In this experiment there were perceptual differences between the control and preferred lighting conditions and also among participants. All participants preferred lower illuminance levels than the control condition (295 lx) for creative work. Participants seemed to have desired more pleasurable settings as lower illuminance was found to be correlated with higher ratings of pleasure and participants reported higher pleasure in the preference condition than in the control condition. More specifically, participants perceived their preferred lighting environment as being relaxing and comfortable. However, the lighting characteristics that afforded the perception of relaxation and comfort differed among participants (see Figure 9.3). Lighting changed the impression of the overall study environment—participants commented more positively on their impressions of the environment when in their preferred lighting settings (e.g., relaxing, spacious). Survey results indicated stronger agreement in the environment being restful, appropriate for the tasks, and affording positive attitudes when in the lighting preference condition than in the control condition. Although Flynn et al. (1977) found that different lighting designs (e.g., overhead lighting, cove lighting, wall sconces, etc.) influenced impressions within a space, the

results from the present study suggest that illuminance, color temperature, and chromaticity of a constant light source can also affect spatial impressions. Lighting can be assumed as a significant physical environment attribute that creates various atmospheres as it was the only attribute manipulated in the two conditions that varied in impressions.

An alternate explanation for the differences in lighting impressions between the two lighting conditions could be from the impact of having control over the environment. Veitch and Gifford (1996) found a relationship between perceived control and preference over lighting in their investigation on personal lighting control in the workplace. Rather than the physical element of lighting, the psychological effect of having control over the environment (i.e., lighting) may have contributed to the change in participants' perception of the environment. More specifically, having control and being in the preferred lighting setting may have freed people from constraints and afforded the feeling of relaxation and a positive attitude toward the environment. However, Veitch and Gifford (1996) also found perceived control to have a detrimental effect on creativity tasks (i.e., idea generation), suggesting that offering choices in lighting is not always beneficial. Although mean scores for insight problem-solving and TTCT were higher in the preference condition than in the control condition, the differences were not significant. Unlike Steidle and Werth's (2013) finding that dim illuminance supported higher creative performance, the insignificant results of the present experiment may have resulted from participants having personal control over lighting.

Perceptual differences in creative places, apart from lighting, are another factor to consider. Only one-third of the participants agreed that the experimental environment was conducive for creative work, and two-thirds disagreed. For some, the environment was perceived to have no distractions, whereas for others the same environment was perceived as having no

source for inspiration. This experiment found that participants who perceived the environment as neutral (i.e., no comment on distraction or inspiration) had significantly higher TTCT scores than those who perceived it to have no distractions. The lack of distractions may not have provided participants with enough stimuli to generate novel ideas. Not meeting the expectation for the environment to be inspiring may have blocked idea generation as well. This relates to the concept of breadth of attention: individuals with narrow breadth of attention are able to screen irrelevant stimuli and are unaffected by their surroundings, whereas individuals with broad breadth of attention are affected more strongly by their surroundings and are highly arousable (Mehrabian, 1995). Kasof (1997) found that complex creativity tasks (i.e., judged creativity of poems) particularly require broad attention. Vohs, Redden, and Rahinel (2013) also found that clutter, or physical disorder, promoted creative performance in the creativeness of generated ideas. Although the present study did not test for individual's breadth of attention or screening ability, this concept may provide another explanation to the perceptual differences of distraction versus inspiration and its results in creative performance. Those who perceived the environment to have no distractions may have had low screening ability (i.e., narrow attention capacity), and those who commented on the environment having no inspiration may have had high screening ability (i.e., broad attention capacity). Individual differences in how people deal with environmental stimuli may have an impact on creative performance. Observations of the TTCT results have found that some individuals did look towards the environment for ideas (see Figure 9.4); however, statistical analyses could not be conducted to further this inquiry. Future studies should take this individual characteristic into account when investigating effects of the physical environment on creative performance.

Environments for Different Creativity Tasks

Participants who agreed that the environment was a creative place had significantly higher scores in solving insight problems but lower scores in TTCT, especially in the fluency of generating ideas. This incongruence in participants' creativity scores suggests that the tasks measured different creativity dimensions. Participants who perceived the environment to have no distractions may have had a better time concentrating on coming up with a solution for the insight problem-solving task. This task may be associated with convergent thinking as there is only a single solution to each problem. On the other hand, the perception of having no distractions or the concept of concentration may have conflicted with divergent thinking required for the fluency aspect of the TTCT. Participants who did not perceive the environment to be a creative place may not have been inspired to come up with an insightful solution, yet may have been stimulated to generate multiple ideas without relying on the environment. In collaboration with how people perceive the environment, the environment may support some activities yet inhibit others.

A single environment may not be conducive to the multiple facets of creativity. Meusburger (2009) emphasized the need for separate spaces for different stages of the creative process or for certain types of activities. It was argued that different tasks and different stages of the creative process had different spatial requirements: preparation and elaboration need both communal and private spaces, while incubation and insight are more supported by privacy (Kristensen, 2004). Haner (2005) also observed multiple environments being accessed according to each stage of the creative process in innovation labs. The ability to engage in creative work may depend on the affordances of the workspace in supporting communication or concentration tasks.

Designing for Affordances

The role of the physical environment may be interpreted through the affordances it provides to the user (Glăveanu, 2013). Affordances are limited to how the individual interprets them, and therefore understanding the individual and how one interprets the environment around them is also essential for designing a workplace for creativity. Further study is needed on what personal characteristics impact individual space perception, particularly in spaces for creativity. In conjunction, lighting research should continue investigations on behaviors impacted by lighting impressions. This research should then inform what atmospheres support creative performance and how lighting can help transform the space accordingly. Further study is also needed in examining the relationship between lighting affordances and the different dimensions of creativity. Organizations should keep in mind what creative performance measures are desired as different tasks and individuals may require different support from the physical environment. Overall, the mere change in lighting may maximize the potential of a physical workplace's impact on creative performance when done purposefully and effectively.

CHAPTER 10
DISCUSSION, IMPLICATIONS AND CONCLUSION

No significant effects of illuminance on creative performance measured by the TTCT were found from the experiments conducted. However, illuminance was found to be related to perceptions of the experimental environment and mood measured by pleasure and arousal. The main findings of all the experiments conducted are summarized in Table 10.1.

Although there were some illuminance effects on mood and environmental perceptions, these mood and environmental perceptions did not extend to effects on creative performance, nor were there any direct effects of illuminance on creative performance. However, the recurring relationships among environmental perceptions, mood, and creative performance measures suggest for further investigation on the lighting effects on creativity.

Lighting Affordances

Lighting plays an important role in the physical environment as spatial impressions such as, spaciousness, pleasantness, and privacy can be altered through different lighting designs (e.g. Flynn, 1992). Lighting is also considered to be a significant attribute in the workplace that influences perceptions (e.g. Flynn et al., 1973; Hendrick et al., 1977), mood (e.g. Küller et al., 2006; Veitch, 2001), and performance (e.g. Knez, 1995; Veitch & Gifford, 1996). Employees are aware of the visual and non-visual effects of lighting and consider both lighting quantity and quality to be of high importance in the physical workplace (e.g. Newsham et al., 2009). The preliminary study reported here also confirms that the emerging work generation regards lighting as an important factor in creative workplaces. This was further confirmed in the use of photographs for surveying important attributes in the physical environment, as these capture the observer's first impression of the space.

Table 10.1. Summary of Findings from Experiments 1-4

	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	Illuminance Levels		Task Lighting		Visual Privacy		Color + Control	
Lighting Control	No		Perceived Control		No		No	Yes
Privacy	Open-plan		Open-plan		Semi-private		Private	
Creativity Tasks	TTCT		TTCT		TTCT, Insight, Structured Imagination (Alien)		TTCT, Insight	TTCT, Insight, Alien
Ambient Illuminance	Low	High	Low	High	Low	High	Control	Preference
Pleasure							Preference > Control	
	Task Lighting effect on Pleasure							
Arousal	↑over time	↓over time						
	Illuminance effect on Arousal: ↑over time in Low; ↓over time in High							
	Illuminance × Privacy effect on Arousal: Low illuminance without Privacy ↑over time							
Environmental Perceptions	yes				yes		Preference > Control: Restful Appropriate for tasks Pleasant Positive affect	
	Illuminance effect on Restful: Low > High							
	Illuminance effect on Concentration: Low > High							
	Illuminance effect on No impact from Surroundings: Low > High							
	Privacy effect on Place for Creative work: Yes > No							
Fluency			(correlation: Concentration)				(correlation: Concentration, Creative Workplace)	
	(correlation: Concentration)							
	(correlation: Layout)							
Originality			(correlation: No impact from surroundings)				(correlation: Concentration)	
Elaboration			(correlation: Pleasure & Arousal)		(correlation: Arousal)		(correlation: Restful)	
	(correlation: Pleasure)							
	Privacy effect on Elaboration: No > Yes							
	Privacy effect on Elaboration: No > Yes							
Overall TTCT			(correlation: Concentration)					
Insight					(correlation: Concentration; Appropriate to task)			
Alien: Creativity					(correlation: Pleasant)			
Alien: Similarity					(correlation: Pleasant, Appropriate to task)			
Alien: Atypicality								

However, the series of lighting experiments reported here failed to confirm any main

effects of illuminance, task luminance, light color, or personal control on an array of creative performance measures. Conversely, the experimental results did indicate that low and high illuminance levels influence certain environmental perceptions, and at times, have an effect on mood ratings of pleasure and arousal. Low illuminance was consistently associated with concentration and non-uniform lighting (i.e. general lighting in combination with task lighting), and was found to be more pleasant throughout the studies. These findings are similar to those reviewed in previous literature—low illuminance relates to the impression of privacy (Flynn, 1992) and non-uniform/compound lighting enhances pleasantness (Ballantine et al., 2010; Summers & Hebert, 2001). This suggests that lighting indeed is a key attribute that influences spatial impressions. The added impressions of restfulness and concentration when visual privacy was provided in combination with low illuminance suggest that certain environmental perceptions can be strengthened by the use of several attributes together. The physical workplace usually consists of many attributes which designers combine to create the intended atmosphere, or goal for the environment (e.g. de Korte et al., 2011).

Environmental Perceptions Supporting Creative Performance

The current experimental studies could not demonstrate that a specific illuminance level was conducive for creative performance, and results failed to confirm previous research suggesting this possibility (Steidle & Werth, 2013). Although not significant, higher mean scores for the TTCT and structured imagination task were found in the high illuminance condition with visual privacy, and more insight problems were solved in the low illuminance condition with visual privacy. The differences in results suggest that arousing high illuminance may support divergent or drawing tasks, whereas restful low illuminance may support convergent tasks (experiment 3). The different effects concur with the difference in thought processes for

divergent and convergent tasks (Guilford, 1968). Conversely, the environmental perception of concentration was found to be related to improved insight problem solving and in the fluency of ideation on the TTCT (experiments 2 and 3) regardless of illuminance level. These results propose that subjective perceptions of the environment or the individual affordances identified in the physical environment have an impact on creative performance rather than objective measures of the physical environment attribute (i.e. lighting characteristics). From these associations with environmental perceptions, the results suggest that creative activities should be performed in different settings according to the goal for creativity. For example, individual brainstorming should take place in spaces fit for concentration. When a chosen idea needs to be further developed, people should look for a place that relaxes them. Design should consider the different stages of the creative process and creative spaces that accommodate the needed requirements for each of them. Haner (2005) investigated innovation labs that were designed around different creative process techniques (i.e. Wallas model, 1926; de Bono's six thinking hats, 1985). The success of these case studies may have been in the agreement between the expectations and perceptions these spaces afforded or in the strength of the message the spatial affordances. Research on embodied cognition indicate that the enactment of creativity-related metaphors (e.g. "think outside the box") improve convergent and divergent (i.e. fluency, flexibility, or originality) thinking in problem solving (Leung, Kim, Polman, Ong, Qiu, Goncalo, & Sanchez-Burks, 2012). Physical environments designed for enhanced creative performance may require a clear and strong message that communicates creativity to the users.

Environmental perceptions that seem to have an impact on creative performance are created by many attributes in the physical environment that interact to create a holistic environment. We perceive the physical environment as a whole rather than its separate attributes.

Although some physical environmental attributes may have a dominant impact on perception, it is still in combination with other attributes that contribute to this effect. Contrary to Steidle and Werth's (2013) findings, the current experiments showed that illuminance levels alone showed no relation to creative performance scores; however, when used with task lighting or visual privacy screens, some relationships were found among environmental perceptions, mood ratings, and creative performance scores. These results suggest that any relationship between lighting design and creativity may be complex and varied. Privacy, in particular, was found to have a main effect on elaboration scores in which having no privacy enhanced elaboration. This suggests that lighting may not be the driving force for improving creative performance, but rather the opportunities that are afforded in combination with other attributes are what support it. Certain workplace designs, for example, a workplace environment designed for high arousal, can be conducive for simple creative team tasks (de Korte et al., 2011). The effect does not come from a single attribute but rather from the interaction of multiple attributes.

The environmental perceptions that support creative performance can be thought of as the mediating processes, or the underlying mechanisms, for creativity. Rather than the physical environment attributes themselves, it is the affordances that they provide in impacting human processes that has an effect on creative performance. Future studies should explicitly state how the physical environment is being perceived and what opportunities it affords in examining the relationship between the physical environment and creativity. This series of studies also found different environmental perceptions that were related with different creativity dimensions. Places for concentration were better for insight problem solving, similar to convergent thinking, and places that were perceived as not being pleasant were better for overall creativity in a drawing task. These should be duly noted in order for the intended results.

Holistic View of Lighting's Role in the Physical Environment for Creativity

The current series of experiments investigated several aspects of lighting and its effects on several creative performance measures with environmental perceptions and mood as the proposed processes impacting the relationship. Experiment 1 investigated lighting as an ambient attribute, experiment 2 looked at task lighting as a symbolic attribute, experiment 3 considered lighting as a support for a spatial attribute (i.e. visual privacy), and experiment 4 incorporated views from all three attributes. Sensory processes were the basic function as lighting is a visual component of the physical environment, the investigation of perception considered it as a cognitive process, and mood was part of the psycho-social process. Based on the conceptual framework proposed in the review of literature on the physical environment's effects on creative performance, this series of studies took a holistic approach in examining the role of lighting in creativity. Further studies on lighting and its effects on creative performance are needed because many characteristics of lighting can affect perceptions in diverse ways; for example, results from experiment 4 show a wide range of color choices selected by participants when given control over their lighting. Although complex, future studies should strive to take into account the role of lighting from a more holistic view of the physical environment and of its relationship to creativity.

The conceptual framework proposed in this thesis offers a systemic view of how the physical environment may affect creative performance. The framework was useful in creating a research model for each experiment in this thesis. The research model was then used to organize the findings of the experiments by separating the specific components, which provides a more focused and concise view of how physical environment attributes affect creativity dimensions measured by certain creativity tasks. The conceptual framework on the relationship between the

physical environment and creativity becomes the overarching illustration of the phenomenon (i.e. macro-perspective), the research model for experiments on a particular physical environment attribute's effects on certain creativity dimensions reviews this relationship holistically and in general (i.e. meso-perspective), and the summary model for each experiment's results organizes the detailed findings (i.e. micro-perspective).

The conceptual framework proposed for organizing literature investigating physical environment effects on creative performance is not limited to just studies on lighting and can be used to identify future studies on any attribute and used to design research methods at a more specific level. The framework emphasizes the mediating processes on how the physical environment affects creativity and can be further developed by examining these processes at a micro-level. The experiments conducted in this thesis have found that physical environment attributes impact environmental perceptions or mood which then has associations with creative performance. Future studies should be explicit and thorough in establishing these indirect effects. The conceptual framework presented here only illustrates the abstract state of research on the physical environment – creativity research to date. It shows the potential for a multitude of future research studies aimed at examining the relationship between the physical environment and creativity. Future studies are needed to further elucidate these relationships and reveal a clearer and more coherent view of how lighting and other environmental attributes might affect creativity.

Limitations of Studies

Creativity is a complex and multi-faceted phenomenon that is difficult to measure. Psychometric tests that have been developed to assess creativity are limited to the dimension targeted for evaluation and does not provide an accurate illustration of creativity as a whole. The

variety of creativity assessments used in this series of studies found that the measures did not correlate with each other and hence, were measuring different aspects of creativity. Although this strengthens the methods by acknowledging the different creativity dimensions and measuring them individually, it also serves as a limitation for not considering other possible dimensions. Another critique on creativity assessments suggest that they measure creative abilities or potential rather than actual performance (Davis, 2004). Creativity assessments that are more practical in measuring creative performance in real-life situations should be developed for future research.

Creativity is a broad concept that can be defined and measured in numerous ways. Some researchers suggest that creativity is domain specific, meaning the skills, aptitudes, traits, tendencies, and motivations that lead to creative performance vary from domain to domain (e.g. Csikzsentmihalyi, 1996). Organizations should explicitly state which creativity dimensions are desired in the workplace and design spaces that cater to those particular needs. Further research is needed in not only exploring the effects of different physical environment attributes on creativity, but also among an array of different creativity dimensions.

Additionally, the series of experiments presented in this thesis did not include multiple creative performance measures in all of the experiments and therefore, although results suggest that lighting may not have a direct effect on creativity, synthesis of the existing findings does not produce a cohesive account of potential lighting effects on multiple dimensions of creativity. Future studies should consider using a multitude of a diverse array of assessments that measure different aspects of creativity that are meaningful and relevant to the research goal. Research focusing on a specific dimension of creativity should utilize multiple assessments for it, while research surveying creativity in general should include multiple assessments that are

representative of different dimensions.

The recruitment process differed slightly across the studies and may have had an impact on the results when comparing between different studies (e.g. comparative analysis for experiments 1 and 2). The classes that participants were recruited from had some emphasis on the importance of the built environment and those enrolled may have had a higher awareness of environmental effects than participants recruited from a general research pool. Participants from experiments 3 and 4 were compensated with money and the difference in motivation may also have had an effect on the results. Within each study, selection bias was controlled for through random assignment.

During the debrief session after the experiments, some participants mentioned prior knowledge to some of the answers to the insight problems. Some of the drawings for the structured imagination task also allude to prior knowledge of the task and its scoring measures. Previous exposure to the creativity measures used in this study gives an advantage to scores that do not signify the creative performance of the individual but of access to knowledge. Creativity is a well-sought out phenomenon of interest and prior exposure to creativity assessments is expected, yet is still a limitation for studies.

The population of interest in this study was the emerging work generation and thus, the recruitment of undergraduate and graduate students were representative samples. However, these results may not be completely generalizable as the expectations of the workplace may differ between undergraduate and graduate students, and perhaps even among the different class standings within undergraduate students. Expectations, like perception, are highly dependent on past experiences. Experiment 4 found that while some participants perceived the study environment as a place for creative work, others disagreed. Similarly, some participants

described the room to have no distractions while others associated this with having no sources of inspiration. These perceptions or expectations of places for creative work may differ according to prior experiences in creative work or in creative workplaces. However, the sample size was not large enough to analyze these perceptions according to specific individual characteristics such as, class standing or discipline. Future studies should take into consideration different individual characteristics that may be related to perceptions of, and expectations for the creative workplace. The nature of today's work is also focused on collaboration (Kilber et al., 2014). Biner et al. (1989) found that lighting preferences differed according to social situations, suggesting that the effects of lighting on individual creativity may differ from that on team creativity. Future study should first investigate the relationship between lighting and team creativity and then compare the differences between individual and team creativity.

The experiments ranged from 45-60 minute duration. It is unknown whether lighting has an impact on human behavior during this short time period. When analyzing data from experiments 1 and 3 to investigate the effects of illuminance and visual privacy, the results revealed an interaction between illuminance levels and time on arousal ratings. Arousal ratings increased in low illuminance conditions whereas they decreased in high illuminance conditions. Although this interaction was not found in other studies, the results suggest that arousal may change over time when visual privacy is provided in the workspace. It is unknown whether this effect persists after the allotted time. The duration of lighting exposure may not have been enough for lighting to have an effect on creative performance and the time may not have been enough for people to exercise creativity. Future studies that inquire lighting effects on creative performance should consider methods that relate to the actual workplace (e.g. field studies). Creativity is complex and requires deep thought processes.

Conclusion

Lighting is a physical environment attribute that has been shown to affect spatial perceptions, differ in preferences by spatial and social purposes, mood, and environmental perceptions, and potentially impact creative performance. Although previous research has investigated various effects of lighting, a holistic view of the relationship among perception, preference, and creative performance in the context of lighting has been missing. This series of experiments found that lighting, in combination with other physical environment attributes, does not appear to affect creative performance but does enhance perceptions of concentration, restfulness, and pleasantness, particularly when illuminance levels are low (e.g. 150-295 lx). However, individuals interpret the environment differently in relation to creativity and also have diverse lighting preferences for creative work. This study further suggests that design affordances, or the environmental perceptions the individual acquires in a space, is what impacts creative performance, rather than the physical environment attribute itself. Further investigation is needed in learning how lighting can be designed to achieve the desired goals for creative performance. As organizations expand their interest in creativity to the design of the physical workplace, research should continue to examine individual responses to the environment from a holistic view of perception, preference, and creative performance.

APPENDIX A

ONLINE QUESTIONNAIRE USED IN PRELIMINARY STUDY

1. How would you describe a creative workplace? Please check all that apply.

Active	Competitive	Frivolous	Ordinary	Spiritual
Adaptable	Conscientious	Habitual	Peaceful	Spontaneous
Adventurous	Conservative	Humorous	Peculiar	Stable
Affirming	Considerate	Impulsive	Practical	Strenuous
Ambitious	Conventional	Independent	Predictable	Supportive
Assertive	Cooperative	Inhibited	Professional	Sympathetic
Cautious	Daring	Intense	Rebellious	Transformable
Challenging	Debate-filled	Isolated	Secluded	Unchanging
Changeable	Efficient	Lively	Self-Expressive	Uncomplicated
Chaotic	Established	Methodical	Serene	Unconventional
Cluttered	Fast-Paced	Music-filled	Slow-Paced	Unpredictable
Communicative	Flexible	Open-Minded	Social	Versatile

2a. For each word pair, choose the extent to which you believe the words describe what a creative workplace environment (social + physical) should be.

Autonomous	○ ○ ○ ○ ○ ○ ○	Collaborative
Energetic	○ ○ ○ ○ ○ ○ ○	Calm
Playful	○ ○ ○ ○ ○ ○ ○	Serious
Consistent	○ ○ ○ ○ ○ ○ ○	Changing
Leisurely	○ ○ ○ ○ ○ ○ ○	Demanding
Individual	○ ○ ○ ○ ○ ○ ○	Teamwork
Personal Space	○ ○ ○ ○ ○ ○ ○	Communal Space
Open	○ ○ ○ ○ ○ ○ ○	Closed
Homogeneity	○ ○ ○ ○ ○ ○ ○	Heterogeneity

2b. For each word pair, choose the extent to which you believe the words describe what a creative workplace environment (social + physical) should be.

Messy	○ ○ ○ ○ ○ ○ ○	Organized
Harmonious	○ ○ ○ ○ ○ ○ ○	Discordant
Unique	○ ○ ○ ○ ○ ○ ○	Standard
Casual	○ ○ ○ ○ ○ ○ ○	Formal
Rational	○ ○ ○ ○ ○ ○ ○	Emotional
Traditional	○ ○ ○ ○ ○ ○ ○	Modern
Quiet	○ ○ ○ ○ ○ ○ ○	Noisy
Natural	○ ○ ○ ○ ○ ○ ○	Artificial
Dim	○ ○ ○ ○ ○ ○ ○	Bright
Warm	○ ○ ○ ○ ○ ○ ○	Cool
Simple	○ ○ ○ ○ ○ ○ ○	Complex
Color	○ ○ ○ ○ ○ ○ ○	Black & White

2c. For each word pair, choose the extent to which you believe the words describe what a creative workplace environment (social + physical) should be.

Constraint	○ ○ ○ ○ ○ ○ ○	Freedom
Stimulating	○ ○ ○ ○ ○ ○ ○	Comforting
Concentration	○ ○ ○ ○ ○ ○ ○	Distraction
Inspirational	○ ○ ○ ○ ○ ○ ○	Boring
Secure	○ ○ ○ ○ ○ ○ ○	Risk-taking
Dynamic	○ ○ ○ ○ ○ ○ ○	Static
Conflicting	○ ○ ○ ○ ○ ○ ○	Cohesive

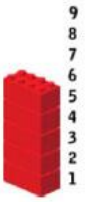
4. Rank the following three images according to how creative the environments look visually (1=Most Creative to 3=Least Creative).

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)



4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would choose to work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)

4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

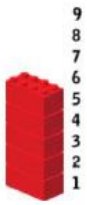
4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)



4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

5. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am a creative person.					
The workplace can foster creativity.					
I like to do creative work.					
Not all workplaces are creative.					
I can be creative in any place.					
My surroundings do not have an impact on my creative behavior.					

6. Rank the following three images according to how creative the environments look visually (1=Most Creative to 3=Least Creative).

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)

4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)

4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

- ☐ Structural Size
- ☐ Structural Shape
- ☐ Quantity of Light
- ☐ Quality of Light
- ☐ Aesthetic Interest
- ☐ Materiality
- ☐ Texture
- ☐ Color
- ☐ Furniture
- ☐ Visual Details
- ☐ Complexity
- ☐ Transparency
- ☐ Furniture Arrangement
- ☐ Symbolic Objects
- ☐ Presence of Nature (e.g. plants, view, etc.)

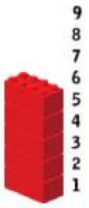
4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

4a. How would you describe this environment? Please write **three adjectives** that best describe the space.

4b. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This is a creative workplace.	○	○	○	○	○
I would work in this environment to do creative work.	○	○	○	○	○

4c. How would you score the creativity of this space from a scale of 1 to 9 (1=low creativity; 9=high creativity)



4d. What physical environment attributes **support** the creativity of this workplace? Please check all that apply.

☐ Structural Size	☐ Materiality	☐ Complexity
☐ Structural Shape	☐ Texture	☐ Transparency
☐ Quantity of Light	☐ Color	☐ Furniture Arrangement
☐ Quality of Light	☐ Furniture	☐ Symbolic Objects
☐ Aesthetic Interest	☐ Visual Details	☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **support** the creativity of this workplace.

4d. What physical environment attributes **hinder** the creativity of this workplace? Please check all that apply.

☐ Structural Size	☐ Materiality	☐ Complexity
☐ Structural Shape	☐ Texture	☐ Transparency
☐ Quantity of Light	☐ Color	☐ Furniture Arrangement
☐ Quality of Light	☐ Furniture	☐ Symbolic Objects
☐ Aesthetic Interest	☐ Visual Details	☐ Presence of Nature (e.g. plants, view, etc.)

4e. Name three specific elements in the image that **hinder** the creativity of this workplace.

7. To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Creativity is important in my discipline/field.	○	○	○	○	○
I hope my future work involves creativity.	○	○	○	○	○
A creative workplace is an important factor in making my future job decision.	○	○	○	○	○

8. Name three specific elements in the physical environment that are essential for your creative workplace.

9. My expected graduation year is

- ○ 2011
- ○ 2012
- ○ 2013
- ○ 2014
- ○ 2015
- ○ 2016

10. I am currently a

- ○ undergraduate student
- ○ graduate student
- ○ other

APPENDIX B
MEASURES USED FOR LIGHTING EXPERIMENTS

Mood Scale

Take about two minutes to really get into the mood of the situation; then rate your feelings in the situation with the adjective pairs below. Some of the pairs might seem unusual, but you'll probably feel more one way than the other. So, for each pair, place an 'X' on the line close to the adjective which you believe to describe your feelings better. The more appropriate that adjective seems, the closer you put your 'X' mark to it.

Jittery	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Dull
Satisfied	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Unsatisfied
Bored	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Relaxed
Excited	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Calm
Melancholic	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Contented
Happy	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Unhappy
Sluggish	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Frenzied
Despairing	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Hopeful
Sleepy	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Wide-awake
Pleased	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Annoyed
Unaroused	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Aroused
Stimulated	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Relaxed

The Adjective Check List

By Harrison G. Gough, Ph.D.

Name: Gender: ❑ Male ❑ Female

Directions: This answer sheet contains a list of 300 adjectives. Please read through them quickly and place a mark beside each one you would consider to be self-descriptive. Do not worry about duplications, contradictions, and so forth. Work quickly and do not spend too much time on any one adjective. Try to be frank, and place a mark beside the adjectives which describe you as you really are, not as you would like to be. Be sure to continue through adjective number 300.

1 ❑ absent-minded	36 ❑ cold	71 ❑ dreamy	106 ❑ hard-headed	141 ❑ lazy
2 ❑ active	37 ❑ commonplace	72 ❑ dull	107 ❑ hard-hearted	142 ❑ leisurely
3 ❑ adaptable	38 ❑ complaining	73 ❑ easygoing	108 ❑ hasty	143 ❑ logical
4 ❑ adventurous	39 ❑ complicated	74 ❑ effeminate	109 ❑ headstrong	144 ❑ loud
5 ❑ affected	40 ❑ conceited	75 ❑ efficient	110 ❑ healthy	145 ❑ loyal
6 ❑ affectionate	41 ❑ confident	76 ❑ egotistical	111 ❑ helpful	146 ❑ mannerly
7 ❑ aggressive	42 ❑ confused	77 ❑ emotional	112 ❑ high-strung	147 ❑ masculine
8 ❑ alert	43 ❑ conscientious	78 ❑ energetic	113 ❑ honest	148 ❑ mature
9 ❑ aloof	44 ❑ conservative	79 ❑ enterprising	114 ❑ hostile	149 ❑ meek
10 ❑ ambitious	45 ❑ considerate	80 ❑ enthusiastic	115 ❑ humorous	150 ❑ methodical
11 ❑ anxious	46 ❑ contented	81 ❑ evasive	116 ❑ hurried	151 ❑ mild
12 ❑ apathetic	47 ❑ conventional	82 ❑ excitable	117 ❑ idealistic	152 ❑ mischievous
13 ❑ appreciative	48 ❑ cool	83 ❑ fair-minded	118 ❑ imaginative	153 ❑ moderate
14 ❑ argumentative	49 ❑ cooperative	84 ❑ fault-finding	119 ❑ immature	154 ❑ modest
15 ❑ arrogant	50 ❑ courageous	85 ❑ fearful	120 ❑ impatient	155 ❑ moody
16 ❑ artistic	51 ❑ cowardly	86 ❑ feminine	121 ❑ impulsive	156 ❑ nagging
17 ❑ assertive	52 ❑ cruel	87 ❑ fickle	122 ❑ independent	157 ❑ natural
18 ❑ attractive	53 ❑ curious	88 ❑ flirtatious	123 ❑ indifferent	158 ❑ nervous
19 ❑ autocratic	54 ❑ cynical	89 ❑ foolish	124 ❑ individualistic	159 ❑ noisy
20 ❑ awkward	55 ❑ daring	90 ❑ forceful	125 ❑ industrious	160 ❑ obliging
21 ❑ bitter	56 ❑ deceitful	91 ❑ foresighted	126 ❑ infantile	161 ❑ obnoxious
22 ❑ blustery	57 ❑ defensive	92 ❑ forgetful	127 ❑ informal	162 ❑ opinionated
23 ❑ boastful	58 ❑ deliberate	93 ❑ forgiving	128 ❑ ingenious	163 ❑ opportunistic
24 ❑ bossy	59 ❑ demanding	94 ❑ formal	129 ❑ inhibited	164 ❑ optimistic
25 ❑ calm	60 ❑ dependable	95 ❑ frank	130 ❑ initiative	165 ❑ organized
26 ❑ capable	61 ❑ dependent	96 ❑ friendly	131 ❑ insightful	166 ❑ original
27 ❑ careless	62 ❑ despondent	97 ❑ frivolous	132 ❑ intelligent	167 ❑ outgoing
28 ❑ cautious	63 ❑ determined	98 ❑ fussy	133 ❑ interests narrow	168 ❑ outspoken
29 ❑ changeable	64 ❑ dignified	99 ❑ generous	134 ❑ interests wide	169 ❑ painstaking
30 ❑ charming	65 ❑ discreet	100 ❑ gentle	135 ❑ intolerant	170 ❑ patient
31 ❑ cheerful	66 ❑ disorderly	101 ❑ gloomy	136 ❑ inventive	171 ❑ peaceable
32 ❑ civilized	67 ❑ dissatisfied	102 ❑ good-looking	137 ❑ irresponsible	172 ❑ peculiar
33 ❑ clear-thinking	68 ❑ distractible	103 ❑ good-natured	138 ❑ irritable	173 ❑ persevering
34 ❑ clever	69 ❑ distrustful	104 ❑ greedy	139 ❑ jolly	174 ❑ persistent
35 ❑ coarse	70 ❑ dominant	105 ❑ handsome	140 ❑ kind	175 ❑ pessimistic

LARK, HUMMINGBIRD or OWL QUESTIONNAIRE

Answer ALL questions in order and independently of others. Do NOT go back and check your answers. For each question choose ONE answer only. Write the answer number in the SCORE box.

1. What time would you get up if you were entirely free to plan your own day?

5-6:30 am	6:30-7:45 am	7:45-9:45 am	9:45-11:00 am	11:00-12 noon	**SCORE**
5	4	3	2	1	

2. What time would you go to bed if you were entirely free to plan your evening?

8-9:00 pm	9-10:15 pm	10:15-12:30 am	12:30-1:45 am	1:45-3:00 am	**SCORE**
5	4	3	2	1	

3. How dependent are you on being woken up by an alarm clock?

Not at all	Slightly dependent	Fairly dependent	Very dependent	**SCORE**
4	3	2	1	

4. How easy do you find getting up in the mornings?

Not at all	Not very easy	Fairly easy	Very easy	**SCORE**
1	2	3	4	

5. How alert do you feel during the first half-hour after having woken in the morning?

Not at all	Not very alert	Fairly alert	Very alert	**SCORE**
1	2	3	4	

6. How is your appetite during the first half-hour after having woken in the morning?

Very Poor	Fairly poor	Fairly good	Very good	**SCORE**
1	2	3	4	

7. During the first half-hour after having woken in the morning, how tired do you feel?

Very tired	Fairly tired	Fairly refreshed	Very refreshed	**SCORE**
1	2	3	4	

8. When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?

Seldom or never later	Less than one hour later	1-2 hours later	More than two hours later	**SCORE**
4	3	2	1	

9. How well would you perform one hour's physical exercise between 7-8:00am?

Would be in good form	Would be in reasonable form	Would find it difficult	Would find it very difficult	**SCORE**
4	3	2	1	

10. When do you feel tired and in need of sleep?

8-9:00 pm	9-10:15 pm	10:15-12:30 am	12:30-1:45 am	1:45-3:00 am	**SCORE**
5	4	3	2	1	

11. Which ONE of the four testing times would you choose to take a 2 hour test?

8-10:00 am	11:00 am-1:00 pm	3:00-5:00 pm	7:00-9:00 pm	**SCORE**
4	3	2	1	

12. If you went to bed at 11:00 pm. how tired would you be?

Not at all	A little tired	Fairly tired	Very tired	**SCORE**
0	2	3	5	

13. If you go to bed much later than usual, but don't need to get up at any particular time the next morning, which ONE of the following events are you most likely to experience?

Will wake up at usual time and will NOT fall asleep	Will wake up at usual time but will doze	Will wake up at usual time but will fall asleep again	Will NOT wake up at usual time	**SCORE**
4	3	2	1	

14. If you had to stay awake between 4:00 - 6:00 am and you had no commitments the next day. Which ONE of the following alternatives would you choose?

Would NOT go to bed until after 6 am	Would take a nap before 4 am and then sleep after	Would take a good sleep before 4am and then nap after	Would take ALL sleep before 4am	**SCORE**
1	2	3	4	

15.You have to do two hours of hard physical work. Now you are entirely free to plan your day. Which ONE of the following times would you choose MOST to do stuff?

8-10:00 am	11:00 am-1:00 pm	3:00-5:00 pm	7:00-9:00 pm	**SCORE**
4	3	2	1	

16. You are planning a hard physical workout with a friend. You will do this for one hour twice a week. The best time for your friend is between 10:00-11:00pm. How well do you think you would perform at this time?

Would be in good form	Would be in reasonable form	Would find it difficult	Would find it very difficult	**SCORE**
1	2	3	4	

17. Suppose that you've graduated High School and you can choose your own work hours. Assume you work a FIVE-hour day (including breaks) at an interesting job and are paid by your results. Which FIVE CONSECUTIVE HOURS would you select?

3:00-7:30 am	7:30am – 12:30pm	Between 9:00 am-2:00pm	Between 2-7:00 pm	Between 5:00 pm–3:00 am	**SCORE**
5	4	3	2	1	

18. At what time of the day do you think that you reach your "feeling best" peak?

4-7:30 am	7:30-9:30 am-	Between 9:30am- 4:30pm	Between 4:30-9:30 pm	9:30 pm-4:00 am	**SCORE**
5	4	3	2	1	

19. Do you think you are a "morning" or "evening" type of person?

Definitely a "morning" type	Probably a "morning" type	Probably an "evening" type	Definitely an "evening" type	**SCORE**
6	3	2	1	

TOTAL YOUR SCORE for all of the questions.

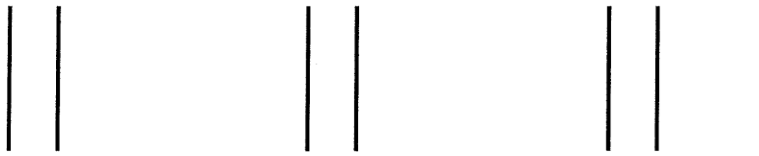
LARK < HUMMINGBIRD > OWL

Definitely a "morning" type	Moderately a "morning" type	Neither type	Moderately an "evening" type	Definitely an "evening" type	**TOTAL SCORE**
70-86	59-69	42-58	31-41	16-30	

Reference:
Adapted from Horne, J. A. and O. Ostberg (1976) "A Self Assessment Questionnaire to Determine Morningness-Eveningness in Human Circadian Rhythms", International Journal of Chronobiology, 4, 97-110.

Activity 3. LINES

In ten minutes see how many objects or pictures you can make from the pairs of straight lines below and on the next two pages. The pairs of straight lines should be the main part of whatever you make. With pencil or crayon add lines to the pairs of lines to complete your picture. You can place marks between the lines, on the lines, and outside the lines—wherever you want to in order to make your picture. Try to think of things that no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one. Make them tell as complete and as interesting a story as you can. Add names or titles in the spaces provided.



1. _____ 2. _____ 3. _____

4. _____ 5. _____ 6. _____

Environment Survey

The following statements ask about your thoughts on the environment where you currently are in (study location). Please indicate the degree to which you agree or disagree with these statements by circling the appropriate response.

		Strongly disagree	*Slightly disagree*	Neutral	*Slightly agree*	*Strongly agree*
1.	The lighting was too dim.	1	2	3	4	5
2.	The environment was restful.	1	2	3	4	5
3.	The chair was uncomfortable to work in.	1	2	3	4	5
4.	I wanted to lower the lights in the room.	1	2	3	4	5
5.	The presence of color in the room would have helped my performance on the tasks.	1	2	3	4	5
6.	I would have liked to have task lighting (i.e. extra light stand).	1	2	3	4	5
7.	The seating arrangement was conducive for the tasks.	1	2	3	4	5
8.	The air quality of the room was just right.	1	2	3	4	5
9.	The surroundings did not have an impact on me.	1	2	3	4	5
10.	I would have liked some daylight in the room.	1	2	3	4	5
11.	The environment was too quiet to complete the tasks.	1	2	3	4	5
12.	The room was brighter than where I normally work.	1	2	3	4	5
13.	I prefer a warmer hue of lighting than the current lighting conditions.	1	2	3	4	5
14.	I had a hard time concentrating in this room.	1	2	3	4	5
15.	I felt cold in this room.	1	2	3	4	5
16.	This environment positively affected my performance on the tasks.	1	2	3	4	5
17.	I would come to this room to do creative work.	1	2	3	4	5
18.	I wish there were some plants in the room.	1	2	3	4	5
19.	The environment was appropriate for completing the tasks.	1	2	3	4	5
20.	The environment has a pleasant atmosphere.	1	2	3	4	5

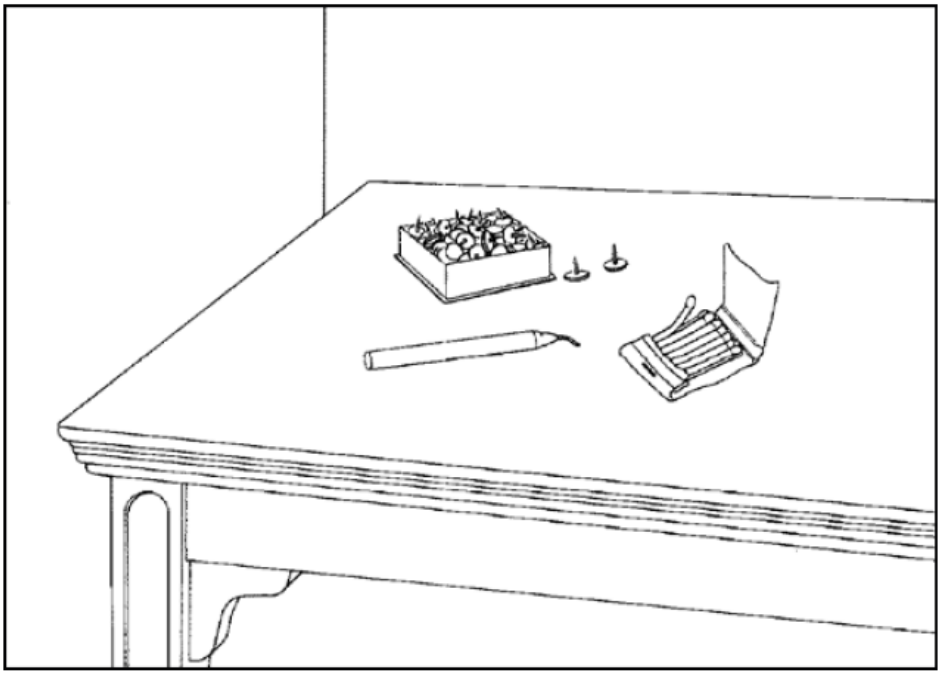
Attitudes toward Creative Work

The following statements ask about your thoughts on creative work and creative workplaces. Please indicate the degree to which you agree or disagree with these statements by circling the appropriate response.

		Strongly disagree	*Slightly disagree*	Neutral	*Slightly agree*	*Strongly agree*
1.	I am a creative person.	1	2	3	4	5
2.	Creativity is important in my discipline/field.	1	2	3	4	5
3.	The workplace can foster creativity.	1	2	3	4	5
4.	I like to do creative work.	1	2	3	4	5
5.	I hope my future work involves creativity.	1	2	3	4	5
6.	I can be creative in any place.	1	2	3	4	5
7.	Not all workplaces are creative.	1	2	3	4	5

APPENDIX C
ADDITIONAL MEASURES USED FOR EXPERIMENT 3

Problem Solving Task #1



Given a candle, a book of matches, and a box of thumbtacks, how would you fix a lit candle on the wall (cork board) in a way so the candle wax won't drip onto the table below?

Problem Solving Task #2

A window washer was cleaning the windows of a high rise building when he slipped and fell off a sixty-foot ladder onto the concrete sidewalk below. Incredibly he did not injure himself in any way. How was this possible?

Problem Solving Task #3

A man had a 2 dollar bill and wanted to buy a train ticket that cost 3 dollars. He took the 2 dollar bill to a pawn shop where he pawned it for $1.50. On the way to the train station, he met a friend to whom he sold the pawn ticket for $1.50. He then had 3 dollars with which to buy his ticket. Who was out the extra dollar?

Problem Solving Task #4

Whoever makes it doesn't use it, whoever buys it doesn't want it and whoever uses it doesn't know it? What is "**it**"?

Drawing Task

Imagine going to another galaxy in the universe and visiting a planet very different from earth. Imagine finding an animal there. What would it look like? Please draw a front and side view of the animal.

APPENDIX D
ADDITIONAL MEASURES USED FOR EXPERIMENT 4

Problem Solving Task #5

Water lilies double in area every 24 hours. At the beginning of summer there is one water lily on the lake. It takes 60 days for the lake to become completely covered with water lilies. On which day is the lake half covered?

Problem Solving Task #6

While on safari in the wild jungles of Africa, Professor White woke one morning and felt something in the back pocket of her shorts. It had a head and a tail but no legs. When White got up she could feel it move inside her pocket. White however showed little concern and went about her morning rituals. Why such a casual attitude toward the thing in her pocket?

Problem Solving Task #7

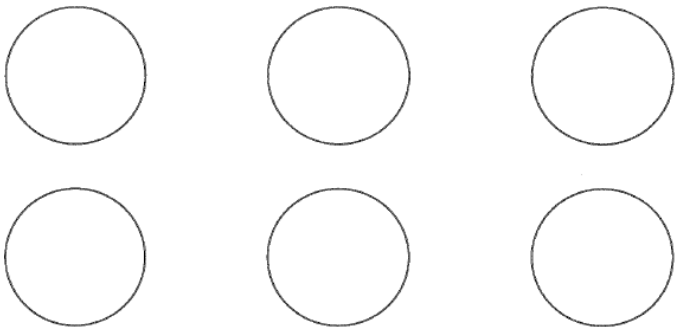
The legendary runner Flash Fleetfoot was so fast that his friends said he could turn off the light switch and jump into bed before the room got dark. On one occasion Flash proved he could do it. How?

Problem Solving Task #8

There are two strings hanging from the ceiling in the room below. The woman cannot reach both. How can she tie the two strings together?

Activity 3. CIRCLES

In ten minutes see how many objects or pictures you can make from the circles below and on the next page. The circles should be the main part of whatever you make. With pencil or crayon add lines to the circles to complete your picture. You can place marks inside the circles, outside the circles, or both inside and outside the circles—wherever you want to in order to make your picture. Try to think of things that no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one. Make them tell as complete and as interesting a story as you can. Add names or titles below the objects.



Environment Survey (Part 1)

The following statements ask about your thoughts on the environment where you currently are in (study location). Please indicate the degree to which you agree or disagree with these statements by circling the appropriate response.

		Strongly disagree	*Slightly disagree*	Neutral	*Slightly agree*	*Strongly agree*
1.	The lighting is dim.	1	2	3	4	5
2.	The environment is restful.	1	2	3	4	5
3.	The chair is uncomfortable for work.	1	2	3	4	5
4.	I want to lower the lights in the room.	1	2	3	4	5
5.	The presence of color in the room would support my creative performance.	1	2	3	4	5
6.	I would prefer to have task lighting (i.e. extra light stand).	1	2	3	4	5
7.	The furniture arrangement is appropriate for individual creative work	1	2	3	4	5
8.	The air quality of the room is just right.	1	2	3	4	5
9.	Physical surroundings do not have an impact on me.	1	2	3	4	5
10.	I would have liked some daylight in the room.	1	2	3	4	5
11.	The environment is quiet for creative work.	1	2	3	4	5
12.	The lighting in the room should be brighter.	1	2	3	4	5
13.	I prefer a warmer hue of lighting than the current lighting conditions.	1	2	3	4	5
14.	This room is set for concentrating on work.	1	2	3	4	5
15.	I feel cold in this room.	1	2	3	4	5
16.	This environment gives me a positive attitude in doing creative work.	1	2	3	4	5
17.	I would come to this room to do creative work.	1	2	3	4	5
18.	I wish there were some plants in the room.	1	2	3	4	5
19.	The environment is not appropriate for creative work.	1	2	3	4	5
20.	The environment has a pleasant atmosphere.	1	2	3	4	5

Perception of Environment

What is your perception of the environment?

_____

_____

_____

Why, or why not, is a place for creative work?

_____

_____

_____

Attitudes toward Creative Work

The following statements ask about your thoughts on creative work and creative workplaces. Please indicate the degree to which you agree or disagree with these statements by circling the appropriate response.

		Strongly disagree	*Slightly disagree*	**Neutral**	*Slightly agree*	*Strongly agree*
1.	I am a creative person.	1	2	3	4	5
2.	Creativity is important in my discipline/field.	1	2	3	4	5
3.	The workplace can foster creativity.	1	2	3	4	5
4.	I like to do creative work.	1	2	3	4	5
5.	I hope my future work involves creativity.	1	2	3	4	5
6.	I can be creative in any place.	1	2	3	4	5
7.	Not all workplaces are creative.	1	2	3	4	5

Creative Workplace Description

Think about the physical environment where you go to do creative work. Briefly describe the physical characteristics of that environment.

What makes the environment creative?

How does the environment support your creativity?

Environment Survey (Part 2)

What are your lighting preferences for doing creative work?

The following statements ask about your thoughts on the environment where you currently are in (study location). Please indicate the degree to which you agree or disagree with these statements by circling the appropriate response.

		Strongly disagree	*Slightly disagree*	Neutral	*Slightly agree*	*Strongly agree*
1.	This environment gives me a positive attitude in doing creative work.	1	2	3	4	5
2.	The environment is restful.	1	2	3	4	5
3.	I want to increase the light level in the room.	1	2	3	4	5
4.	I would prefer to have task lighting (i.e. extra light stand).	1	2	3	4	5
5.	The environment has a pleasant atmosphere.	1	2	3	4	5
6.	This room is set for concentrating on work.	1	2	3	4	5
7.	The lighting is dim.	1	2	3	4	5
8.	I would come to this room to do creative work.	1	2	3	4	5
9.	The lighting in the room should be dimmer.	1	2	3	4	5
10.	The environment is appropriate for creative work.	1	2	3	4	5

Perception of Environment

What is your perception of the environment?

What makes it a place for creative work?

Creative Workplace Scale

For each word pair, place an 'X' on the line which reflects the extent to which you believe the words describe what a creative workplace environment should be.

Messy	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Organized
Traditional	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Modern
Quiet	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Noisy
Natural	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Artificial
Unique	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Standard
Casual	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Formal
Warm	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Cool
Symmetric	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Asymmetric
Color	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Black & White
Familiar	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	New
Dim	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Bright
Public	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Private
Simple	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Complex
Energetic	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Calm
Inspirational	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Boring
Concentration	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Distraction
Playful	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Serious
Consistent	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Changing
Autonomous	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Collaborative
Dynamic	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Static
Risk-taking	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Secure
Personal Space	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Communal Space
Purposeful	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Undirected
Open	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Closed
Constraint	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Freedom
Stimulating	_____ :: _____ :: _____ :: _____ :: _____ :: _____ :: _____	Comforting

Demographic Information

Please indicate your gender:

- ☐ Male
- ☐ Female

Please indicate your class year:

- ☐ Senior
- ☐ Junior
- ☐ Sophomore
- ☐ Freshman
- ☐ Other: _____

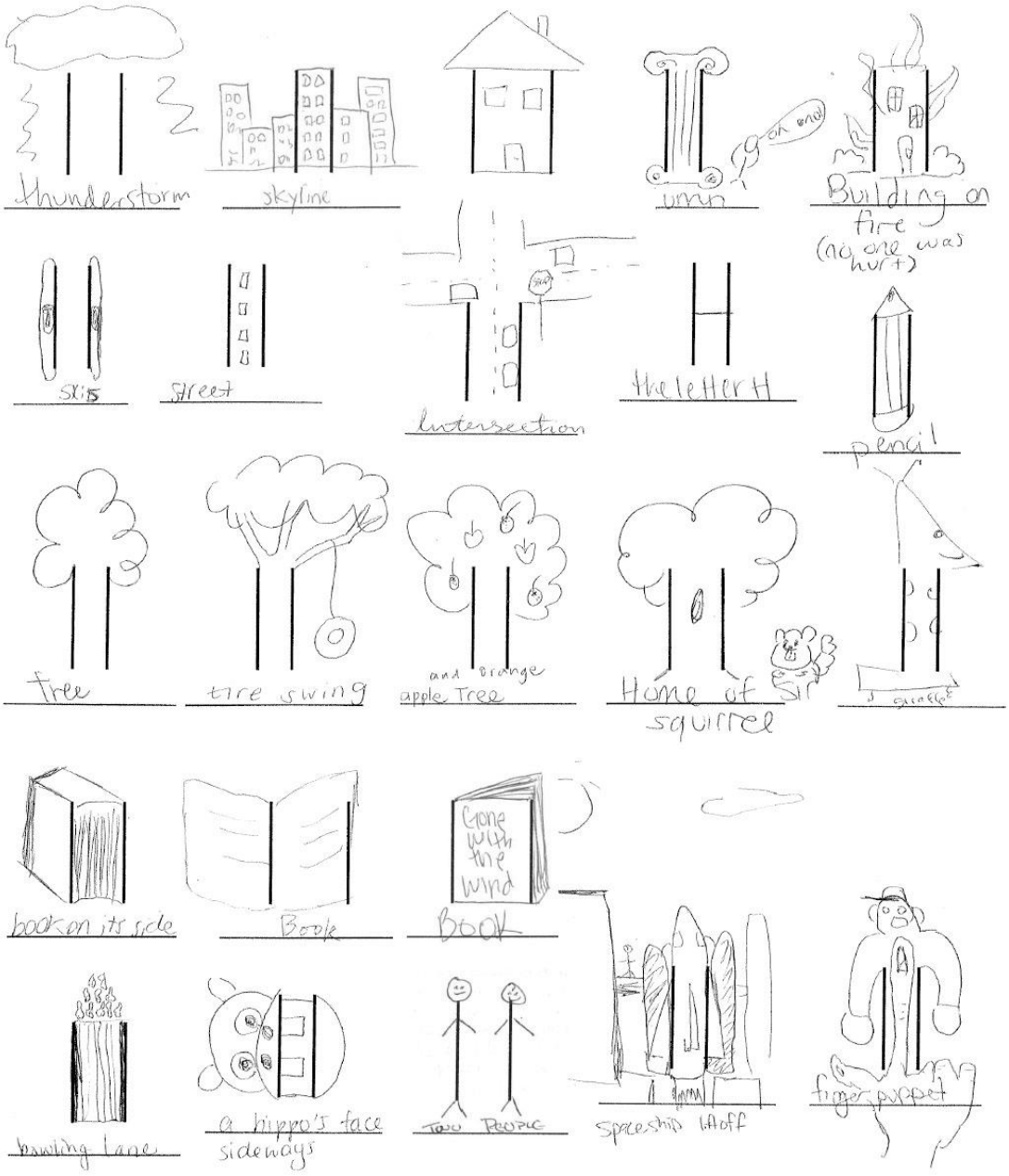
What is your age? _____ What is your major? _____

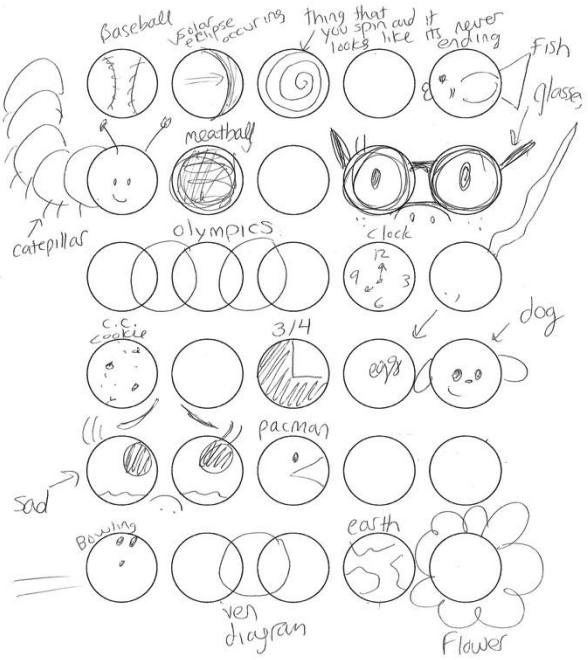
Thank You!

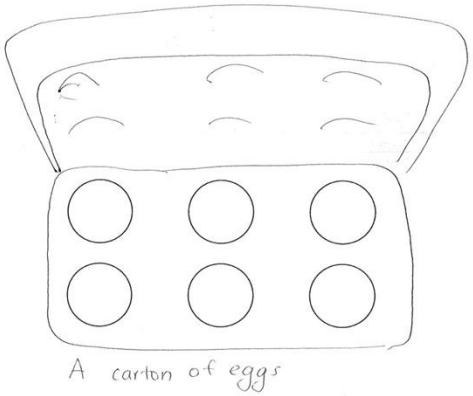
APPENDIX E

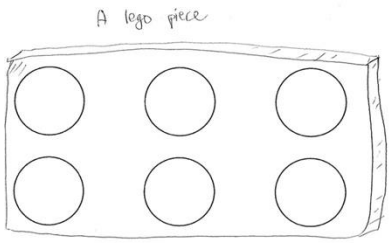
EXAMPLES OF OUTCOMES FOR THE TORRANCE TEST FOR CREATIVE THINKING

FIGURAL FORM A AND FORM B



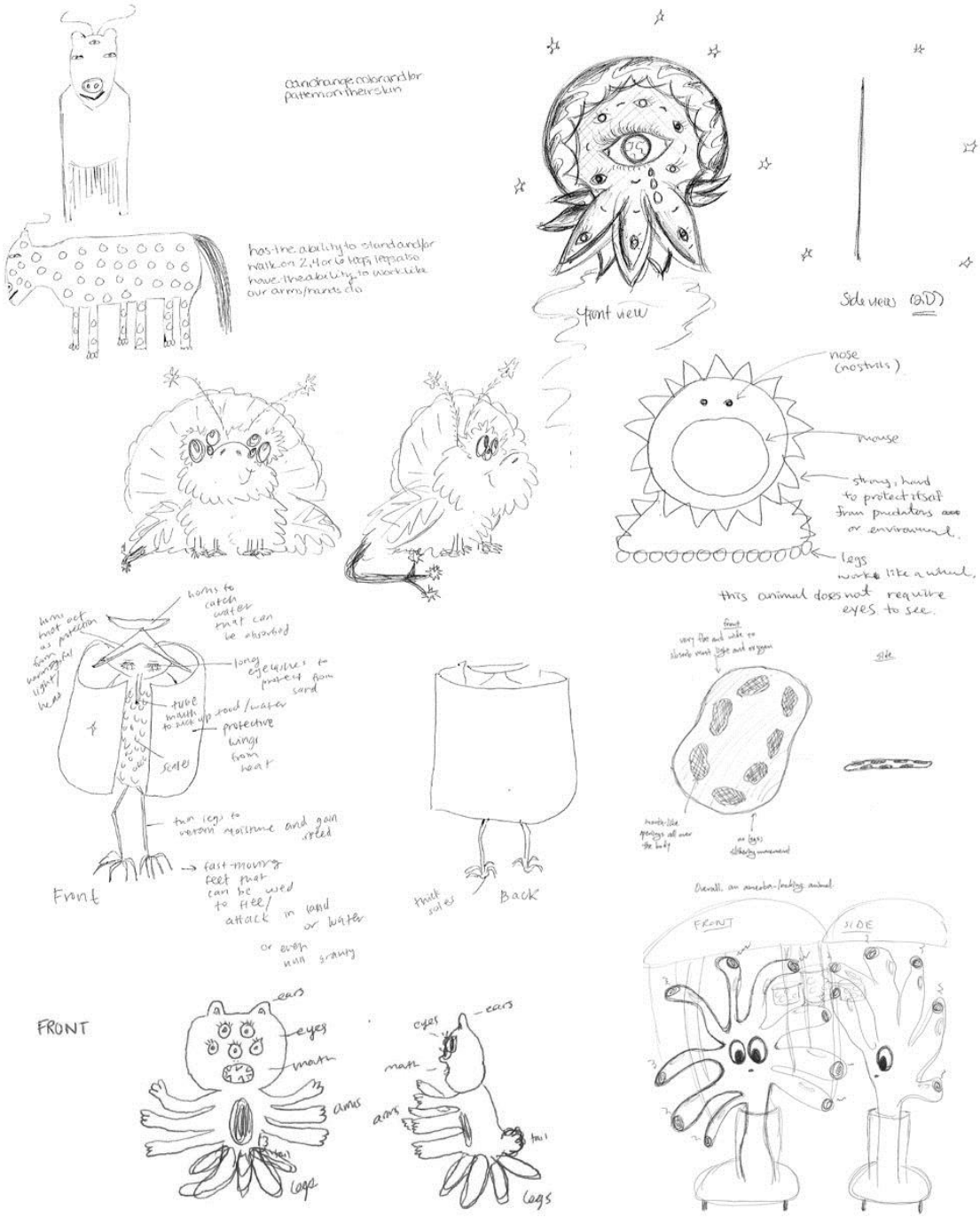

Baseball
Solar eclipse occurring
thing that you spin and it looks like its never ending
Fish
glasses
meatball
caterpillar
olympics
clock
c.c. cookie
3/4
dog
eggs
pacman
sad
Bowling
earth
ven diagram
Flower


A carton of eggs


A lego piece

APPENDIX F

EXAMPLES OF OUTCOMES FOR THE STRUCTURED IMAGINATION TASK



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