2003

An analysis of architectural space using stereoscopic visualization

Lee Choon Loh
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Loh, Lee Choon, "An analysis of architectural space using stereoscopic visualization" (2003). *Master's Theses*. 2410.

DOI: <https://doi.org/10.31979/etd.apwq-29xg>
https://scholarworks.sjsu.edu/etd_theses/2410

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

NOTE TO USERS

This reproduction is the best copy available.

UMI[®]

AN ANALYSIS OF ARCHITECTURAL SPACE USING
STEREOSCOPIC VISUALIZATION

A Thesis

Presented to

The Faculty of the Department of Interdisciplinary Studies

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Lee Choon Loh

May 2003

UMI Number: 1415722

Copyright 2003 by
Loh, Lee Choon

All rights reserved.

UMI[®]

UMI Microform 1415722

Copyright 2003 by ProQuest Information and Learning Company.

All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

© 2003

Lee Choon Loh

ALL RIGHTS RESERVED

APPROVED FOR THE DEPARTMENT OF
INTERDISCIPLINARY STUDIES

Dr. Robert Cooper, Thesis Chairperson

Professor Brian Kimura, Thesis Committee Member

Dr. Jill Steinberg, Thesis Committee Member

APPROVED FOR THE UNIVERSITY

Abstract

AN ANALYSIS OF ARCHITECTURAL SPACE USING STEREOSCOPIC VISUALIZATION

by Lee Choon Loh

This study is an investigation of the effect of architectural space and the environment on work performance, a topic of particular relevance to interior space designers. Previous research focused on the importance of windows in a working environment. This experiment simulated a workspace environment and manipulated a wall to suggest the existence of a window using stereoscopic visualization. A one-way ANOVA was used to assess differences in performance measured using the Figural Form of the Torrance Tests of Creative Thinking and the Mental Rotation Test. Each participant (n=44) performed both tests under one of four conditions: stereoscopic view of the three-dimensional window image, monoscopic view of the three-dimensional window image, a two-dimensional image of a calligraphic character or no image at all. Although participants in the “windowed” environment did not perform significantly better than participants who were in the “windowless” environment, the mean results indicate a marginal increase. Implications and suggestions for future research are discussed.

ACKNOWLEDGEMENTS

There are a few people in my life that I would like to thank for my accomplishment. First of all I thank my parents, Mr. and Mrs. Loh Chong Urn, who had showed me that nothing is impossible. They believed in me from the very beginning and helped me follow through with my dream.

My sister, Lina van Scherrenburg, supported me for so long and never gave up on me. She sacrificed so much to see her little sister succeed. I cannot thank her enough for being such an inspiration to me.

The two Mikes in my life, my brother, Michael Loh, and my brother-in-law, Micheal van Scherrenburg, gave me insightful suggestions and encouraged me whenever the journey got a little rocky.

I would like to give my dearest thanks to my husband, Hak-Leong Ng, who was always there with me every step of the way, giving me wonderful ideas and encouragement. Not only was he my technical support and my baby-sitter to our beautiful daughter, Samantha, he was my shoulder-to-cry-on. Thank you for your loving care and your commitment.

My professors, Dr. Robert Cooper, Dr. Jill Steinberg, and Professor Brian Kimura, showed me the way. Their guidance and wise advice brought this project to reality. I would also like to thank John Empey who had scouted high and low for the right equipment for this simulation.

Last but not least, I thank my friends, Jennifer Walters, Tuan Tran and Khim Lok for their time, energy and most importantly, their unconditional friendship.

TABLE OF CONTENTS

SECTION	PAGE
INTRODUCTION.....	1
Architectural Psychology.....	1
Window and Embellishment.....	2
Simulation and Presence.....	5
Hypothesis 1.....	9
Hypothesis 2.....	9
METHOD.....	10
Materials.....	10
Stimuli.....	12
Mental Rotation Test and Torrance Tests of Creative Thinking.....	13
Procedure.....	14
RESULTS.....	15
Mental Rotation Test.....	15
Torrance Test of Creative Thinking.....	15
DISCUSSION.....	18
REFERENCES.....	25
APPENDICES.....	28
Appendix A. Human Subjects-Institutional Review Board Approval Form.....	28

Appendix B. Layout of the Laboratory.....	29
Appendix C. Torrance Tests of Creative Thinking.....	30
Appendix D. Mental Rotation Test.....	38

LIST OF TABLES

TABLE	PAGE
1. Analysis of Variance for Mental Rotation Test.....	16
2. Comparison of Means and Standard Deviations of Mental Rotation Test.....	17
3. Comparison of Means and Standard Deviations of Torrance Tests of Creative Thinking.....	19
4. Analysis of Variance for Torrance Tests of Creative Thinking.....	20

Introduction

Architectural Psychology

As early as the 1960s, people began to recognize the existence of a connection between architecture and psychology, and strove to understand it (Garling, 1969). A report released in 1965 by the Pilkington Research Unit provided a better understanding of the importance of the environment in modern office buildings (Manning, 1965). It was the first example of a multi-disciplinary team investigating the causal relation between people's performance and their physical world. This multi-disciplinary team included an architect, a geographer, a physicist, and a psychologist. Each of them delved into different parts of the "total environment" (i.e., lighting, heating, ventilation, acoustics) to find important information that would assist building design professionals develop more fruitful work environments. The team also advanced the concept that the office environment must be viewed as a whole, and in so doing, advocated the notion that each element's effect is influenced by all the other elements. It was the first step towards a quantifiable approach, replacing architects and owners' intuition with knowledge and methods of measurement. The study successfully demonstrated that a working environment, designed by an architect, could influence human behavior in many ways.

A new generation of designers began to realize the crucial role they play influencing human behavior by manipulating physical space (Lee, 1971). They started to collect feedback information from tenants of existing buildings, and analyzed the results to research possible effects of the environment on human behavior. An example of this would be the Post Occupancy Evaluation (POE), a technique used by designers as an

observation method to evaluate buildings after they were built (Philip, 1996). Over time, patterns emerged from these assessments. Scientists investigated the repetitive disposition of the variables in hopes of finding formulas that would synthesize information and knowledge. This in turn would allow investigators to predict behaviors of subjects when exposed to certain variables. That information would eventually loop back to designers to manipulate existing structures or environments in hopes of achieving optimum results in human performance (Lee, 1971). Unfortunately, the POE technique prevented architects and designers from exploring beneficial variables in the building that would contribute to appropriate behavioral requirements because evaluators focused solely on deficiencies (Philip, 1996). Today, with the capabilities of advanced technologies, researchers are trying out new ways to test alternate designs, using simulation techniques, so that different environments can be studied to understand the roles different variables have on human behavior. Data collected would be used in a systematic method of measurement that is quantifiable so that various elements can be discovered. Architects and interior designers could then assimilate the factual information and modify their designs accordingly.

Window and Embellishment

There are several building structures that influence human behavior, but windows seem to be the one structure most explored. It is because windows influence many criteria in a building, from sunlight to view and privacy (Marcus, 1967). Historically, windows symbolized a “hole in the sky” for the entrance of spirits from the cosmos.

Aesthetically, it serves as a work of art for design purposes. Functionally, windows, especially in a work environment, are an important part of an intense and growing interest in the behavioral sciences.

Many employees prefer to have a window located near their workspace (Collins, 1975; Finnegan & Solomon, 1981; Wotton, Blackwell, Wallis, & Barkow, 1982; Cuttle, 1983 and Wotton & Barkow, 1983). Although people might prefer to have different size windows in different environments (bathroom, family room, etc.), participants in Butler and Biner's (1989) experiment suggested that they prefer to work in an office with a clear, medium-sized window on one wall. These participants reported that with a view of the outside and sunlight from the window, they are able to sustain a better frame of mind. Hence, they perform better at their tasks. Analysis also showed that females, who show a stronger liking for sunshine than males, sit significantly further away from the nearest window (Markus, 1967). Stone and Irvine (1994) concluded that participants perform better when facing a window during the tests, judging from the number of items completed in the filing, computational, and creativity tasks they used in their study.

Heerwagen and Orians (1986) surveyed 75 offices to investigate how individuals from a windowless environment cope with their spaces using visual decorations. Results revealed that participants in windowless offices display significantly more visual decorations to make up for the loss of window scenes. Many displays consisted of landscapes rather than cityscapes, and windowless offices had significantly more nature-oriented visual materials compared to windowed offices. Apparently, people developed a strong need to connect nature to their workspace in order to create a source of comfort for

themselves. People working in windowless offices apparently use nature-oriented visual materials to substitute for the natural world.

Tognoli (1973) examined, in the laboratory, variations of the environment that might affect participants' attitude. Laboratory variations included presence or absence of a window, presence or absence of decorations, and the type of chair given to the participants to sit on during the experiment. Fifty-six undergraduate male and female college students individually watched a ten-minute videotape before rating their attitude towards the room. The attitude scale revealed that participants rate embellished rooms more interesting than unembellished ones. It was also reported that participants felt significantly more pleased to participate in the study with the presence of a window rather than without a window.

Hence, there is ample evidence to suggest that windows are a major contributor to a better working environment. Those who work in windowless offices display pictures or decorations with a nature theme. When exposed to a windowed environment, employees are more energized. They score higher in creativity tests when exposed to a windowed environment as opposed to one without. People's attitude towards a room changes when the room is embellished and has a window.

The obstacle faced here is that not all offices can afford a window for each employee. Hence, instead of having just pictures and embellishments in the workspace, it is our intention to test the effect a room with a simulated window has on employees.

Simulation and Presence

Winkel and Sasanoff (1966) developed a laboratory tool using simulation of an architectural environment to experimentally study human behavior. The researchers took pictures of the intended environment using a camera loaded with slide films. They then used slide projectors to project the slides onto the screens that were placed around the laboratory booth to simulate the real world environment. Their main objective was to develop a method to study the planned or designed architectural, urban or landscaped environments without building the site beforehand. Results obtained were similar between the real and the simulated world environment, encouraging the possibilities of replicating results from the real world environment in experimental studies. In addition, the researchers were in control of the environment during the manipulation because they did not have to worry about changes and distractions that occurred in the real world environment. The disadvantage was that the pictures, although they depicted real scenes, did not simulate reality in three dimensions. The present study adopted ideas from this experiment, but took another leap to increase the reality of the environment using stereoscopic images.

Today, stereoscopic display systems exist in many fields of research and in many professions. Especially in the medical field, doctors and surgeons “play God”, conducting miraculous operations that were not possible before. Recently, a pair of Nepalese twins, born joined at the head, were successfully separated using a state-of-the-art three-dimensional imaging system (Associated Press, 2001). Photographers made use of stereographic techniques to prevent confusion, clutter and crowding in pictures and films

(Halbrook, 1998; Leonardo, 1999). NASA reported an enormous amount of investment in the flight simulation programs for scientific exploration of space (“9/30/88: SYRE receives,” 1988). Raytheon, a subcontractor to the BOEING Company, developed three-dimensional simulations of actual construction of several space-launch sites before construction even began, in order to prove that they would meet the requirements for the project provided by the US Air Force (Mahoney, 1998). The simulation incorporated information of the entire construction, from site preparation to structural development, all connected to a digital project schedule. It was not just an architectural rendering. The process allowed Raytheon to demonstrate the complexity of the construction process visually, using three-dimensional simulation. It also confirmed their ability to finish the construction within the two-year schedule.

Scientists are also looking into the possibility of combining Virtual Reality with Artificial Intelligence to develop more advanced and sophisticated forms of entertainment, communication, and education (Luck & Aylett, 2000). Slingshot Entertainment of Burbank, California allowed viewers to watch large-format (LF) films on DVD using the 3D home video system (Bankston, 2002). Viewers wore liquid-crystal shutter glasses or head mounted displays to view the stereoscopic images on their televisions. Yeh and Silverstein (1992) proposed that three-dimensional spatial perception would become critical in task performance. Due to the binocular disparity of the stereoscopic image, three-dimensional spatial judgment could be drastically improved compared to monoscopic presentation of perspective, and better judgments could be formed.

The study of stereoscopic visualization can be traced back to as early as ancient Greece (Sorensen & Russette, 1999). The famous painter/scientist, Leonardo da Vinci, understood the theory behind stereoscopic visualization (Sekular & Blake, 1994), but was unable to relate it to the art of his time. The reason was that it was almost impossible to produce two pictures from different perspectives where deviation in angle was as small as that which occurs between the left and the right eye. It was another 300 years before Sir Charles Wheatstone invented the first stereopticon while conducting research in the field of perception in 1838. His invention allowed for the fabrication of artificial three-dimensional images. All these took place before photography was even invented.

The word “stereo” is derived from the Greek word, meaning solid or firm. Stereoscopic visualization allows a person to see an object as a solid form with three different dimensions: width, height and depth. Since human eyes are set about two-and-a-half inches apart, each eye sees a slightly different image when looking at the same object from a slightly different angle. A stereoscopic image occurs when the brain fuses these two images together and constructs depth from two monoscopic images. As a result, a spatial relationship occurs between near and far objects, creating clarity, detail and depth perception. For the purpose of the present study, we focused on the realism aspect of the three-dimensional experience.

Although more sophisticated devices have been available on the market, a successful simulation does not require complete realism, but the ability to duplicate the system under study as precisely as possible without accessing the system itself (Sheridan, 1992). Thomas and Deemer (1957) defined simulation as, “the ability to attain the

essence of, without the reality.” Hence, participants could be situated at one location, but physically or mentally retrieving information from another location. Sheridan (1992) described this level of presence as the perception of the person situated at one location, but consciously responding to another remote location. As the response to the remote location increases, so does the person’s sense of presence. Jonathan, Avons, Pearson, and Ijsselsteijn (1999) conducted three studies to examine the extent of accurateness in visual displays needed to achieve that sense of “being there” in the remote location with the help of monoscopic and stereoscopic film clips. Participants watched three film clips in a monoscopic condition and then watched it again in a stereoscopic condition. These participants watched the film clips while sliding a hand held slider. The location of the hand held slider set the basis for the level of presence and was recorded by a personal computer. The first film section involved the observer moving around and the camera constantly following the observer. In the second film section, the observer and the camera remained still, but other actors around the room moved around. The third film section recorded minimal motion, and the camera remained still.

Participants felt a higher level of presence while they were watching the scene with the camera in motion during the stereoscopic condition in experiment one. Non-significant results in experiment two suggested that participants’ interest in the movie did not affect their ratings. A statistical interaction between training group and motion in experiment three revealed that the group previously trained in stereoscopic viewing understood that motion parallax increased the three-dimensionality of the picture. Consequently, despite their interest in the film clips, the extent of realism achieved while

viewing the film clips stereoscopically increased the participants' response to that remote location, and thus elevated their rating of presence.

Hypothesis 1

To this point, studies have shown that participants performed significantly better in a windowed room compared to a windowless room. Based on these results, it is hypothesized that participants in a three-dimensionally simulated windowed environment, regardless of whether it is stereoscopically or monoscopically presented, would perform significantly better than the participants who were in a room with a two dimensional picture or no picture at all. The view of the outdoors should increase participants' performance during the experiment.

Hypothesis 2

It was predicted that results from the stereoscopic environment would be significantly better than the results from the monoscopic environment. This prediction was based upon the fact that a three-dimensional simulation improved the realism of the environment. Participants would be more likely to believe that the stereoscopically enhanced picture of the window is real and hence would perform better.

If however, results for the present study did not show any significant results between the stereoscopically enhanced picture and the monoscopic picture, we would conclude that a picture of a window might be enough to satisfy participants' desire to have window in their working environment.

Method

Materials

The experimental apparatus consisted of three parts: the preparation of the pictures in the form of slides, the testing laboratory, and the equipment for stereoscopic projection.

The simulated image consisted of two nearly identical slides of a window on a wall overlooking a building behind that was partly covered by trees. A white wooden rim framed the window. A single lens, 35mm manual camera (Minolta, Dynax 3xi) captured the identical images paralleled to each other. A slide bar that allowed for the camera to move from side to side at precisely the distance desired kept the camera completely leveled and paralleled so that trimming or re-aligning of the slide films would not be necessary. The camera was mounted on a tripod, along with the sliding bar, to recreate the height of a person and also to prevent additional hand movements or shaking.

Depth of field was adjusted using the focus, aperture and shutter speed settings on the manual control camera. The shutter speed and the aperture controlled the amount of light that would pass through the lens, which in turn determined the depth of field of the picture. In this experiment, an aperture of f3.5 was used to create a relatively shallow depth of field, focusing mainly on the rim of the window. The building in the background appeared not in focus as if it was in the far distance. This was intentionally done to produce an obvious separation between outdoors and indoors. The window was centered and remained as the focal point for that particular wall in the picture.

The laboratory room measured 13'6" long by 7'6" wide, and contained a door at one end of the room and a window at the other. A lenticular screen stretched in front of the 4'0" by 6'0" paned window, blocking the view from the room to the outside and also much of the light that penetrated the white Venetian blinds. A ladder that held the projectors stood beside the door and projected to the opposite side of the room towards the screen. A chair and a desk were placed in the middle of the room facing the screen. Images from the projectors projected from behind the subjects onto the screen in front of them. The room was dimmed to increase the visibility of the slide pictures on the screen. An overhead lamp was used to illuminate the desk during the tests (please refer to Appendix B for the layout of the laboratory).

Two Kodak Carousel 4200 slide projectors, enhanced with 5" wide-angle lenses, projected a big three-dimensional picture onto the screen. The projectors sat on a six-foot A-shape ladder. One projector was directly above the other one. When both the slides were projected, the projectors were adjusted so that all corners of the images met. It was also crucial that the pictures projected on the screen were in focus the whole time. Two custom-made polarized lenses were made to fit over the projector lenses. One polarized lens was always perpendicular to the other in order to attain the three-dimensional image when viewed with the polarized glasses.

Custom-made polarized glasses were made to fit on participants whether or not they wore corrective lenses. Made out of soft cardboard, these glasses were shaped to look like a normal pair of glasses. A strap was fastened behind these glasses and a bead on the strap was used to control how tight the glasses would fit over the participants'

faces once they put it over their eyes or their corrective lenses. Another piece of soft cardboard, that took the shape of these cardboard glasses, held the polarized lenses. Again, the polarization on one eye was exactly orthogonal to the polarization on the other, and the angle of polarization corresponded with those on the projector lenses so that one eye sees only one image.

The images were projected on a six-foot by six-foot lenticular screen. The lenticular screen was an important part of this project because a regular white screen would not preserve the polarized images projected by the slide projectors. This silver lenticular screen reflected the two-dimensional images projected from the two projectors. When viewed with the polarized glasses prepared earlier, the double images fused into a perfect three-dimensional picture.

During the experiment, participants were asked to complete a Mental Rotation Test and a Torrance Tests of Creative Thinking. Pens, pencils and boxes of crayons were provided for their use during the tests.

Stimuli

Two pictures were prepared for the experiment. The first was a picture of a wall with a window overlooking another building that was partly hidden by trees. It appeared in both the stereoscopic and monoscopic environments. The second picture was a two dimensional Chinese calligraphy that reads “Wind and Water.” Finally, there was an empty slot in the slide projector that allowed the projector to only project light with no picture on the screen, indicating a blank wall. Participants were randomly selected to participate in one of the four conditions: stereoscopic view of the three-dimensional

window image, monoscopic view of the three-dimensional window image, a two-dimensional image of a calligraphic character or no image at all.

Mental Rotation Test and Torrance Tests of Creative Thinking

The Mental Rotation Test and the Torrance Tests of Creative Thinking were chosen as measuring tools in this experiment because of their long history in psychological testing and measurement. Over the years, they have withstood assessments by a wide range of professionals and have been proven to be useful and reliable in cognitive assessments. Most importantly, they were both accessible in the public domain, a feature that is most valuable to all students.

The Mental Rotation task has been vigorously studied and popularly employed in research since the early 1970s (Shepard & Metzler, 1971). Researchers were eager to learn more about the underlying cognitive representational process. In the present experiment, participants performed a two-part Mental Rotation Test, each part consisting of ten questions. Before participants attempted the twenty questions, they were given a few minutes to try out a practice test. Every question had five three-dimensional objects: four on the right and one on the far left of the page. The task was to match any two of the four objects on the right to the one object on the left. Participants were given three minutes for each part (A copy of the Mental Rotation Test can be found in Appendix C).

The Figural Test from the Torrance Tests of Creative Thinking was used as a measure of creativity as it is a well-standardized test with good validity and reliability (Torrance, 1974). Sommers (1961) collected results from two groups of college students and reported that test-retest reliability was .97 and .80. There were some concerns

regarding the subjectivity of the scoring method. Yet, evidence concerning the test-retest reliability confirmed that the intercorrelations have been consistently above the .90 mark and the difference in the means has been small. The Figural Form A, which included three main activities, was the only form used in this study (A copy of the Mental Rotation Test can be found in Appendix D).

Procedure

The room was set up before participants arrived. Participants were tested singly in each experimental situation. When a participant arrived, he or she was received outside the laboratory room and was instructed to put on the polarized glasses before entering the room. The experimenter assisted each participant with the glasses, making sure the pair of glasses was securely placed in front of the participant's eyes or corrective lenses before entering the room. All participants wore the glasses regardless of the condition they were tested in.

Once in the room, each participant was instructed to sit on the chair in the middle of the room. At that moment, the experimenter would read a set of instructions to the participant explaining the questionnaires he or she was about to receive. During this time, the participant would have a chance to get accustomed to the room and also the picture projected in front of them on the lenticular screen. Because this was a between-subject experiment, each participant was exposed to one of the four scenes from the beginning to the end of the experiment: stereoscopic view of the three-dimensional window image, monoscopic view of the three-dimensional window image, a two-dimensional image of a calligraphic character or no image at all.

Regardless of the condition, each participant had to complete two tests; The Torrance Tests of Creative Thinking that lasted for about 30 minutes followed by the Mental Rotation Test that took place for another 20 minutes. Upon completion of the tests, a short debriefing concerning the nature of the experiment was offered to the participant before he or she left the room. Any participants who did not perform the experiment under the influence of the stereoscopic three-dimensional slide picture were given a chance to view the images before they removed their polarized glasses. All participants were advised not to tilt their head from side to side at any time during the experiment because it would interfere with the stereoscopic effect.

Results

Mental Rotation Test

A one-way analysis of variance with four levels was performed on the number of correct answers for the 20-item Mental Rotation Test (Table 1). There was no main effect in the scores collected from the Mental Rotation Test, $F(3,40)=2.12$, $MSE=31.32$, $p=n.s.$ Although the main effect was not significant, there was a trend in the direction that participants performed better in a windowed environment as opposed to a windowless environment. Means are presented in Table 2.

Torrance Tests of Creative Thinking

The creativity scores were based on results collected from three activities. Each of the activities bore four different sets of scores: fluency, flexibility, originality and elaboration. The different scores measured different kinds of mental functioning. All the scores were added up in each of their activities. Using means and standard deviations

Table 1

Analysis of Variance for Mental Rotation Test

		SS	df	MS	F
TOTAL	Between				
	Groups	199.34	3	66.45	2.12
	Within				
	Groups	1252.91	40	31.32	
	Total	1452.25	43		

* $p < .05$.

Table 2

Comparison of Means and Standard Deviations of Mental Rotation Test

	Mean	Standard Deviation
3-Dimensional Stereoscopic	22.64	4.92
3-Dimensional Monoscopic	20.91	6.12
2-Dimensional	17.36	5.37
No Picture	18.09	5.89

provided by the manual, the scores were then converted into a standardized z-score. For convenience, the z-scores were transformed into T-scores to eliminate negative numbers. The entire analysis was based upon the calculated T-scores.

During the analysis, data points that were more than two standard deviations from the mean were altered to take on the numbers at exactly two standard deviations. This procedure prevented values that were unusually extreme to distort the variability of the results. Of the 176 scores, six were changed in this way. Participants in the three-dimensional monoscopic condition were most creative, followed by participants in the three-dimensional stereoscopic condition, two-dimensional condition and the no-picture condition. A one-way ANOVA was performed on the data recorded for this part of the experiment $F(3,40)=.94$, $MSE=1104.79$, $p=n.s.$ Although the main effect was not significant, the mean results in the creativity test suggested a decrement in performance when participants were tested in a no picture condition, as opposed to the three-dimensional and two-dimensional conditions. Results for the no picture condition was the lowest amongst all the other conditions. The results of this analysis are presented in Table 3 and Table 4.

An independent sample t-test on Total Creativity scores between the windowed and the non-windowed conditions gave a t_x value of .334 ($p>.05$).

Discussion

Stereoscopic and monoscopic window access and wall decorations (with picture and without picture) were manipulated to investigate their effect on participants' performance. Although not significant, the data of the present study marginally supports

Table 3

Comparison of Means and Standard Deviations of Torrance Tests of Creative Thinking

	Mean	Standard Deviation
3-Dimensional Stereoscopic	146.77	48.50
3-Dimensional Monoscopic	146.39	48.79
2-Dimensional	137.14	49.24
No Picture	124.83	33.79

Table 4

Analysis of Variance for Torrance Tests of Creativity Thinking

		SS	df	MS	F
TOTAL	Between				
	Groups	3110.88	3	1036.96	.94
	Within				
	Groups	44191.44	40	1104.79	
	Total	86506.54	43		

* $p < .05$.

the first hypothesis: Participants would perform better in a windowed environment as compared to a windowless environment. Both the creativity task and mental rotation task produced the highest scores when participants were performing in a windowed environment. While there is a potential to make advanced applications in the field of intensive design, further research is needed before designers can accept as valid any criteria concerning window and work productivity.

Contrary to expectation, participants who were in the stereoscopic environment did not score higher in the creativity task and the mental rotation task compared to those in the monoscopic environment. A reason for the identical results could be due to priming of expectation. Since participant recruitment was based on “advertisement” for a “stereoscopic experiment,” participants might be biased by the title of the thesis, suggesting that they will be participating in a stereoscopic condition. All participants were required to wear polarized glasses while viewing the display. They might be led to believe that the stereoscopic presentation would occur. This might also explain why participants performed better while viewing the three-dimensional picture, stereoscopically or monoscopically, as opposed to the two-dimensional picture. To avoid this pitfall, a more neutral title could be used in the future.

With the exception of some exploratory investigations there is little work concerned with analyzing people’s experience of stereoscopic visualization for a normal eight-hour workday while they are in their workspace. This experiment limited participants’ exposure to an hour and they were only able to look at it directly before and after the experiment, and peripherally while accomplishing their tasks. Since there was a

time constraint as to when they were expected to complete their tasks, lifting their head during the test to check out the environment was less likely to occur. Hence, much further research will be needed to explore a longitudinal study where office workers would be exposed to the same scenario in the experiment, but not limited by time and effort to experience the environment.

One of the concerns involving participants' viewing conditions was brought up during the experiment. Several participants reported having headaches during and after the experiment. Long-term exposure to stereoscopic images disrupted the visual coupling between accommodation and convergence causing eyestrain and headaches (Mon-Williams, Wann & Rushton, 1993). Our investigation led us to believe that it was not mainly the stereoscopic environment that had caused the discomfort. One characteristic that might have caused the discomfort could be the level of illumination in the room. The room was dimmed for a relatively clear and sharp projection of the pictures. We compensated for the low illumination in the room by attaching a projection lamp to the participants' desk. Glare from the projection lamp might have indirectly caused eyestrain for the participants that subsequently resulted in headaches.

With today's advancing technology, three-dimensionality can be made increasingly realistic with more depth cues in an image without sacrificing the illumination in the room if not restricted to practical considerations of cost. Due to insufficient funding to incorporate more sophisticated gadgets and technologies, we were unable to compare the difference in results using better graphic enhancements. New technologies are out there waiting to be tested: high-density video, high-resolution and

fast computer graphics, head-coupled displays, instrumented “data gloves” and “body suits,” and high bandwidth, multi-degree-of-freedom force-feedback and cutaneous stimulation devices (Sheridan, 1992). Recently, Dimension Technologies Inc. in Rochester, New York developed a true three-dimensional flat panel LCD display that allows viewers to acquire the three-dimensional simulation without having to put on awkward glasses (Kay, 2001). The simulation was so incredibly real, it makes the viewers want to reach into the screen and grab something in the picture. Unfortunately, the “eye-popping” experience comes with a price. The cost for a 15” monitor is \$1,699 and an 18” [1280 x 960 pixel (SXGA) resolution] is a whopping \$6,999. This technology would be most suitable for this experiment since participants would not have to wear the polarized glasses in order to view the three-dimensional picture. Also, it would not have been necessary to dim the room for this simulation experience, a criteria that might have caused discomfort for participants.

In other aspects of three-dimensional technology, thousands of web cameras are set up all over the world to allow for continuous viewing of images at remote locations. High bandwidth allows for transmission of images within seconds. Images can be projected on a cubicle wall to give the illusion of working in that remote location. Holograms can be used to produce realistic three-dimensional images. A hologram is like a photograph that captures still images from many viewpoints. Although imagining an office to be like a holodeck in Star Trek may be too far a stretch, there is still a possibility of assembling light into a hologram on a wall. Only the image would be a still image, almost like a watching a three-dimensional picture without the polarized glasses.

There may be an unacceptable level of display clutter or flaws in the display elements of our present study, and these may have undermined the results of the experiment. On the basis of the results from the present study, it may be justifiable to conclude that further research, perhaps involving more realistic three-dimensional projection or visualization, may be worthwhile.

To sum it up, the new generation of designers has to recognize the burden they carry today because design is no longer just about colors and swatches, but intermittent layers of information from other fields of studies, including psychology, sociology, human factors and technology. The environment is enmeshed with intervening variables, which exist and influence peoples' behavior. Windows are just one aspect of the environment this experiment has decided to delve into. Although designers may not be able to make an inference from this experiment regarding window and work productivity, evidence does suggest that there may be a connection between the two. Architects and designers should not simply base their designs on their intuition and insights, but should capitalize on the work of the people who are seeking quantifiable facts and information that can be synthesized into elements of design. With reasonable monetary contributions, high technological influences can be incorporated into the investigations and more options may be explored to manipulate the environment and to gather more reliable factual information for future research.

References

- 9/30/88: SYRE receives 5-year, \$44 million contract. (1988). Retrieved November 4, 2002 from
<http://spacelink.nasa.gov/NASA.News/NASA.News.Releases/Previous.News.Release/s/88.News.Releases/88-09.News.Releases/88-09-20>
- Associated Press (2001). Different rooms at last as surgeons separate twins. Retrieved April 10, 2001 from
<http://www.cnn.com/2001/WORLD/asiapcf/southeast/04/10/singapore.twins/index.html>
- Bankston, D. (2002). 3D comes to DVD: Slingshot releases 3D home theater system, large format DVDs. American Cinematographer, 83, 107-108.
- Butler, D., & Biner, P. (1989). Effects of setting on window preferences and factors associated with those preferences. Environment and Behavior, 21, 17-31.
- Garling, T. (1969). Studies in visual perception of architectural spaces and rooms. Scandinavian Journal of Psychology, 10, 250-268.
- Frank, K. (1984). Exorcising the ghost of physical determinism. Environment and Behavior, 16, 411-435.
- Freeman, J., Avons, S., Pearson, D., Ijsselstein, W. (1999). Effects of sensory information and prior experience on direct subjective ratings of presence. Presence: Teleoperators & Virtual Environments, 8, 1-13.
- Halbrook, M. (1998). Breaking camouflage: Stereography as the cure for confusion, clutter, crowding, and complexity. PSA Journal, 64, 30-36.

- Heerwagen, J., & Orians, G. (1986). Adaptations to windowlessness: a study of the use of visual décor in windowed and windowless offices. Environment and Behavior, 18, 623-639.
- Kay, R. (2001). True 3D without glasses. Computerworld, 35, 53-54.
- Lee, T. (1971). Psychology and architectural determinism, (part 1). The Architects' Journal, 154, 253-262.
- Luck, M., & Aylett R. (2000). Applying artificial intelligence to virtual reality: Intelligent virtual environments. Applied Artificial Intelligence, 14, 3-32.
- Mahoney, D. P. (1998). Launching a construction simulation. Computer Graphics World, 21, 60-63.
- Manning, P., Ed., (1965). Office design: A study of environment. Liverpool: University of Liverpool Press.
- Mon-Williams, Wann & Rushton (1993). Binocular vision in a virtual world: Visual deficits following the wearing of a head mounted display. Ophthalmic and Physiological Optics, 13, 387-391.
- Philip, D. (1996). The practical failure of architecture psychology. Journal of Environmental Psychology, 16, 277-284.
- Sheridan, T. (1992). Defining our terms. Presence: Teleoperators & Virtual Environments, 1, 272-274.
- Sorensen, V., & Russett, R. (1999). Computer stereographics: The coalescence of virtual space and artistic expression. Leonardo, 32, 41-49.

- Stone, J., & Irvine, J. (1994). Direct or indirect window access, task type, and performance. Journal of Environmental Psychology, 14, 57-63.
- Tognoli, J. (1973). The effect of windowless rooms and unembellished surroundings on attitudes and retention. Environment and Behavior, 5, 191-201.
- Torrance, E. P. (1974). Torrance tests of creative thinking. Lexington, MA: Personnel Press.
- Winkel, G., & Sasanoff, R. (1987). An approach to an objective analysis of behavior in architectural space. In H. M. Proshansky, W. H. Ittelson & L. G. Rivlin (Eds.), Environmental Psychology: People and their physical settings (pp. 351-363). New York, NY: Holt, Reinhart and Winston.
- Yeh, Y. (1992). Spatial judgements with monoscopic and stereoscopic presentation of perspective displays. Human Factors, 34, 583-600.

Appendix A

Human Subjects-Institutional Review Board Approval Form

**Office of the Academic
Vice President
Associate Vice President
Graduate Studies and Research**
One Washington Square
San Jose, CA 95192-0025
Voice: (408) 924-2480
Fax: (408) 924-2477
E-mail: galsuckos@vps.sjsu.edu
<http://www.sjsu.edu>

TO: Lee Choon Loh
355 Avenida Arboles
San Jose, CA 95123

FROM: Nabil Ibrahim, *N. Ibrahim*
Acting AVP, Graduate Studies & Research

DATE: April 2, 1999

The Human Subjects-Institutional Review Board has approved
your request to use human subjects in the study entitled:

"The Effect of Environmental Stressors on
Human Performance"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at
(408) 924-2480.

The California State University:
Chancellor's Office
Folsomfield Office, Dominguez Hills,
Fresno, Fullerton, Hayward, Humboldt,
Long Beach, Los Angeles, Maritime Academy,
Merced, Monterey, Northridge, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

Appendix B

Layout of the Laboratory

*Note: Drawing is not to scale. Measurements are indicated on the drawing itself.

Appendix C

Torrance Tests of Creative Thinking

Thinking Creatively With Pictures

By E. Paul Torrance

Booklet A

Name _____ Age _____ Sex _____ Grade _____

School _____ City _____ Date _____

PERSONNEL PRESS A Division of Ginn and Company • A Xerox Education Company LEXINGTON, MASS.

© Copyright 1966, PERSONNEL PRESS, INC., All rights reserved

NO PART OF THE MATERIAL COVERED BY THIS COPYRIGHT MAY BE PRODUCED IN ANY FORM OR BY ANY MEANS OF REPRODUCTION.

Activity 1. PICTURE CONSTRUCTION

On the opposite page is a curved shape. Think of a picture or an object which you can draw with this shape as a part.

Try to think of a picture that no one else will think of. Keep adding new ideas to your first idea to make it tell as interesting and as exciting a story as you can.

When you have completed your picture, think up a name or title for it and write it at the bottom of the page in the space provided. Make your title as clever and unusual as possible. Use it to help tell your story.

YOUR TITLE: _____

Activity 2. PICTURE COMPLETION

By adding lines to the incomplete figures on this and the next page, you can sketch some interesting objects or pictures. Again, try to think of some picture or object that no one else will think of. Try to make it tell as complete and as interesting a story as you can by adding to and building up your first idea. Make up an interesting title for each of your drawings and write it at the bottom of each block next to the number of the figure.

1. _____	2. _____
3. _____	4. _____

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. _____

7. _____

8. _____

9. _____

10. _____

11. _____

12. _____

13. _____

14. _____

15. _____

16. _____

17. _____

18. _____

GO ON TO NEXT PAGE

19. 20. 21.

22. 23. 24.

25. 26. 27.

28. 29. 30.

Appendix D

Mental Rotation Test

M.R.T. Test

This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.

Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.

Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always two of the four drawings are the same object as the one on the left. You are to put Xs in the boxes below the correct ones, and leave the incorrect ones blank. The first sample problem is done for you.

Go to the next page

page 2

Do the rest of the sample problems yourself. Which two drawings of the four on the right show the same object as the one on the left? There are always two and only two correct answers for each problem. Put an X under the two correct drawings.

Answers: (1) first and second drawings are correct
 (2) first and third drawings are correct
 (3) second and third drawings are correct

This test has two parts. You will have 3 minutes for each of the two parts. Each part has two pages. When you have finished Part I, STOP. Please do not go one to Part 2 until you are asked to do so. Remember: There are always two and only two correct answers for each item.

Work as quickly as you can without sacrificing accuracy. Your score on this test will reflect both the correct and incorrect responses. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

PART I

page 3

1.

2.

3.

4.

5.

GO ON TO NEXT PAGE

page 4

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

STOP

PART II

page 5

11.

12.

13.

14.

15.

GO TO THE NEXT PAGE

16.

17.

18.

19.

20.