

Psychological, physiological, and phenomenological effects of colored light

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Abstract. This research explores colored light from historical, scientific, and technological vantage points. Effects of colored light on the human condition are examined on multiple levels, comparing theories in physiological, psychological, and phenomenological areas of study, addressed across a broad scope of literature. The focus of this research is to gain an understanding of the effects of colored light on the human condition, and how designing with it can provide an engaging phenomenological experience which marries centuries' old design techniques with modern technological innovations. The stages of research include a literature review, followed by a series of creative explorations with light, texture and form through small-scale models. Data gathered is then analyzed, categorized, and used to create a taxonomy for designing with colored light. Research is then explored on a larger scale through a pilot study conducted in a 5' x 9' room designed to create an experience of being bathed in colored light with user-controlled variability. Each research method may then be used to inform the design of interior environments, affecting the participant's physiological, psychological, and phenomenological experiences.

1 Background

Colored light has been used by architects and designers to shape our built environments for centuries. Daylight through colored glass panes adds a sense of transcendence and awe to sacred spaces. The advent of light-emitting diodes (LEDs) has enabled colored light to become a more ubiquitous presence in the designer's toolbox; a single fixture can produce every color in the visible spectrum. Research indicates that exposure to colored light has layered effects on the human condition – from physiological responses such as changes in blood pressure and eye-blink frequency [1-3] to psychological responses to specific *hues* (colors), *values* (lightness or darkness), and *chroma* (saturation) [4-6]. Given the potential for such a range of responses to colored light and given that technological advances have made this tool so readily available to designers, it is important to understand existing literature on the subject in order to make informed and strategic design decisions. The application of this research in a day spa provides an opportunity to design for the human condition in all three categories – physiologically – designing spaces which are bathed in

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colored light, inducing physiological responses; psychologically – tapping into color theory which carries through cultural, experiential, and personal references; and phenomenologically – designing experiences which provide tangible engagement with colored light, providing momentary suspension of reality through extraordinary experiences.

1.1 Theoretical Framework

This research on the effects of colored light on the human condition can be traced back to an ever-evolving body of knowledge in the field of color theory – specifically considering chromotherapy. Scientists, artists, designers and writers have attempted to explain our perceptions of color. Linguistics, though able to offer poetic descriptions of color, is also limited in its variety of descriptors. According to Elliot and Maier, there are an estimated 2.3 million discernable colors [6]. Why then do we limit our identification of the colors of the rainbow to only seven? Our language is unable to adequately describe what our eyes perceive.

Color representation systems have dramatically evolved since the 1600s. Sir Isaac Newton (1643-1727), who discovered that the white light that surrounds us is actually made up of all of the colors in the visible spectrum, identified seven unique colors through his prism experiment in 1666 [7]. Johann Wolfgang von Goethe (1749-1832) published his *Theory of Colors* in 1810, in which the botanist and poet identified six colors, which he displayed as a color wheel. Unlike Newton, Goethe's interest was in our perception of color, and not in its physiological origins [8]. In the late 1800s, Michael-Eugene Chevreul (1786-1889), a French chemist, developed a 72-hue color circle, and began experiments with simultaneous contrast [7]. Perhaps the most influential to how we currently evaluate and analyze color perception is Albert Henry Munsell (1858-1915). Munsell categorized color as hue, value, and chroma. His 3D color system has been used in various case studies to determine psychological associations with color [4,5]. Though much research exists in the area of color theory, there is little available research specific to color theory as it pertains to psychological effects of colored light. A pilot study in this area was an initial step in bridging this gap, in the "User-Controlled Immersive Light Room Experience" discussed later in this paper.

1.2 Literature Review

A literature review was an initial step in the research process – collecting, analyzing, and categorizing existing literature which addresses the effects of colored light. Information gained from this review provided a framework through which to more thoughtfully apply colored light in interior design solutions – taking into account its empirically-proven as well as its perceived effects on the human condition. The literature covers a broad range of fields of study: medical, holistic nursing, psychology, sociology, and cultural anthropology, as well as interior design and architecture journals, to name a few. Colored light is of interest to many different fields of study for its impact on our physiology, psyche, and its influence on how we experience our built environment. Through the research strategy of logical argumentation, existing research and case studies in the realms of medicine, psychology, and design were examined. It was then sorted into three categories: psychological, physiological, and phenomenological effects of colored light.

1.2.1 *Physiology*

According to Peter K. Kaiser, Psychology Professor at York University Downsview in Ontario Canada, color has a physiological effect on us, whether we perceive it visually or not. Kaiser asserts that “physiological human responses to color as evidenced by the electroencephalogram, galvanic skin response, blood pressure, heart rate, respiration rate, and eyeblink frequency, and suggests that some are indirect effects mediated by cognitive responses to color.” [9] Color is perceived visually, and changes with the quality of light. The eye perceives color based on the light that is reflects off of a surface – different wavelengths result in different perceived colors. A particular shade of blue will look lighter when the sun shines directly upon it than it does when cast in shadow. When in a dark space, or when we suffer from severe visually impairment, colors all become shades of black. Color does not exist without the presence of light.

Our perception of color is simply our minds interpreting wavelengths – or vibrations – of light. Since color would not exist without light, it makes sense that cultures have for centuries connected the two. According to Day and Rich, it was believed in ancient Egypt and Greece that healing was accomplished through a treatment of the body, mind, and soul – something which was addressed with the use of colored light [2]. In ancient Egypt, the “sick were diagnosed by color and then laced in rooms that radiated the particular color prescribed.” These rooms were lit with colored light produced by positioning colored gems such that daylight would pass through [1,2]. Today, with the advent of modern technologies and advancement in medical treatments, colored light is still used in to treat chronic physical conditions. Colored light is used to cure dental fillings; red light has been found to prevent scar tissue; different colors of light are used in optometry to improve eyesight and balance; monochrome light domes are used to treat phobias, depression and stress; blue light is used to treat jaundice in infants; the list goes on [2]. As science advances our understanding of the human body, we are drawn back to ancient healing techniques, but in more precise, empirically-proven ways.

1.2.2 *Psychology*

Color is an integral part of our lives in many ways, both culturally and psychologically. Research indicates that color has an effect on our mood [9-11]. Research has correlated emotional reactions to and psychological associations with color hue, saturation, and brightness. [4, 5, 10, 11). The color red has been associated with excitement, anger, passion; orange has been perceived as distressing and upsetting; purple as dignified and stately; bright yellow as cheerful, blue has been associated with comfort; and green as having a calming effect [10]. However, these psychological associations, though shown to be somewhat consistent across cultures due to shared experiences (i.e. we are all familiar with the blue of a warm summer sky, the green of freshly mown grass, and the warm hues of a sunset), are also affected by personal experiences [5]. According to Elliot and Maier, psychological responses to color are biologically based (i.e. red is associated with strong, highly stimulating emotions, possibly because the wavelengths of red light are longer, penetrate the skin more deeply, and produce more intense physiological reactions), but they are also based on learned associations of color meaning [6]. There is substantial empirical evidence regarding the physiological effects of color and colored light, but much of the research related to the psychological effects of color are, by the nature of the subject matter, somewhat subjective.

1.2.3 Phenomenology

Research in phenomenology began long before it was applied to the built environment. It is an exploration of the essence of being human, the essence of existence. Considering the physiological and psychological effects of color, it follows that color itself plays a strong role in our experience of place – in the essence of our existence. According to Seamon and Mugerauer, “the phenomenologist works to circumvent the natural attitude and to undertake a fresh, exhaustive examination of consciousness and experience” [12]. It is through this fresh examination that architects and interior designers conceive spaces which provide engaging phenomenological experiences. In his book *The eyes of the skin: Architecture and the senses*, Pallasmaa questions “why, when there are five senses, has one single sense – sight – become so predominant in architectural culture and design?” [13]. He argues that by suppressing the other four sense, the experience of the built environment is less rich, and less engaging that it could be – than it should be. Research indicates that architecture is more than just visual – it is place, which through all of the senses, and through memory, provides a deeper meaning to what it is to be human, and is ingrained in our self-identity [14]. Since color is tied to memory, and is connected to our sense of place, of self-identity, and is a trigger for recollection of experience, color itself is a gateway to a multisensory experience, and can be used in strategic ways in design.

1.3 Primary research questions

- How can we design with colored light in deliberate, controlled ways?
- What is a person’s response to being bathed in colored light, and how can we provide a positive phenomenological experience?
- How can this research be applied effectively in an interior design project?

2 Research methodology

Three phases of creative research inform the design of the day spa. The first is a series of light model studies which lead to a categorization of design output as well as a taxonomy of designing with colored light. The second phase is an evaluation of design precedents by six designers who incorporate the categories identified in Research Phase 1 in order to create a phenomenological experience through interior design or art installations. The third and final phase is a pilot study which builds on the work of James Turrell – specifically his Perception Cells. This study involves the design and installation of an immersive user-controlled light room experience. Participants spend time in the light room, controlling and changing the colors and intensity of the light, and then answer a series of open-ended interview questions to determine their perception of the experience. This feedback is later applied to the hypothetical design of the day spa to explore incorporating these ideas into an interior environment.

2.1 Creative Research

This phase of research began with a series of study models developed by members of the Fall 2016 Graduate-level Interdisciplinary Design Studio. We each created physical models with which to study daylight as it interacts with different materials and forms. I took these models and applied colored light through various techniques including white light through colored filters, RGB LCD light fixtures, and a combination of both. (Fig. 1)

Methods were documented, and then the models were photographed, resulting in a library of images which were then categorized. Three categories of design outputs were identified, which were labeled Painting with Light, Immersion in Light, and Capturing Light. (Fig. 2)

The findings of this research phase include the categorization of design outputs as well as a taxonomy of designing with colored light (Fig. 3).



Fig. 1. Photos of light study models, models photographed by Jennifer Scott



Fig. 2. Photos of light study models were categorized into these three categories: models photographed by Jennifer Scott

CATEGORY	OUTCOME	LIGHT SOURCE	TECHNIQUE	COLOR SOURCE 1	MATERIAL 1
Painting with Light 	Blend	Single	Masking	Filter	Reflective
	Pattern	Multiple	Projection	Colored Light	Rough
	Wash	Daylight	White Light	Pigment	Opaque
Immersion in Light 	Beam	LED	Colored Light	Prism	Absorbent
	Pool	Fluorescent	Aperture Hidden	COLOR SOURCE 2	Smooth
	Dematerialize	Incandescent	Aperture Visible	Filter	Transparent
Capturing Light 			Direct Light	Colored Light	Reflective
			Indirect Light	Pigment	Rough
				Prism	Opaque

Fig. 3. Taxonomy of designing with colored light, developed by Jennifer Scott

2.2 Design Precedents

Identification of design precedents was based on the three categories identified through the creative research: Painting with Light, Immersion in Light, and Capturing Light. Six designers were selected and evaluated to determine how that work can inform the design of an interior space

2.2.1 James Turrell: Immersion in light: manipulating perception

Turrell explored the idea of manipulating perception through the use of colored light. His Perception Cells (images on right) created personalized phenomenological experiences through immersion in colored light and helped to inspire the Pilot Study discussed in Research Phase 3.

2.2.2 Rem Koolhaas: Immersion in light: immersive experience

Koolhaas designs color into his interiors in a powerful, unapologetic way. Through strategic materiality and lighting techniques, he creates spaces which immerse the visitor in colored light. His use of color is referenced in the day spa in the colored glass atriums, though in a less intense way, allowing for more universal comfort

2.2.3 Architects of Air: Immersion in light: suspension of reality

These inflatable installations are bathed in colored light with variations in internal temperature adding another dimension to the experience.

2.2.4 Regine Shumann: Capturing light: creating walls of light

Shumann’s art installations sandwich colored LED light between clear panes, resulting in translucent walls which appear to be made exclusively of light. Her work is referenced in the spa in an indirect way – colored light grazes waterfalls which act as partitions between the changing rooms and the pool area. These light “walls” incorporate water for a multisensory experience.

2.2.5 James Carpenter: *Painting with light: daylight mutability*

Carpenter’s work utilizes daylight as an integral element in his designs. The colors produced by his windows move around the room as the sun moves across the sky. Carpenter’s work is referenced in the lobby of the spa, where daylight is refracted off of prismatic columns, casting mutable rainbows around the room and across the visitors, providing an engaging experience.

2.2.6 Steven Holl: *Painting with light: vessels of light, reflection*

Steven Holl creates the effect of colored light by applying colored pigment to surfaces which are hidden from view, but which reflect daylight, filling the room with blocks of color. Holl’s work inspired me to hide the light source where possible, and to keep the viewer’s eyes on the light, and not on the lighting fixture.

2.3 User-Controlled Immersive Light Room Experience

This research phase is a pilot study of a user-controlled immersive colored light room experience. An LED light installation was installed in a 5’ x 9’ room with no natural light. The LED lights consisted of two 30’ long RGB tape lights which were installed around the room at heights of 2’ and 6’. Prior to installing the tape lights, the walls were covered in white paper to create a consistent and reflective backdrop for the colored lighting. Each strand of lights was controlled with a remote, allowing the participant to control the intensity and color of the lights. Participants were recruited from design studios within the School of Design + Construction at Washington State University. A total of 22 subjects participated in the experience. They spent five minutes alone in the room, using the remote to explore different lighting conditions. Afterward, they were asked a series of open-ended interview questions, and their responses were recorded, transcribed, and analyzed.

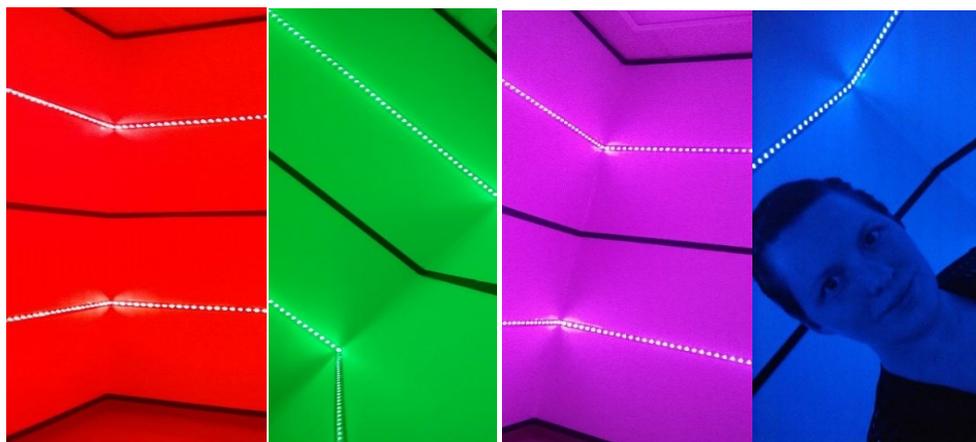


Fig. 4. Immersive Light Room Experience, developed and photographed by Jennifer Scott of the 22 participants, 100% claimed to enjoy the experience. The ability to change the color and intensity of the lights was cited by many as a positive aspect to study. When asked which color felt calming and which color felt stimulating, their answers varied dramatically. Some felt calm in a white room, since they are used to that color of light. Certain colors, such as red, elicited strong reactions – some positive and some negative.

Blue also had varying responses. This study informed that people do enjoy being bathed in colored light but need to be in control of the color and intensity. Also, nobody remained in the room for longer than five minutes, so it is undetermined if a longer exposure would lessen their enjoyment.

3 Application to a conceptual design project

The overall design objective is to utilize techniques for designing with colored light in the programming, wayfinding, and phenomenological experiences of a day spa – incorporating colored light as a tangible and interactive design element.

Three distinct design strategies for designing with colored light were identified in the literature review: first, the historical technique of designing with colored glass panels through which daylight or white artificial light is passes; second, the scientific technique of refracting light through a prism, resulting in the full spectrum of colors broken down into individual hues; and third, using light emitting diodes (LEDs), a modern technological technique. The first and second options offer the possibility of mutability as daylight shifts, though, each technique may be highly controlled if the light source is artificial, such as with LEDs. The design of this Day Spa incorporates all three techniques in strategic ways.

Historical: Used in the exterior glass atrium spaces, six in total and each with a different color (red, orange, yellow, green, blue, and purple). These spaces are lit with colored glass panels which illuminate the cavern-like interior space, providing a mutable softly-lit experience.

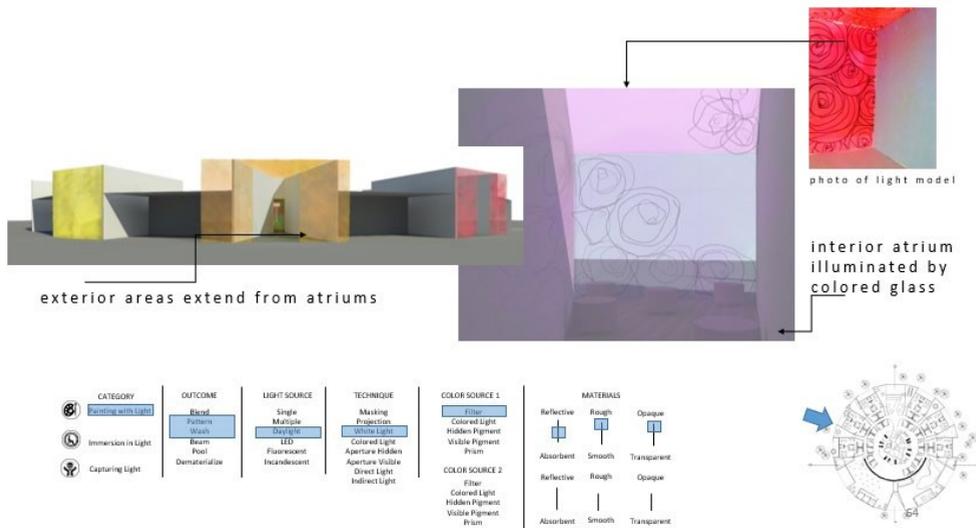


Fig. 5. Atrium Spaces of Conceptual Day Spa, developed by Jennifer Scott

Scientific: The lobby is filled with a forest of prismatic glass columns which refract daylight from the exterior glazing, and are also lit with white LED angled downlights, allowing for rainbows of light to paint the walls, floor, and visitors as they pass through the lobby to the main corridor. These rainbows will shift as the sun crosses the sky, and will stabilize as daylight ceases, and the lobby is lit purely with artificial light.

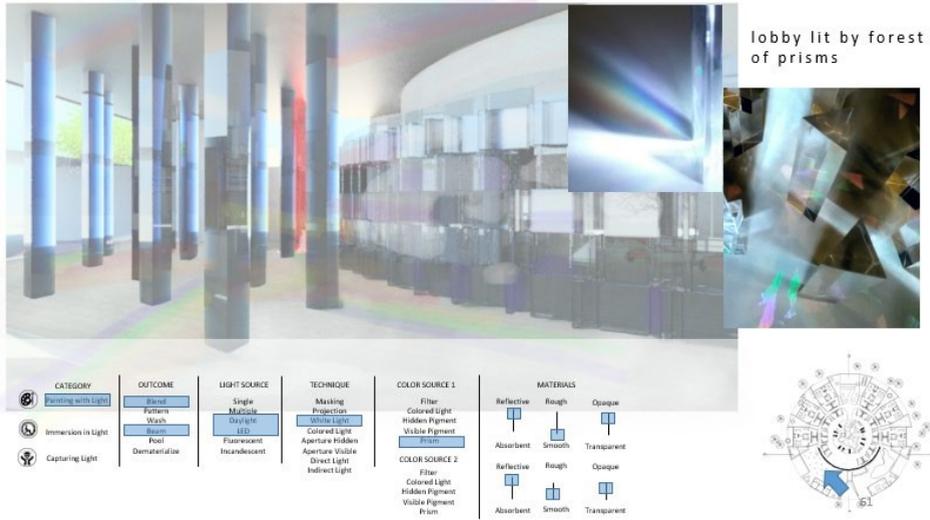


Fig. 6. Lobby of Conceptual Day Spa, developed by Jennifer Scott

Technological: LED lights provide stable, consistent color in areas which would not be possible with the first two methods: LEDs illuminate the underground stream which functions as a primary source of wayfinding. LEDs also fill the wall alcoves, allowing for controlled colored light along the corridor. LED fixtures also cast colored light which grazes the water at the entryway, and along the border between the changing rooms and the pool area.

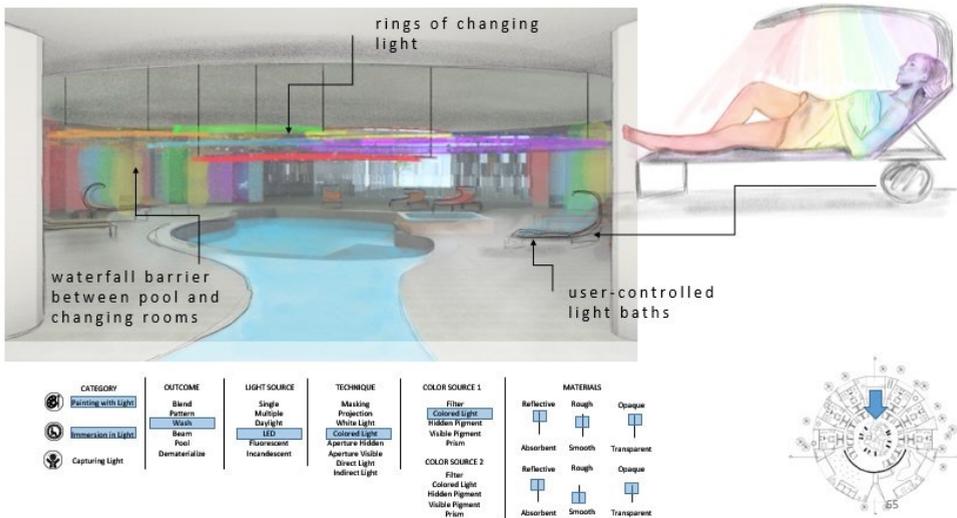


Fig. 7. Pool area of Conceptual Day Spa, developed by Jennifer Scott

4 Reflections

This project began with research into the effects of colored light on the human condition in order to better understand how this design tool engages our bodies, minds, and experience of place. A series of light model studies followed, which resulted in a taxonomy of design techniques from which to draw ideas for designing with colored light. A pilot study examining the psychological responses to being bathed in colored light in a user-controlled environment added to the body of knowledge in this project.

It is possible to imagine how one might feel when moving through this series of phenomenological experiences. It is not, however, possible to confirm that the spaces designed do in fact have physiological effects on the visitors. For this data, a more complete and controlled study would need to be conducted. We can infer, based on the research, that there would be some level of physiological response, but to what degree is uncertain. We can also assume, based on the research and the pilot study conducted in Research Phase 3, that the proposed design solutions would elicit psychological responses as well, and that the visitors would enjoy this more with a level of control over their environment.

As designers, it is important to understand the far-reaching impacts of our design choices. Since research indicates effects of colored light on so many different levels. This research aims to add to the body of knowledge in the field of color theory. It addresses color theory in relation to colored light, as opposed to applied color. While there is a substantial amount of empirical research regarding physiological effects of colored light, its psychological effects are not clearly known. This is a gap in the research that I lightly addressed in my pilot study, and plan to further address as a PhD thesis project.

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