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Drawing Light: A Graphical Investigation of Light, Space, and Time in Lighting Design

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KEYWORDS *Architecture, communication, drawing, graphic, information, light, lighting design, representation*

ABSTRACT In this paper, we propose to rethink the drawing of light in Architectural Lighting Design: the design discipline dedicated to lighting the human environment.

Representation and presentation graphics serve to visually organize and communicate design information through drawing: making ideas clear, demonstrating conceptual value, and providing technical information. Lighting design is an associative discipline. Its documentation is typically formatted to fit within the normative classification conventions of an architectural project's documentation. Graphic standards consist of using icons and symbols that situate the equipment used in plain view, with tables and schedules providing supplementary technical descriptions. (This practice applies throughout the schematic design, design development, and construction documentation phases of a project.)

We argue that this convention is reductive—we propose a new graphical syntax that would allow the visual communication of a lighting design project to implicitly and explicitly convey qualitative and quantitative information about light, space, and time. A new graphical syntax is appropriate since properties of a given light source are absolute, but variations in materiality and reflectance make lighting effects relative. Moreover, control systems modulate the light output of any source or group of luminaires, and these temporal variations (referred to as lighting scenes) are orchestrated within nested scales of time (e.g., circadian or seasonal conditions).

Lighting Design raises unique visualization questions, and new representation strategies must be explored for improving the visual organization and communication of design information about light, space and time. A cross-disciplinary exploration of current work on visual design thinking in cognitive science in conjunction with expanded drawing strategies will help provide answers. We argue that a renewed graphical language will lead to more performative drawings of light in Lighting Design.

DRAWING ARCHITECTURE VERSUS DRAWING LIGHT

The problem of representation is intrinsic to architecture. Robin Evans has contributed notable writings on the elusive relationship between an architectural construct and its representation—including drawing. In the late twentieth century, computerization of architectural graphic production also led to new areas of research, in the field and in the lab respecting the practice of drawing in architecture (e.g., CAD [Computer Aided Drawing] and more recently BIM [Building Integrated Management]).

Throughout these studies, the practitioners, researchers, and theoreticians interested in the problems of representation have concluded that robust drawing practices have endured even though advancements in digital technologies should have revolutionized the production of graphic information in architecture. Moreover, orthographic drawings conventions and classifications (e.g., ISO [International Standardisation Organisation]) were originally developed to facilitate communication among actors in the field of architectural practice. However, their cultural inheritance has sustained a robust canon of representation and stifled evolution within normative drawing strategies.

The problem of visual representation and communication in lighting design practice intersects with the problem of drawing in architecture; but, it is different. The evolution of drawing protocols for lighting information does not depend on the development of—or there lack of—new architectural drawing practices. Should architectural representation even evolve radically, current graphical conventions will nonetheless continue to generate ineffective lighting visualizations unless new drawing constructs are conceived.

The architectural drawing situates the lighting project that is designed for the architectural project. Yet lighting design is a space/time-based experience that is intrinsically linked to the dynamic perception of materiality. Communicating information on materiality and time requires that the visual information related to lighting be expanded beyond the context of the architectural drawing. We posit the gestalt of light in architecture as a premise to explore new graphic standards for lighting design.

IMMATERIAL LIGHT VERSUS MATERIALITY

Architects have often addressed relationship between light and architecture. In *Luminosity-Porosity*, Steven Holl writes, "Light as matter is invisible. We cannot perceive light as it passes by unless it is trapped in dust, smoke, or water droplets. Nothing is contained "in" the light beam. Even laser light beams appear to pass through each other as if made of nothing."[2] Light is not apparent without surrounding elements; we are able to see objects because there is light, and we are able to see light because there are objects. Per Hans Hollein, "Light and matter are both present in physical space; their polar relationship is existential for both—each provides the other with life. Light is the elixir that gives life to colours, contours and surfaces. Light gives objects their reality as objects, it links space and form."[3]

By extension, the representation of light happens through the representation of objects. As a result, visual information on the properties of the surrounding space should complement the characteristics and location of the lighting elements in order to adequately communicate information on the performance of the lighting scheme.

In the chapter "Light on Things" in *Atmospheres*, Peter Zumthor describes light as a design tool to create space, and writes on two ideas about working with light. In his first idea, Zumthor thinks of light as a mass that excavates darkness. This concept challenges the graphical translation of light since it is understood as an entity of immaterial quality. Zumthor's next thought is to work with light through the reflections of materials and surfaces: "The second idea I like is this: to go about lighting materials and surfaces systematically and to look at the way they reflect the light. In other words, to choose the materials in the knowledge of the way they reflect and to fit everything together on the basis of the knowledge."[4] In graphical translation, edges of light can become clear if visualized through the materiality of spatial boundaries.

These comments on light and space underscore a fundamental drawing problem in the practice of lighting design and support our argument. The representation of light requires an expanded visual communication about materiality in the documentation of the architectural space.

DYNAMIC LIGHT IN STATIC SPACE

A singular lighting design scheme includes multiple lighting scenes. Lighting design is a spatio-temporal design field; its intrinsic temporality also highlights the drawing question of dynamic visualization within the frozen context of the architectural drawing. Lighting designer Mark Major writes, "The movement of light is a linear process where time and space meet. Any moment reveals frozen movement in time...Through the passage of light we track the change of day into night as well as form and surfaces moving in light."[5]

Dynamic electric light and dynamic natural light differ but share a temporal dimension. Sun paths and circadian, or seasonal cycles, are predictable and the qualitative and quantitative design of natural light can be precisely modeled—variations due to weather are only unpredictable through time. Moreover, the output of electric light can vary through the use of dimming and switching.

Lighting scenes and their controls are at the core of lighting design. Scenes and the transitions between them are temporal designs among infinite possibilities. Their implications are fundamental, since our perception depends on how space is revealed, in other words, on how it is lit (it should be noted that perception also depends on individual variations related to vision and personal history, but this expands beyond the normative format of drawing explored here). Variations in natural and electric light are integral to the lighting design intent, with the resulting changes in contrast, color, dimension and scale modeled throughout the design studies.

A critical feature in the lighting project—control systems—are designed to orchestrate pre-programmed scenes, as well as interactively supplement natural light with electric light. The sequential transformations of space, whether pre-programmed or random, are nested within a global lighting scheme. They constitute—rather than contribute to—design in lighting.

The consideration of how time translates into visualization problems are unique to lighting design, since it must communicate the multiplicity of spatial transformations within a singular space. Mapping this information requires a representational context that expands beyond the limitations of the frozen architectural drawing.

CURRENT DRAWING PRACTICES IN LIGHTING

Lighting designers typically represent lighting information over the orthographic backgrounds provided by architects (modifications to enhance legibility may include a background inverted in black, or a greyed line background). Inserted onto architectural plans, coded symbols situate the distribution of the lighting equipment, and their groupings indicate electrical circuits. These symbols refer to schedules for the technical description of luminaires and controls. Via sections, the lighting equipment is shown to describe the mounting conditions and to reference details. These are often supplemented with dotted lines to portray fixture orientation and beamspread. Such drawing conventions are largely inadequate because they make *primary* information about light *secondary*, and feature as primary what should be secondary. Moreover, they do not relate information on lighting and materiality.

Computer programs such as AGI32 or ECOTECT are also used to communicate lighting information. They allow the study of light performance metrics in space by importing lighting files into 3D architectural models in which the reflectance of finish materials is specified. In both programs, output can include precise quantitative calculations, gridded plans with gradients of light, luminaire technical information, and false color visualizations. However, critical parameters are omitted, such as spectral distribution (the amount of photons emitted within each wavelength), color temperature (the perception of the color of light), and color rendering index (how surround colors are perceived).

In consideration of these inadequacies and omissions in current lighting visualizations, we propose that new means of visualizing and communicating lighting information should start with the phenomena of light itself. Moreover, quantitative (measurable) and qualitative data is desirable to describe light both at the source and in the architectural space, and the modulation of light output must be translated into graphic form.

DRAWING LIGHT: A THESIS ON THE GRAPHICAL EXPLORATION OF TIME AND MATERIALITY

In her thesis, Peon-Veiga analyzed the drawing methodology of three drawing case studies, deducted representational strategies useful for lighting, and developed a series of hypothetical drawing models for a sample lighting project. A botanical illustration led to the representation of varying materiality, cinematic architectural graphics led to the representation of sequential light qualities, and musical notations by composer Iannis Xenakis led to graphical propositions for temporal lighting scenes.

Peon-Veiga's thesis is entitled "Drawing Light: Processing the Lit Environment."[6] Peón-Veiga explored the visualization of qualitative and quantitative lighting data within technical and diagrammatic technique. We selected this restrictive format because it dominates the graphical reasoning and drawing production throughout the schematic, design development, and construction documentation phases of a spatial design project. We also established that her drawing palette would be all-inclusive of drawing tools such as varying line types and thicknesses, arrows, opacities, basic shapes, textures, color, time lines, and time loops to translate architectural data (materials) and light data (intensity, color temperature, color rendering index, spectrum, light technology and lighting controls).

Peón-Veiga's preliminary diagrammatic study served to define, classify, and organize all the criteria we deemed relevant to communicate a lighting project. Her final diagram was produced in two versions: one with words, and another with representative graphic samples. These were then presented with information parameters within a logical framework of hierarchies, adjacencies, and intersections (see FIGURES 1 & 2).

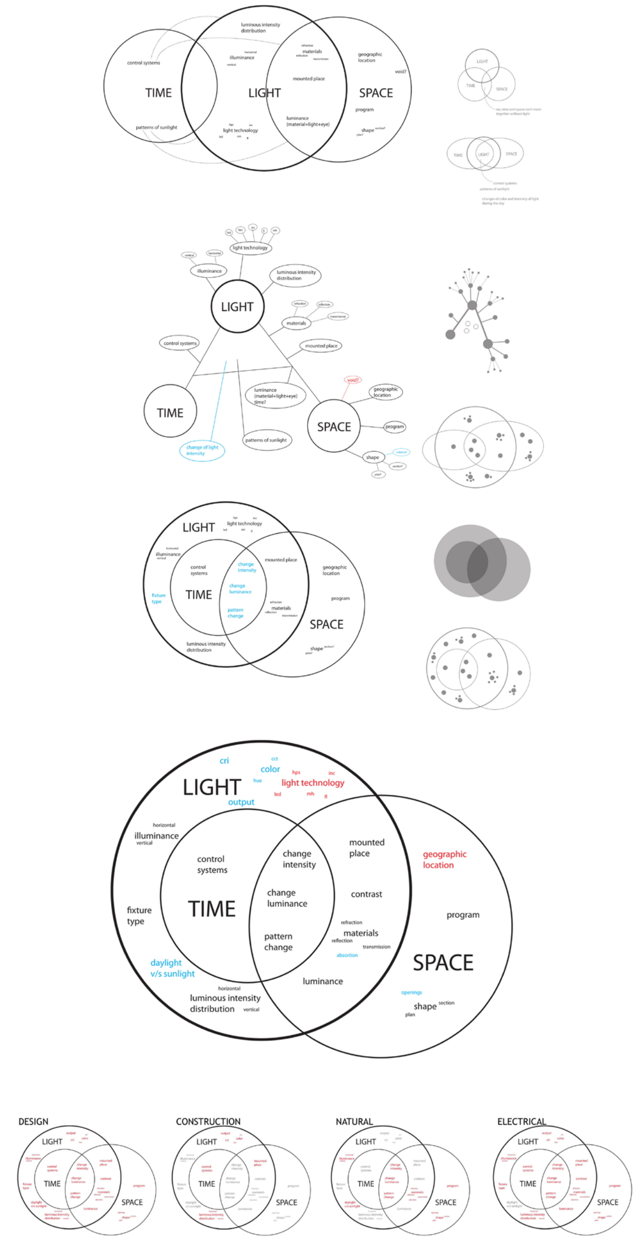

FIGURE 1: *Process of the Light+Time+Space Diagram.*

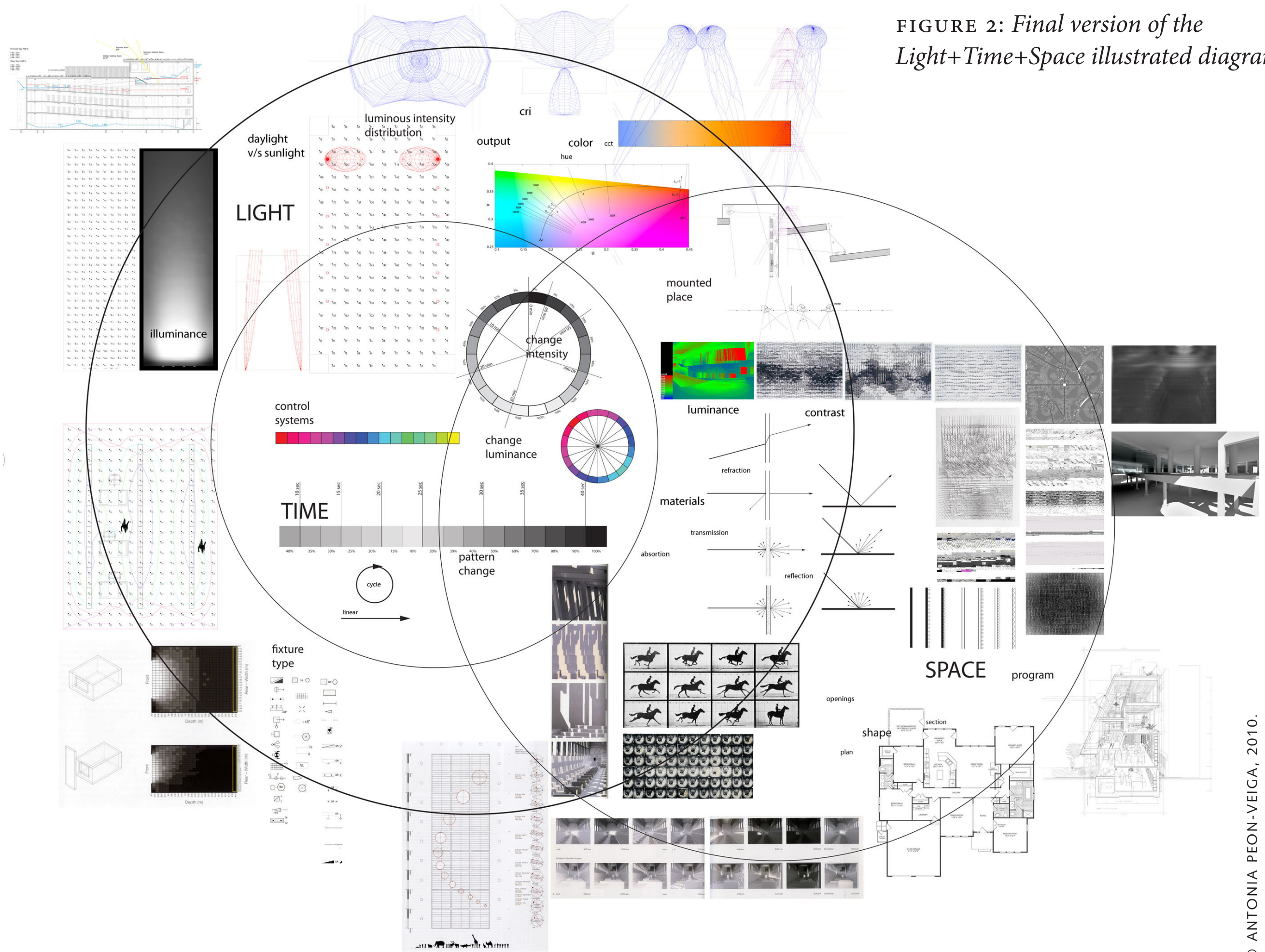

FIGURE 2: *Final version of the Light+Time+Space illustrated diagram.*

In her next steps, Peón-Veiga proceeded to identify useful representational methodologies, and to translate them into hypothetical models for the visual communication of lighting information (within the diagrammatic framework previously established). She also developed a lighting design scheme of average complexity, thus suitable for the purpose of communicating lighting information.[7] The medium-scale architectural project included programmatic requirements such as an auditorium, an exhibition space, a kitchen, a hydroponic growth area, and a restaurant. Below is a description of her thesis process, during which she "dissected" three drawing case studies, analyzed their construct of time and materiality, and developed radical approaches to lighting drawing in format and content. The architectural orthographic projections provided by the architect (plans and sections) situated her drawing project, and her thesis culminated in the production of exploratory visualizations (FIGURE 3, next page).

PARTS AND SCALE

CASE STUDY ONE: BOTANICAL ILLUSTRATION, JOSEPH PEYRITSCH, 1879

> *"The purpose of every botanical illustration is to give an exact picture of a plant or of parts of a plant... Botanical illustrations have very little to do with art, but belong rather to the realm of the sciences."*[8]

This nineteenth-century botanical illustration is synthetic, as it shows shifts both in scale and in viewing angles (FIGURE 4, page 6). Numbers signify processes. For example, number 15 shows a seed in plan and side view; 17 a detail inside the seed; 18 its mature state; 19 its dry state; and 20 and 21 the sprouting plant. The illustration also features time as a change of state in the plant by showing sequential flowering stages. The adjacent visibility of temporal states is not a realistic representation, but this strategy allows to communicate more information.

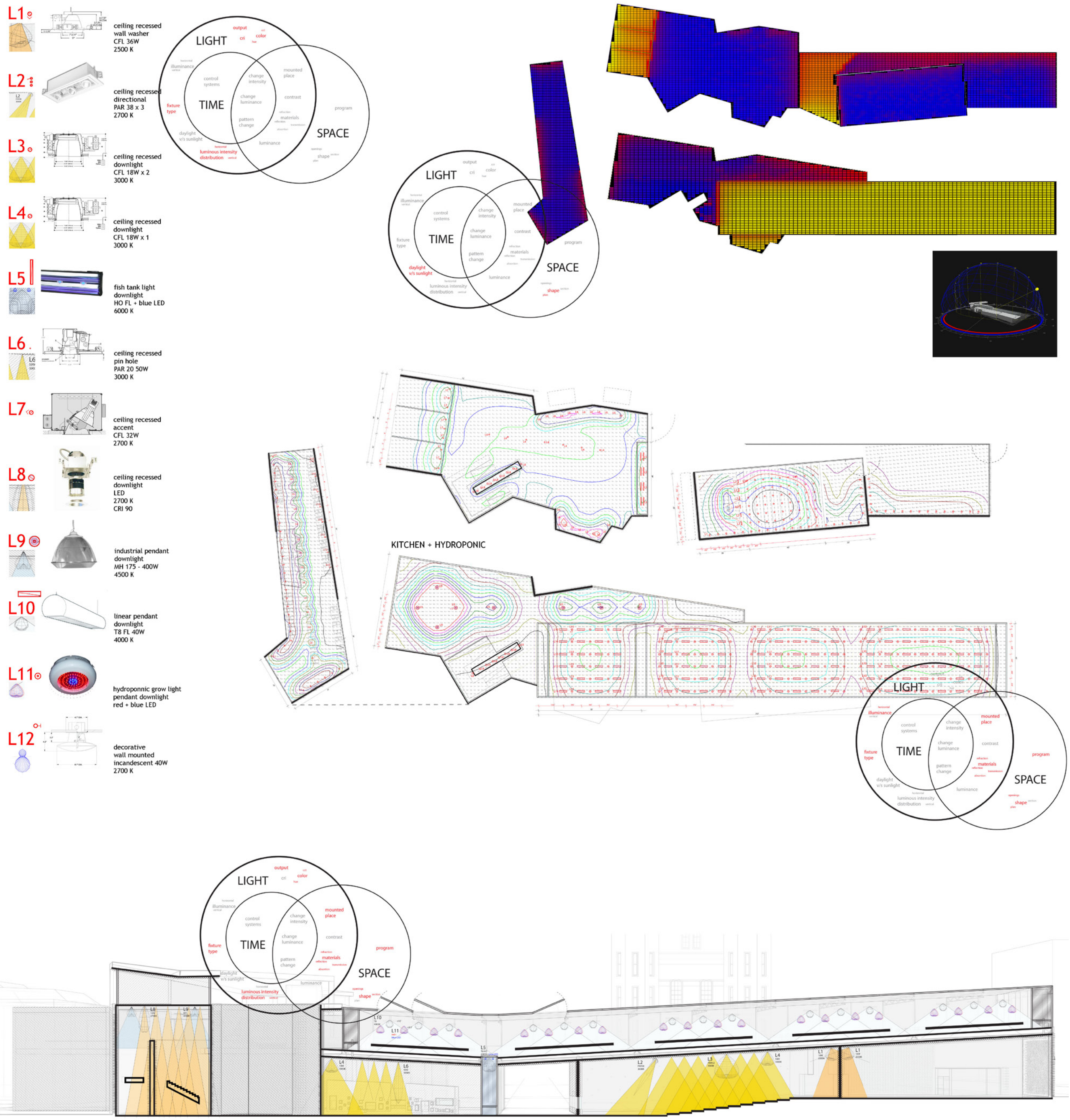

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FIGURE 3: *Fixture schedule, plans, daylight factor analysis grid, and section of project using Light+Time+Space diagram.*

In her analytical drawing, Peón-Veiga color-coded the illustration's numbering system to reflect thematic processes (for instance, yellow for flower from 2 to 11). She reorganized all the numbered details in a linear fashion, and visually translated the shifts in scale by modifying the size of numbers and letters.

Peón-Veiga applied this representational structure to create lighting design visualizations for the exhibition area, since it featured localized design elements of varying scales (compost space, mushroom wall, and fish tank), as well as sequential lighting scenes. Each representation included the complete design element, with lighting fixture types and locations, and the materials being lit (FIGURE 5). In specific areas, the lighting scenes were illustrated with a time loop diagram that showed the dynamic process and the perceived changes of texture (for instance the controlled light output of the downlights or the color temperature contrast at the mushroom wall).

The representation also overlapped quantitative and qualitative parameters such as color temperature and contrast with the intent to communicate the qualitative parameters that are driven by quantitative data and designed by lighting (for instance, as a result of the visual contrast between the main room's warm color temperature [2700 K] and the fish tank's cold white [6000 K], the users will initially perceive the room as orange).

FIGURE 4: *Case Study of a botanical illustration by Joseph Peyritsch, 1879*

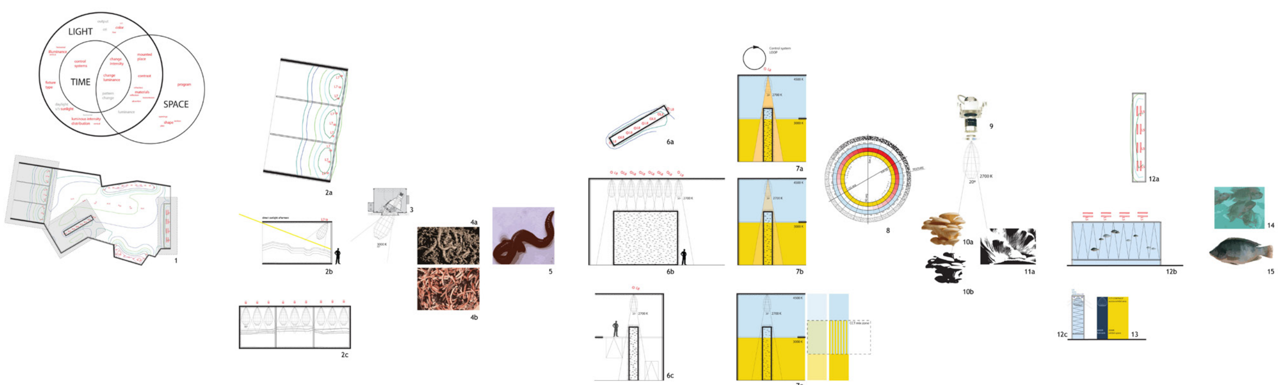
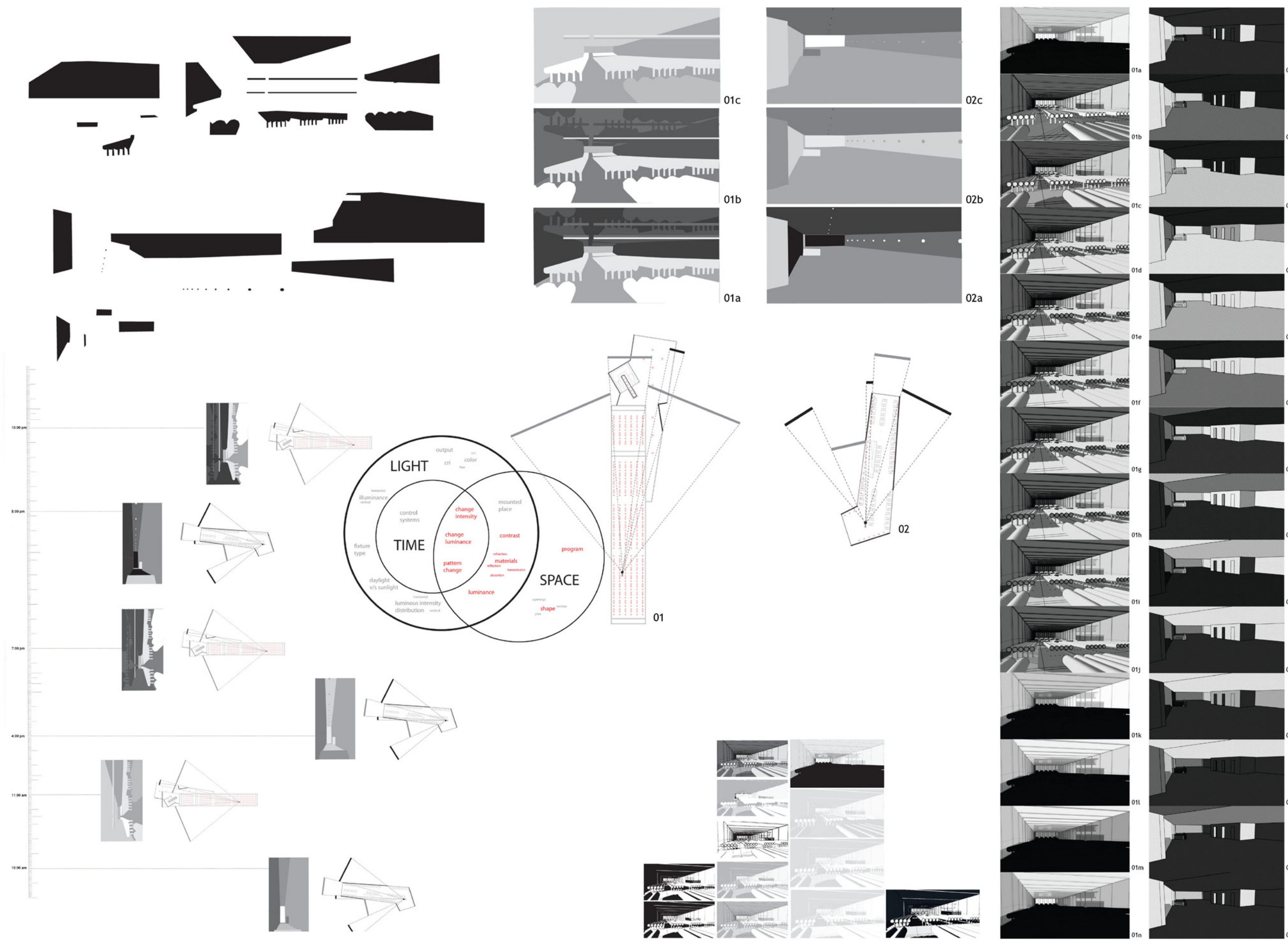


FIGURE 5: *Representation of the exhibition area using structure of* FIGURE 4.



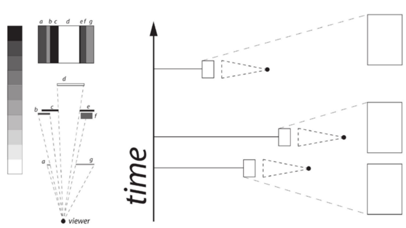


FIGURE 6: *Structure of Cinematics, Dynamic Contrast in Hydroponic Room. A case study of Brian Macgrath & Jean Dardner's Cinemeterics.*

DYNAMIC CONTRAST

CASE STUDY TWO: CINEMETRICS, BY BRIAN MACGRATH AND JEAN GARDNER, 2007

> *"Cinemetrics is an exciting demonstration of a cinematically-inspired cybernetically-based, architectural drawing system, which embeds architecture in relationships within the world at large."*[9]

The authors of *Cinemetrics* articulate the process of representation in composite illustrations, in which drawing is never singular. Two representational axes frame the drawing structure: (1) the plan view (the viewer location combined with the viewing angle make a conic plan view, and the superimposition of all of the cones generates an abstract shape that represents the space as it is experienced), and (2) the visualization of shades of grey, which effectively conveys changes in luminance levels. The representation of time, expressed as a linear sequence of frames along the viewer's movements, further expands the drawing palette.

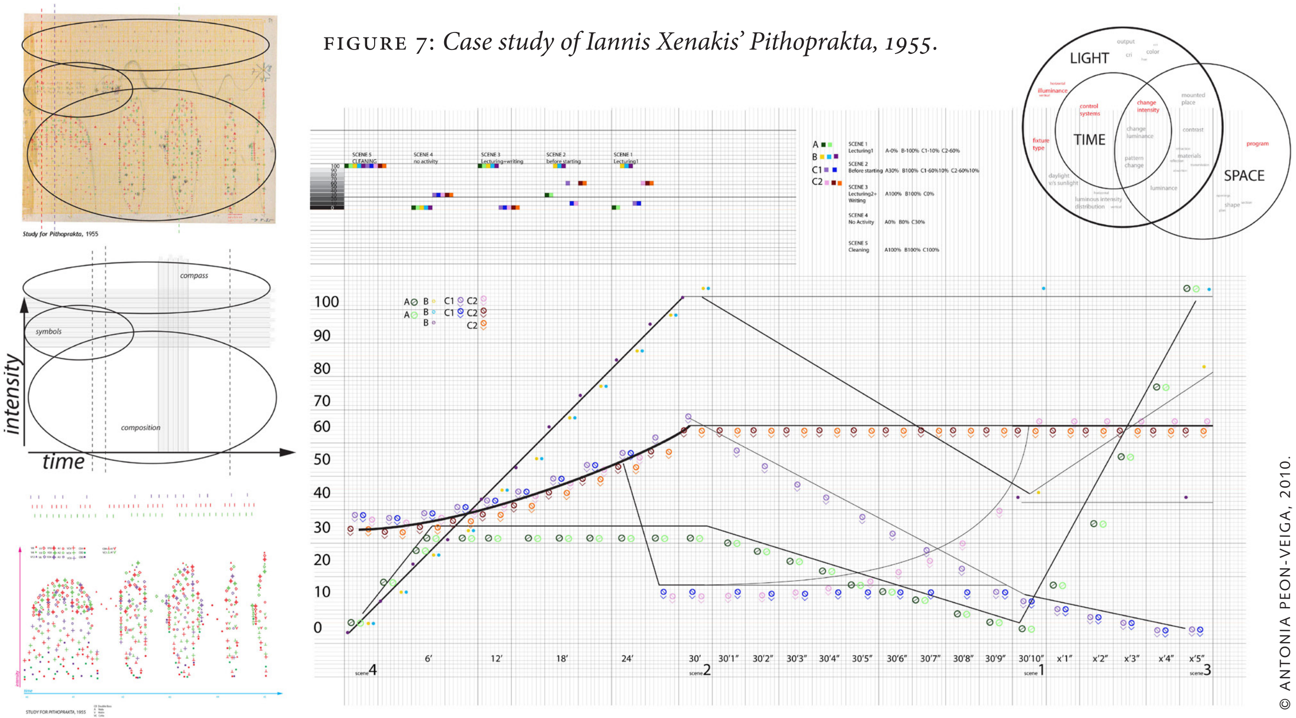


FIGURE 7: *Case study of Iannis Xenakis' Pithoprakta, 1955.*

In her analysis, Peón-Veiga's positioned images in a time graph, and created a new composite drawing that informed location, time, and space. For a panoramic visualization, she placed each frame and its angle of vision next to a vertical graph bar that indicated time. Lastly, she explored the visualization of time by repeating frames (FIGURE 6, previous page).

Peón-Veiga applied this structure to the building's space for hydroponic growth which received dynamic daylight and electric light. Glass walls and ceiling created dramatic perceptual changes, as the space would transform from transparency in daytime to an infinite mirrored space at night.

This case study contributed to the thesis in two main areas: the representation method used to compose view, and the communication of location in time and space. Visualizations using image repetition could communicate qualitative spatial changes due to variations in luminance and materials properties, multiple viewer positions (inside or outside the room), and time scale. However, important quantitative data was lacking; these diagrams could be further developed and supplemented to integrate more information between plan and image, such as fixture type, sun path diagram, or materiality.

TIME, CONTROL AND TRANSITION

CASE STUDY THREE: STUDY FOR PITHOPRAKTA, BY IANNIS XENAKIS, 1955

> *"Drawing exists in two dimensions. But its conceit is that flatness transforms into an illusory three-dimensionality—or into a different kind of fictive space, where figuration creates imaginary landscapes."*[10]

In these notations by Xenakis, three main groups of data are organized in different areas of the page: the main music composition (at the bottom), the compasses (at the top), and the four instruments (violin, viola, cello and bass), each of which can be shown with up to three symbols to indicate its subgroups (at the middle-left). Within the composition each symbol can be shown in three different colors—green, red and purple—to illustrate compass differentiation. Color determines symbol location. The graduated paper connects both symbols and compasses. By visualizing information on pauses, superimposed compasses, and sound levels, Xenakis's graphic method is effective, and visually communicates his music.

In her analysis, Peón-Veiga used different colors, symbols, lines, and locations on paper, and used graphic paper to measure time (from left to right) and intensity (from bottom to top) (see FIGURE 7, above).

Peón-Veiga applied this study to the auditorium. She used a modified version of this structure to show quantitative light data during and between scenes. Graduated paper also supported a structure of time (horizontal axis) and intensity (vertical axis), but in this case, for lighting. Each group of fixture types—downlights, spotslights and wallwashers—was individually controlled in subgroups to create lighting scenes (FIGURE 8).

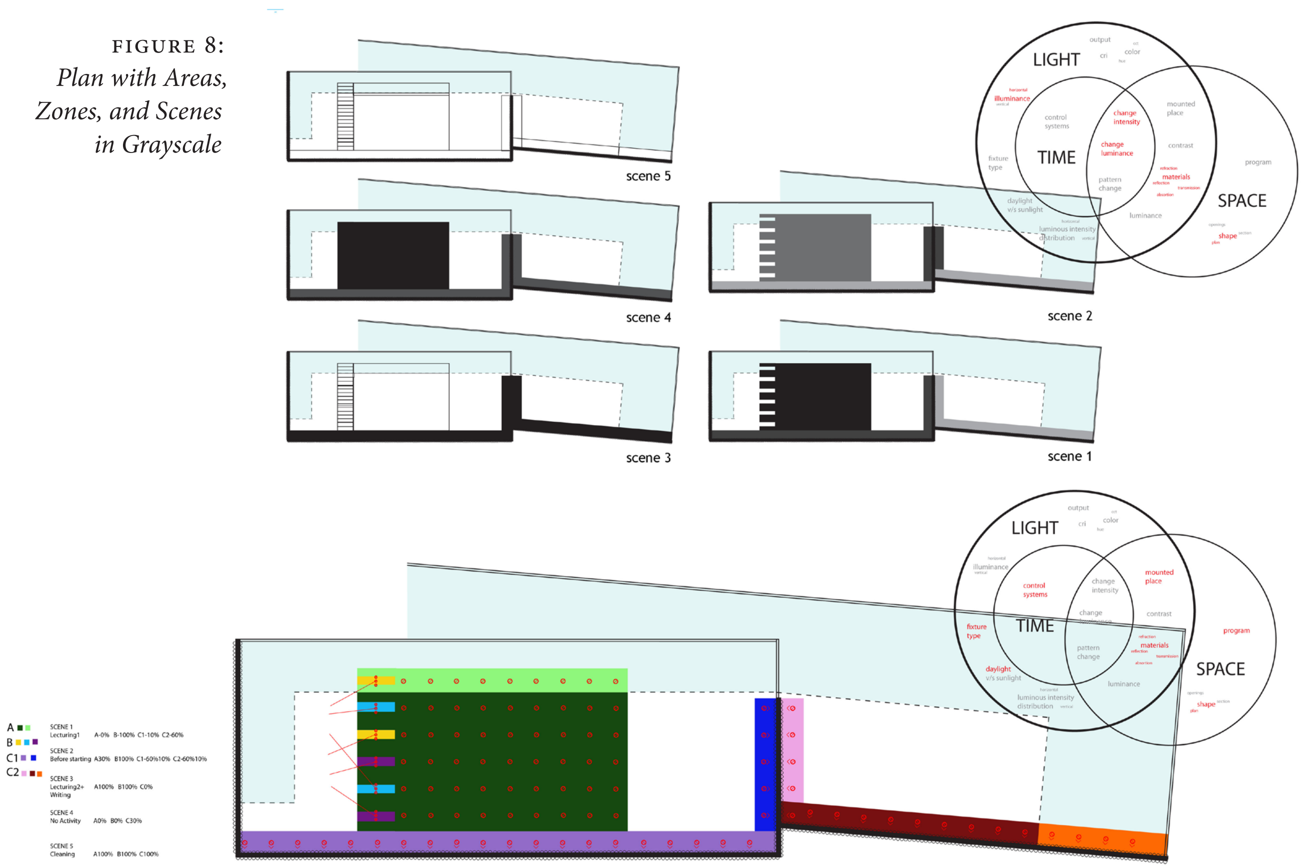
This representation was compelling, as it visually communicated detailed control information for both the lighting scenes and the transitions between them. A comprehensive visualization of quantitative data and qualitative effects required the addition of plans to show the lighting scenes and symbols to show materials. Completed with information on materiality, lighting fixture types and locations, and sequential lighting scenes, this third investigation suggested that new drawing practices could successfully portray the transformative effects of lighting in the representation of architectural space.

VISUAL COMMUNICATION: FROM COGNITIVE TO CREATIVE STRATEGIES

Peón-Veiga's investigation was focused on articulating and exploring the question of representation in lighting. Her thesis was provocative, yet not proposed as an alternative model to existing drawing conventions. Rather, it speculated on the hypothesis that the development of a radical contravention of the traditional use of drawing should not be confined to the drawing practices that are generated within spatial design disciplines. As we argue that a drawing revolution in the communication of lighting design information is needed, we also argue that there is a need to establish a sound prescriptive framework. Scientific and design fields that research and implement visualizations can inform this process.

Design, diagrams, sketches, and visualizations play an essential role in many cognitive activities, and these have been studied in numerous disciplines (e.g. computer science, architecture, mechanical engineering, graphic de-

FIGURE 8: *Plan with Areas, Zones, and Scenes in Grayscale*



sign, statistics, philosophy, medicine, geography, biology, physics, geology, psychology etc.).[11] In studying the evolution of visual communication, cognitive scientists and psychologists have established that the concepts we form in everyday thinking are designated in languages and in formal descriptions by symbols, and that in graphics and visualizations, iconic and symbolic elements are organized with semantics and syntax. Visual information has its own logic and is valid for reasoning, just as conventional sentential reasoning. Therefore, the problem of visual communication for lighting information involves research and development for the effective graphical design of new symbols, semantics, and syntax.

In her research on drawings and graphics, psychologist Barbara Tversky explains that drawings reflect conceptualizations, not perceptions of reality.[12] This simple cognitive function of drawings highlights not only how we understand visualizations, but also how we ought to conceive them. For instance, it explains why simple graphics that abstract the essential conceptual information are more effective than more realistic ones. Moreover, effective graphics rely on a correspondence between format and content. According to the *Congruence Principle*, the content and format of the graphic should correspond to the content and format of the concepts to be conveyed. The structure and content of the external representation should also be readily and accurately perceived and comprehended to conform to the *Apprehension Principle*.[13] Tvesky's findings support our argument that essential conceptual information about light should be generative of graphical reasoning in lighting (as opposed to today's reliance on drawing formats created for architecture).

These two principles are useful to explain the limitations of animations in visual communication.[14] The visibility of sequential information embedded in static representation allows one to situate time within context with clarity. This effectively addresses the problem of representing dynamic information. This validates our effort to explore the temporal dimension of lighting scenes and controls in drawing.

The problem of representation is not limited to lighting design; creative drawing and modelling strategies explored in other design disciplines can serve as useful references. For instance, MacGrath and Gardner propose in the introduction of Cinemetrics that "Computer-generated drawing has only recently become more than just an efficient two-dimensional drafting tool...It is being recognized as a new way of conceiving architecture multidimensionally in space, movement and time."[15] In *Digital Modelling for Urban Design*, MacGrath argues that digital drawing can provide new methodologies for urban modelling, and his drawing questions resonate with our own: "schizoanalysis examines the multiplicity of urban experiences in cross-sectional perspectives where one can observe simultaneously the production of symbolic space and its reception by individual sensorial perceptions."[16]

CONCLUSION

Quintessential design features distinguish lighting design from architectural design. This requires that we rethink the drawing of light. Architectural drawings provide a conventional visuo-spatial framework which is useful but insufficient. The dissociation from the iconic architectural drawing is a prerequisite to explore and elaborate a transformative structure and design for effective lighting drawings. Critical content about light, such as the interactions between light and materiality, and the time-based narrative of the variation of light, can generate successful representational formats (supplementary schedules and charts could still be used to convey non-visual information, e.g. technical performance).

The hypothetical semantics and syntax developed in Peón-Veiga's thesis, deducted from drawing case study analyses and investigative studies, suggests methods that can lead to an improved design for the visual communication of lighting design information.

The cognitive functions served by information graphics support our argument that drawing content and format must be situated within the question of communicating information about light. However, an effective design of graphic strategies requires extensive research on the cognitive implications and creative applications of visualizations.

A field at the crossroads of health sciences (the physiology of vision), social sciences (the psychology of perception), physics, design and technology, lighting design is a largely unknown but vital young design discipline, and one which lacks critical study. Today's "architecture-centric" culture, from design to drawing practices, is inherenly reductive: only new creative research from within lighting design will allow this discipline to define itself and to invent its method for drawings.

BIOGRAPHIES

Antonia Peón-Veiga received a degree in Architecture, and a Masters in lighting design at Parsons the New School of Design in 2010 (School of Constructed Environments). In her thesis project, which received the Thesis Prize, she explored the graphic representation of light in lighting design.

Nathalie Rozot is a multi-disciplinary planning and design consultant whose design and research work is focused on critical studies in lighting design. A part-time Assistant Professor at Parsons in the Masters of Fine Arts in Lighting Design since 2000, she teaches thesis seminar and thesis studio, and served as Peón-Veiga's primary thesis advisor. Her curricular contributions to the program include "Vision and Representation," which she created and taught from 2000 to 2007, and "Graphical Reasoning in Lighting Design," developed in 2009.

NOTES

1 This paper is based on Antonia Peón-Veiga's process for her graduate lighting thesis project: "Drawing Light: Processing the Lit Environment" (Thesis Prize, MFA of Lighting Design, Parsons School of Design, 2010). Nathalie Rozot served as Peón-Veiga primary thesis advisor.

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3 Kress & Adams, *Light Spaces* (Basel: Birkhäuser, 2003).

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10 Sharon Kanach and Carey Lovelace, *Iannis Xenakis: Composer, Architect, Visionary* (New York: The Drawing Center Publications, 2010), 12.

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IMAGE CITATIONS

FIGURE 1:

Peón-Veiga, Antonia. Process of *Light+Time+Space* diagram. 2010.

Peón-Veiga, Antonia. *Drawing Light: Processing the Lit Environment.* Parsons MFALD, 2010.

FIGURE 2:

Peón-Veiga, Antonia. Final *Light+Time+Space* Illustrated Diagram. 2010.

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FIGURE 3:

Peón-Veiga, Antonia. Fixture schedule, plans, daylight factor analysis grid and section of project using *Light+Time+Space* illustrated diagram. 2010

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FIGURE 4:

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FIGURE 5:

Peón-Veiga, Antonia. Representation of the exhibition area using structure of FIGURE 4. 2010.

Peón-Veiga, Antonia. *Drawing Light: Processing the Lit Environment.* Parsons MFALD, 2010.

FIGURE 6:

Peón-Veiga, Antonia. *Structure of Cinemeterics, Dynamic Contrast in Hydroponic Room.* 2010

Peón-Veiga, Antonia. *Drawing Light: Processing the Lit Environment.* Parsons MFALD, 2010.

FIGURE 7:

Iannis Xenakis, Study for Pithoprakta, 1955.

Archival exhibition print, 19 × 24 inches. Paris: Iannis Xenakis Archives, Biblioteque nationale de France.

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FIGURE 8:

Peón-Veiga, Antonia. *Plan with Areas, Zones, and Scenes in Grayscale*, 2010.

Peón-Veiga, Antonia. *Drawing Light: Processing the Lit Environment.* Parsons MFALD, 2010.