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LIGHT AND SHAPE: EXPLORING THE IMPACT OF LIGHT DURING THE PRODUCT DESIGN PROCESS

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ABSTRACT
Industry's increasing expectations for optimization within product design are clearly evidenced today. Designing physical objects for mass production involves a range of critical considerations. As part of these considerations, shaping the external surfaces of a clay model, a mock-up or a final model intended for mass production often constitutes complex considerations, where visual qualities such as shape, surface structure and texture must be assessed. Light constitutes a critical framework for aesthetical assessment during this process. This paper explores in particular how light may be utilized - as one critical resource - in order to enable the designer to build control and insight through visual observations during the act of designing an artefact or product. During a series of experiments where different shapes with different form characteristics have been exposed to different light sources, light's capability as a form-analytical tool has been assessed. These experiments have produced a body of knowledge and a growing awareness of the essential role of light as a form-describing tool during the design process. This paper explains our ambition to develop an approach for a form-describing tool when designing products. Our intention has been to describe how the conscious use of light may contribute as an important and valuable asset as a form-analytical tool for both product designers and design students during the product design process.

Keywords: Light, product design process, observations, visual perception, form characteristics.

1 INTRODUCTION

When studying light as phenomenon, one easily understands that the basic challenge is to understand the nature of light and how light influences our daily life activities. However, from our own experience in academia, it seems that within design education, light is rarely considered as an important or crucial aspect of the process of assessing aesthetic qualities in object form during the product design process. By acknowledging that light is crucial for design activity, our starting point has been the investigation of light as creative tool for designers while being in creative model building mode, as part of the physical design process. Historically there has been done limited amount of research on light and colour as phenomenon. Based on a large number of international publications, journals and conferences, the research survey and PhD-course Nordic Light and Colour show that neither light nor colour are any large issues in international research on architecture and design [1]. Contemporary research on light often relates to the large architectural scale of interior design or buildings, monuments, installations, bridges, landscape etc. Today, several research societies perform multi-disciplinary research on light and colour, exemplified by The Light and Colour Group, Dept. of Architecture and Technology, NTNU, having developed two high quality laboratories, ROMLAB and Daylight Laboratory. Both are ranged as rather unique and internationally important assets, as there exist only very few well equipped lighting laboratories around the world. Typically, most of the research performed within these and other research environments addresses questions with direct application in architecture [2], and not the much smaller object scale related to human body. Knowledge about sensorial richness and dynamism enabled from light design usually originates from research on a large, architectural scale. It is also common to discuss lightning in a framework of rational light efficiency [3], having less emphasis on human centred light quality. There are examples of advanced studies of luminance-based measures of 3D objects under daylight conditions [4], where for example contour distinctness is considered as a component of the broader light modelling and regarded as a significant metric of quality lightning. As light differs from moment to moment, this variation can provide any architectural object an additional dimension. Changes of light may give a building a different character [5]. How could light influence an object on the much smaller human centred, body-related scale - in the same way? This question has provided inspiration and influenced our approach on investigating light as a form-describing media. One problematic issue when studying architecture in daylight conditions, is that - on the large architectural scale, variable daylight conditions can produce instability of the perceived surfaces [6]. On the other hand, working with small objects on the small, human-centred scale, light quality and luminous intensity may be totally controlled and unwanted light may be eliminated in laboratory settings. Today, designers often assess digital 3D appearance of a physical model in virtual mode on a computer screen. In our view, the analogue act of assessing aesthetical qualities in a physical product shape may provide enhanced sensorial stimulus facilitated by the presence of physical models being appropriately illuminated. This paper supports the idea that stimulation of human sensorial capabilities through vision represents a trust in the designer's human capabilities and the human sensorial apparatus, as an addition to digital tools. Physical model building represents an analogue strategy which may constitute an fruitful complement to the use of computer based 3D-software during CAD modelling. Independent of the final prototype is being made by hand, machined or 3D-printed, the fact that products are made for humans strengthens the argument that design proposals should be extensively assessed through human sensorial processes that maximize perceptual experience. One could even argue that the act of assessing physical shape of an object on computer screen actually constitutes a poor and insufficient form assessment methodology compared to the rich flow of sensorial stimulus that the total human sensorial apparatus constitutes during physical observation and assessment, through vision, tactile feedback etc.

1.1 Scope

The scope for this experimental and explorative work is not light in relation to interior architecture or fashion. This paper focuses solely on the human scale, more specifically to objects related to the human body, and typically hand-held objects that naturally develops from human scale. By simulating a product design process, our focus was the application of light during product design assessment and its potential application in academia, in teaching or instruction as part of studio courses, design research etc. Even though light and colour might be considered as the same [7], due to the enormous complexity that colour theory represents, the aspect of colour is not included in this thesis. When considering the complexity of human sensorial stimulation, this paper trusts in the human eye's ability - as an intriguingly advanced and capable instrument - to assess light's impact through visual perception, connected to the designer's need of aesthetical assessment of form. Rather than taking a theoretically or technological approach to the extensive terminology within light theory, this paper investigates light from a practical, human-centred and 'designerly' perspective. Light efficiency and environmental impact will always constitute important ethical issues, however, our focus has been on the practical utilization of light sources, rather than evaluating how these light sources will appear in environmental impact diagrams.

1.2 Research question

Our research question is: How can light become valuable as form-analytical tool during aesthetical assessment in the product design process? Our main hypothesis is that conscious use of light during aesthetical assessment and physical shaping of models may constitute an important element of a designer's tool-box. One additional hypothesis is that facilitating a relative movement between either observer, object or light source will enhance the observer's perceptual experience and ability to build a three-dimensional understanding of the object's shape and surfaces during the observations. A second hypothesis is that tangential exposure of light onto a three-dimensional object form may improve our ability to detect imperfections of shape and texture on model, enabling the correction of these. A third hypothesis is that objects illuminated by condensed light such as bright micro-spots or light patterns may improve the visual perception and understanding of complex 3D shape.

2 RESEARCH METHODOLOGY

In order to develop an understanding of the enormous complexity of light as phenomenon, there has been a need to build a framework for how light can be categorized and explored, as foundation for the our experiments. A list of critical parameters that influence the observation settings was developed.

Table 1. Qualitative and quantitative parameters relevant to the experiments

1.	**Nature of physical models - type of model relating to educational situations / needs**	Teaching / instruction, visual assessment during studio course, research purposes, other purposes /situations
2.	**Type of light sources – illumination principles (not limited to electrical discharge categories)**	Halogen, LED - Light Emitting Diodes, Laser - Light Amplification by Stimulated Emission of Radiation, ILB – Incandescent Light Bulb, sunlight
3.	**Number of light sources; physical light set-up**	Singular light source, numerous light sources
4.	**Principal light modes**	Still, variable in intensity, moving, flashing, rotating, oscillating, patterns etc.
5.	**Principal object situation**	Still object, moving object, rotating object etc.
6	**Principal mode of illumination**	Perpendicular versus tangential exposure of object surface
7.	**Principal spatial configuration between light source(s) and object**	Flat (geometrically plane), spherical, diagonal, linear, triangular, cubic, pentagonal, mirroring / transverse image etc.
8.	**Principal form categories – form parameters**	Amorphous, organic, geometric / crystalline shaped object(s)
9.	**Principal form categories – form variables**	Symmetry vs. asymmetry, convexity vs. concavity, massive vs. hollow form, positive vs. negative, dynamic vs. static, opaque vs. transparent form etc.
10.	**Material categories**	Plastic mass (clay and the like), static mass, compact (high density) mass, porous (low density) mass etc.
11.	**Principal surface categories**	Structure, texture
12.	**Relation to specific design process stage(s)**	Analysis vs synthesis stage, initial ideation mock-ups, concept mock-ups, form describing models, surface describing models, realistic appearance models, functional models etc.
13.	**Nature of making**	Hand-made models, machined models, 3D printed models etc.
14.	**POV – Point Of View, or other positioning**	Spatial position of observers eye relative to recording media (video/photo)
15.	**Distance between object and eye**	Relative distance between observer's eye and illuminated object
16.	**Nature of surrounding surfaces**	Light absorbing surfaces, light reflecting surfaces etc.
17.	**Reduction /elimination of false light**	To which extent unwanted light from other sources is reduced or prevented
18.	**Observation / registration method**	Observer's eye(s), still photo camera (3D), video (4D) etc.
19.	**Level of illuminance (Lm/cm2)**	Amount of light falling on surface of object

Table 1 describes both qualitative and quantitative parameters relevant to the experiments. In addition, sub-categories, variants and combinations may be added to each parameter, constituting the enormous complexity that study of light encounters. In order to handle the overwhelming multitude and substantial complexity of parameters described in table 1, it was necessary to make a strict selection of qualitative and quantitative parameters to investigate during experiments.

3 THE STUDY

Except for those experiments involving sunlight, all light experiments were executed by setting up different configurations of light sources and object forms in a dark room. The six objects were systematically changed between video recordings, while exploring the perceived effect given from different light sources, as well as exploring different spatial configurations combining different light sources and object forms. The following matrix - table 2 - describes three different stages of this process, combining procedural stage and completion level of model with relevant light sources. Most of the experiments have utilized the advantages of a 'black box', which has the ability to block out unwanted light. In order to answer the first hypothesis about relative movement, most of the experiments were executed by putting the object into slow motion while using a rotating disc, making a full rotation each 50 seconds. The second hypothesis about tangential exposure was investigated by observing illumination from parallel sunbeams through different lattices. The second hypothesis of micro-spots or light patterns was investigated by using laser units, utilizing the ability to concentrate or diffuse the laser beams into different illumination patterns on the surface of each model.

Table 2. Matrix combining procedural stage / completion level of model with relevant light sources

Process stage / form category / model level	A. Sunlight	B. Laser	C. Halogen	D. LED
GEOMETRIC 1 **Initial form concept phase. *Idea descriptive model***	GEO1SUN Spatial configurations: Linear – Black box with variety of filters	GEO1LAS Spatial configurations: Variations over 'Spot cloud' mode	GEO1HAL Spatial configurations: Linear – Black box with filter	GEO1LED Spatial configurations: Spherical 'Light flow' (360°) + black box
GEOMETRIC 2 **Form development phase. *Form descriptive model***	GEO2SUN Spatial configurations: Linear – Black box with variety of filters	GEO2LAS Spatial configurations: Variations over 'Spot cloud' mode	GEO2HAL Spatial configurations: Linear – Black box with filter	GEO2LED Spatial configurations: Spherical - 'Light flow' (360°) + black box
GEOMETRIC 3 **Product finalizing phase. *Surface descriptive model***	GEO3SUN Spatial configurations: Linear – Black box with variety of filters	GEO3LAS Spatial configurations: Variations over 'Spot cloud' mode	GEO3HAL Spatial configurations: Linear – Black box with filter	GEO3LED Spatial configurations: Spherical - 'Light flow' (360°) + black box
ORGANIC 1 **Initial form concept phase *Idea descriptive model***	ORG1SUN Spatial configurations: Linear – Black box with variety of filters	ORG1LAS Spatial configurations: Variations over 'Spot cloud' mode	ORG1HAL Spatial configurations: Linear – Black box with filter	ORG1LED Spatial configurations: Spherical - 'Light flow' (360°) + black box
ORGANIC 2 **Form development phase. *Form descriptive model***	ORG2SUN Spatial configurations: Linear – Black box with variety of filters	ORG2LAS Spatial configurations: Variations over 'Spot cloud' mode	ORG2HAL Spatial configurations: Linear – Black box with filter	ORG2LED Spatial configurations: Spherical - 'Light flow' (360°) + black box
ORGANIC 3 **Product finalizing phase. *Surface descriptive model***	ORG3SUN Spatial configurations: Linear – Black box with variety of filters	ORG3LAS Spatial configurations: Variations over 'Spot cloud' mode	ORG3HAL Spatial configurations: Linear – Black box with filter	ORG3LED Spatial configurations: Spherical - 'Light flow' (360°) + black box

3.1. The models

In order to cover a wide range of aesthetical spectre, two different ranges were developed to simulate two design processes with opposite aesthetical directions and explore how they influence the visual experience during illumination; One form category dominated by geometric idiom (figure 1), and one form category dominated by organic idiom (figure 2). All models were shaped in Cibatool urethane foam with different density properties according to their individual completion level.

Figure 1. Geometric form category

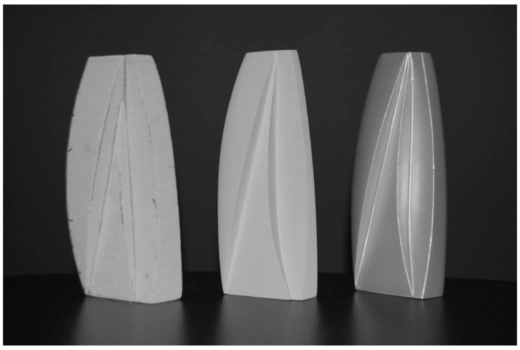

Figure 2. Organic form category

In figure 1, a procedural development originated from geometrical form inspiration is described from left to right: Idea descriptive model in initial form concept phase, form descriptive model in form development phase, and finally surface descriptive model in product finalizing phase. In figure 2, a procedural development process originated from organic form inspiration is described in the same manner as in figure 1. Figure 3 describes the black box; a rectangular volume designed with sufficient internal space for the rotating disc and ports for light exposure from external light sources, as well as fixtures for a video recorder and photo camera, the internal walls painted black for minimal reflection.

Figure 3. Black box

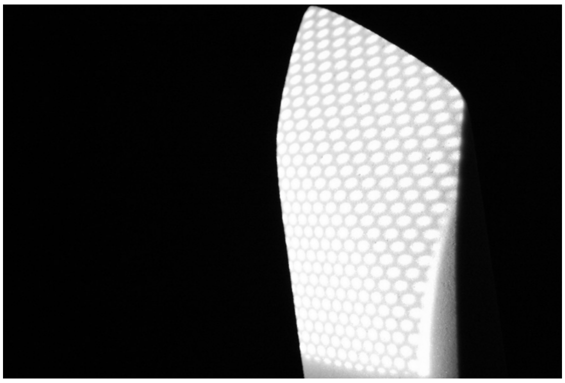

Figure 4. ORGSUN matrix configuration

Figure 5. GEO3LAS matrix configuration

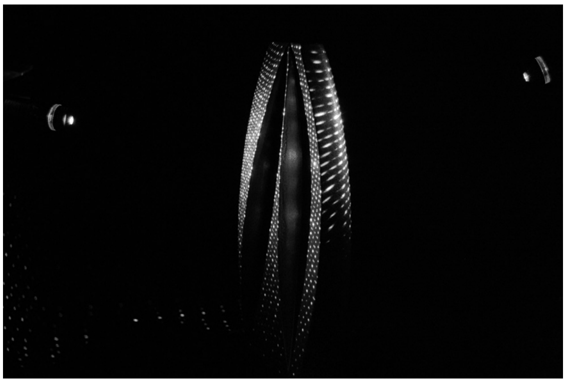

Figure 6. ORG3LAS matrix configuration

In these experiments, figure 4 describes one of the initial experiments with an organic, free-form model exposed to sunlight, constituting a typical ORGSUN matrix configuration. Tangential exposure may be achieved by orienting the illuminated object in such a way that the light beams barely touches the surface, in the same way as a line may tangent a circle or a convex surface. This configuration seem to increase our ability to detect and reveal irregularities in shape and imperfections in surface texture, and to describe a complex three-dimensional shape through light patterns. While rotating slowly, this effect is evidenced as the illuminated pattern onto the object surface slowly deforms according to the angle of tangential exposure. Figure 5 describes the GEO3LAS matrix configuration, provided by the final surface descriptive model within the geometric family, being illuminated with laser beams. Figure 6 describes the ORG3LAS matrix configuration, provided by the final surface descriptive model within the organic family, also being illuminated with laser beams.

4 CONCLUSIONS

One important consideration while performing light experiments is how the nature of light beams strongly influence our visual perception and experience when observing an illuminated object. One aspect is the difference between concentric versus parallel light beams, and how they influence the perception of illuminated surfaces. When light emits from an artificial light source, typically a light bulb filament, the beams will normally create a concentric pattern - also called spherical flux distribution – as the reduction of luminous flux follow the pattern of an imaginary sphere. The light beams will not be parallel, and this phenomenon will influence how the light beams distribute onto an object surface. Sunlight on the other hand emits from a light source one astronomical unit away from earth, and the sunbeams are considered as parallel, creating a stringent pattern on the object surface, avoiding unwanted distortion from spherical distribution. Our observations indicate that a slow motion of the object is a very efficient way of enhancing the three-dimensional understanding of both object form and surface qualities. When initiating this movement, our ability to build a spatial image of the object seems to improve. By acknowledging the advantage of motion, video has proved its position as relevant medium to document the visual impressions from our experiments, as photographs often lack the ability to capture the real-life, visual dynamism these experiments contain. The importance of choosing appropriate quality of light seems to increase according to the given level of completion of the physical model. As our observations indicate, a physical model that aims at communicating a high level of details and surface texture will require a light source that enhance these qualities accordingly. Irregularities in shape and imperfections in surface texture are seemingly easier to detect by choosing an 'investigative' mode of illumination or light source, exemplified by the principle of tangential exposure. By orienting the illuminated object in such a way that the light beams are almost parallel to the surface in the same way as a line may tangent a circle, this configuration may increase the designers ability to reveal bodily irregularities and textural imperfections. One remarkable effect of illumination produced by laser beams is their ability to strongly illuminate and describe concave surfaces - which are often difficult to explore because of the object's 'negative surface'. One additional observation is that laser advantageously illuminates the surface so intensely that these beams will remain clear on the object's surface even if the object is additionally enlightened by light sources with moderate luminous intensity.

5 DISCUSSIONS / REFLECTIONS

In design education, observation gained through these experiments may prove relevant and supportive to product design students while producing generative form models. After initial mock-ups are being shaped into real-life form concepts, spatial aspects such as symmetry as well as surface structure and -texture may be explored and developed through iterations. Our ambition is that these insights will initiate rich form discussions between student and educator - as well as enabling highly precise feedback and instructions from educator. Given the fact that appearance is basic in spatial design, designers are obliged to understand the condition for visual perception as imperative part of aesthetical assessment in design schools. By acknowledging that visual perception totally depends on the given light conditions, we support enhanced focus and critical attitude towards utilizing appropriate light source for aesthetical assessment sessions, as integral part of product design instruction in academia. Further research into this theme could include studying how digital 3D scanning techniques may complement our insights of complex 3D object shapes, which are likely to be assessed in studio courses both on Bachelor and Master level, as well as in academic design research environments.

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