Perceptual Interactions between Light and Architecture:
A graphical vocabulary using models and photographs

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ABSTRACT: The research proposes a vocabulary of the main parameters linking objects and light, leading to the elaboration of a design method and analysis to assist architects and artists in their creative explorations. The theoretical framework releases notions, principles and terms related to space, form, light and perception, assisting in the construction of physical models to visualize and control aspects of the invention. An exploration of a series of parameters relating objects and light through a collection of over 200 spatial compositions serves as a basis to stimulate the imagination and creativity in architectural design. It suggests the resetting of the creative process by direct and simple manipulations with matter, through physical models and photography, two familiar media of architectural practice. These minimal interventions simultaneously present richness in spatial relations as well as information on luminous patterns.
Keywords: light, models, objects, photography, perception, research-creation in architecture, design, architectural space

INTRODUCTION
The main objective of architectural design is to provide a framework to the human activity, socially as well as environmentally. Architects and artists are particularly sensitive to the relation existing between light and architecture, which directly implies an exploration of forms and materials. Through the architectural discipline, knowledge and interventions are related to multiple aspects of design such as technical, constructive as well as aesthetical, and that its scope is significant on the behaviour and well-being of humans. In the design process, the creative portion plays an important role in the research to attain aesthetical solutions that are also comfortable to humans. An aesthetical design solution may have the potential to generate ambiences of pleasantness, intriguing, as well as rich in terms of sensorial experiences. The notion of light associated with space is complex, encompassing numerous aspects related to simultaneous environmental variables. Amongst other things, its evaluation begins with the observation of ambiences and the relation between space and architectural features (objects: structures and built-in furniture). The research asserts that acquiring more knowledge about light and its relation with spatial forms and geometries will accelerate the creative process to provide more confidence about the qualitative expectation of a design. This study proposes a method that uses physical modelling and digital photography to allow the observation and analysis of certain physical phenomena [1] to stimulate the creative process. The research addresses two questions:

-How to identify interactions between space, *objects* and light in a space?

-How to visualise and analyse these interactions?

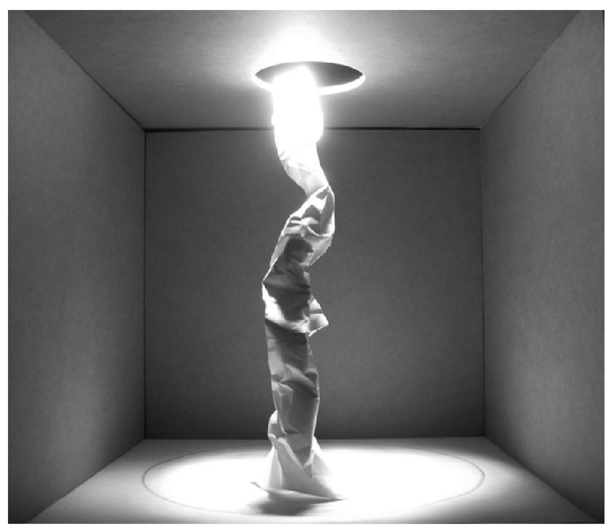

Figure 1: Viewpoint inside the cubic physical model.

PHYSICAL CONTEXT
Although an entire *architectural promenade* or sequence influences the apprehension of a space, it appears that certain spaces generate impressions of emotional intensity because of a particular quality of light, forms, materials and geometry. In a carefully designed space, the occupant’s field of view is stimulated by spatial

configurations, which ensure that the space is perceived as attracting and unique. Such spaces would be called primary while others would be secondary in emotionally arousing the senses, creating a certain hierarchy. While perceiving a space, the generation of a *global* image derives from the integration of fixed images of viewpoints as reference points [2] [3] [9]. These viewpoints become reference points or landmarks that influence the sequential discovery of architecture. The research on strategically positioned viewpoints through physical modelling and photography was therefore justified as a mean to transcendent the general impression of a space. Figure 1 shows the viewpoint that was used in the experimental setting designed to analyse several configurations of space/object interactions with light.

The research proposes an experimental approach that consists of digital images acquired through digital photography in a physical model. Although the geometry of the box is constant during all experiments, zenithal apertures and objects are variables that have been analysed in relation to concepts relating subjective theories of architectural aesthetic and a more quantitative evaluation of lighting patterns. Experiments are conducted using a modifiable physical model consisting of a cubic box. The dimensions of the model have been chosen to ensure access to photographic data as well as ease of manipulations in a creative process, offering a constant and privileged viewpoint in the space. Materials of the space are uniform, using a brown *Gatefoam* board, chosen for its mid-range reflectance of approximately 50%. Other reflectances were used on architectural features and objects inserted in the model. An artificial source of direct light (tungsten lamp with different angles) is used to ensure comparative results between different experiences. Photography under a real sky was also used to compare different lighting pattern and to obtain spatial interactions variety.

An array of simple objects and materials are inserted in the physical model to constitute a source of lighting and formal typologies explorations. Images are then subjected to digital processing by modes [7] and filters [4] to analyse the physical content, decomposing the space into structures that are visually active.

A VOCABULARY OF LIGHTING PERCEPTIONS

Recognized sources of architectural theory provide a basis to establish a vocabulary of lighting perception. Most of these theories are related to subjective analysis of spatial configurations, making it difficult for architects to associate visual impressions with definitive interpretations. Digital image analysis therefore constitutes an additional support that provides more quantitative complement to these interpretations. Although the research encompasses a much larger array of variables, the scope of paper only enables a discussion on some of them. The qualitative analysis of spatial relations between light and objects asks for the formulation of a vocabulary that translates previously discussed theoretical concepts into visual and identifiable parameters [4]. These parameters can eventually be classified into two categories: directions and zones (table 1). The directions refer to the main orientations while the zones refer to surfaces. Both can be qualified in to static or dynamic elements. One favouring stillness or even a complete stop, while the other favouring physical movement or suggesting a more dynamic perception of a scene. The classification of the parameters of the visual field (table 1) enables a discourse about qualitative aspects of light and space based on theoretical concepts that are not necessarily part of environmental sciences but serve as a guide to interpret different architectural configurations. Several grids of qualitative analysis are detailed according to theories of lighting perceptions and the quantitative information provided by digital lighting analysis.

Table 1 Classification of variables related to the visual field into categories: directions and zones.

Type of interpretation		Parameters	Categories	
			Dynamic	Static
Directions	Objects	1 • object's orientation	vertical, diagonal linear according to orientation convex irregular asymmetric	horizontal curved open, circular concave regular symmetrical without orientation
		2 • visual gravity	strong (high)	weak (low)
	Light/shadow	3 • light orientation /shadow	vertical, oblique linear razing	horizontal circular without orientation
Zones	Objects	1 • type of form object	articulated	unique
		2 • position object	peripheral high zenithal	central low lateral
		3 • number of elements:	multiple	unique
		4 • dimension of object	large	medium/small
	Light/shadow	6 • reflexion from surface	important	medium/small
		7 • type of form light/shadow	projected light projected shadow well-defined	light of aperture attached shadow poorly-defined
		8 • position of light and shadow	peripheral zenithal high	central lateral
		9 • number of elements light and shadow	multiple	unique
		10 • proportion of light/shadow	small proportion ex. : 1/5 high contrast	large proportion ex. : 1/2 low contrast
		11 • motif	complex	simple
		12 • dominance of the pattern	concentration: high contrast	dispersion: low contrast
		13 • delimitation	well-defined	poorly-defined
		14 • distribution	non uniform	uniform
		15 • light intensity	strong: high contrast	weak : low contrast

Visual forces in a space Arnheim's concepts of visual *forces* relates to notions of solid and void in spatial concepts [2], which have an impact on environmental stimuli [5] [15]. Although these concepts relate to subjectivity, the proposed typologies become of an environmental discourse on space as they play an important part in describing interrelations existing between spatial architectural features and space. The typologies translate into graphical representations that are used as a tool of analysis for images captured in the physical model. In this research, Arnheim's visual *forces*, expressed for an entire space, are identified within the field of view of the camera lens, recognizing the role that light plays in accentuating or diminishing details and contours of objects in the visual field, generating impressions of materialization and dematerialization of surfaces [9, 11, 16]. Although spatially concentrated on a specific viewpoint, the representation acknowledges a certain influence that is exercised on the perception of an entire space.

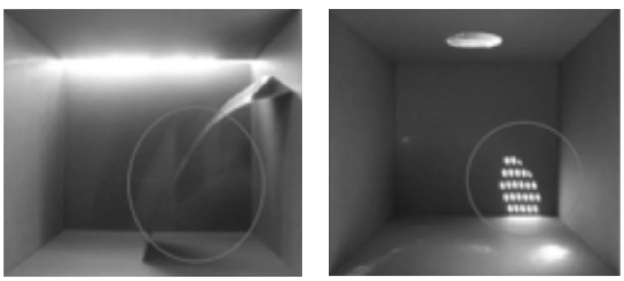

Figure 2: Lighting patterns created by interactions of light and objects. Reflected light (left) creating a diffuse pattern on the rear wall; direct light from an aperture creating a well-defined pattern (right) on rear wall and floor.

Centers of attention Primarily perceived certain elements of the visual field occupy in greater proportion our centre of attention [10] [12] [14] and are visually dominant [3]. They are creating focal accents that allow certain decomposition of a scene into several reference points. In figure 3, the centers of attention and lighting patterns are coinciding, reinforcing the presence of the central dominating feature added in the space by its high brightness.

Dynamic axis There are elements of a visual field that may refer to other more organised compositions space perception. They are associated with the notion of dynamic axis, which is either expressed as a dominant direction (axis) or zone (surface). These axis associate with the human body in defining relative height, weight, verticality, horizontality, inviting perceptions of movement or stillness [2] [6] [14]. Although such notions of visual and spatial composition developed in architectural theory are, in this research, completed with the introduction of light in relation with space. The theories of dominant axis (directions) and surfaces (zones) are therefore applied to lighting interactions with space.

Figure 3. Photography of the physical model (plaster block linear aperture, direct source of light).

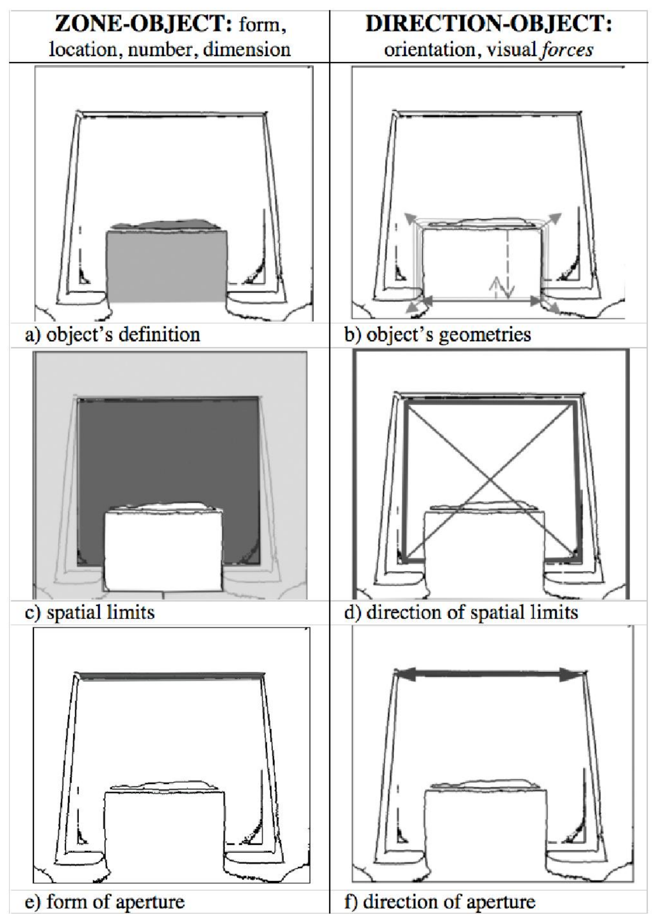

Figure 4: Graphic representation of directions and zones of the space-object configuration.

VISUALIZATION OF LIGHTING THEORIES

Categories expressed in Table 1 are illustrated in a series of tables that enable a visualization of space, objects and light in architecture. As an example, the theoretical notion of *projected-light* refers to the pattern obtained from a reflected light on a surface, often creating a motif (encircled on figure 2) that can be diffuse or well-defined depending if the light is reflected. Visual elements such as *light-apertures* or *projected-light* (figure 2), and *attached shadows* [4] create centers of attention, producing a dynamic perception of a space when lighting patterns are sufficiently defined. The analysis is divided into three categories: 1) the space itself as a container that provides certain limits to its occupation; 2) apertures (windows and doors) in terms of cut-out alterations on surfaces; 3) *objects* introduced in a space such as low partitions and built-in furniture. In the following examples, directions and zones are identified according the theoretical framework. They may reveal a dynamic impression to an observer looking in the view field of the camera (figures 4 & 5).

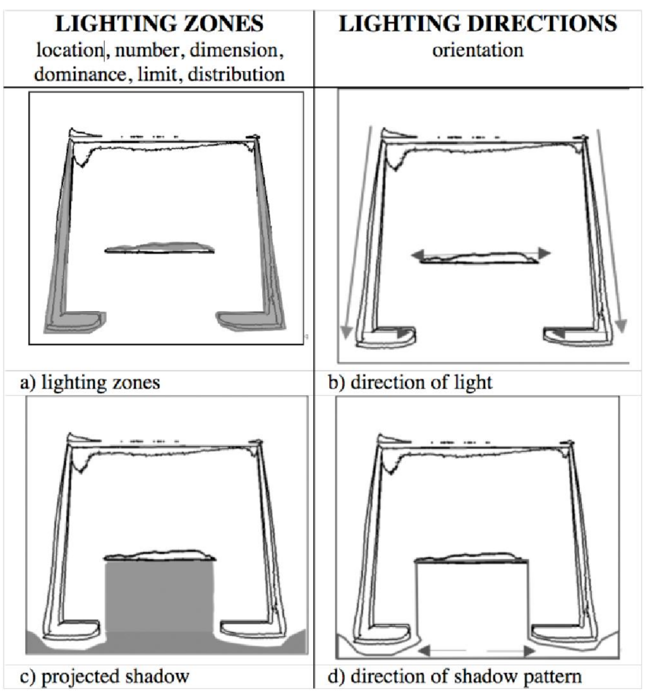

Figure 5: Graphic representation of directions and zones of the light and shadows in a space using the vocabulary developed through theoretical concepts.

Theoretical grids of analysis combined with the digital image analysis enable to identify forms of space-objects, orientation, location, spreading of the lighting pattern, shadows, lighting reflections, as well as contextual qualities of light-objects. A graphical synthesis provides an interpretation for light in relation to space (figure 6) and objects (figure 7). The notion of dynamical perception of the image is presented by the arrows, suggesting a movement in this direction and orienting our reading (figures 6 & 7). The direction of these arrows is relevant to the dominating source (initial viewpoint, most attracting visual interest) as a departure point. The symmetrical composition of the space-object (figures 3 to 7), centrally located, however produces an asymmetrical composition when light is added, reinforcing the vertical dynamic in the image (figure 7).

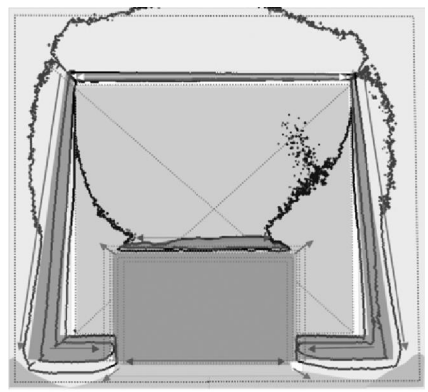

Figure 6: Graphical synthesis of the spatial analysis.

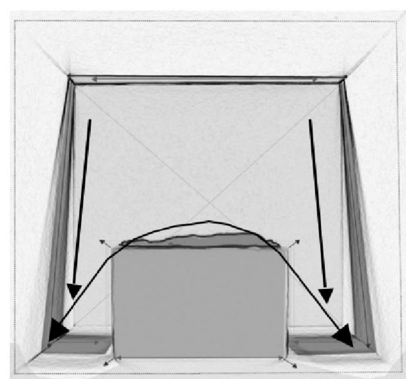

Figure 7: Graphical synthesis of the dominating perceptual actions between light and objects.

Figure 8 shows an array of different spatial configurations with some apertures and objects experimentations. The first row shows greyscale images while the second row presents examples of graphical analysis, capturing and underlining essential features of each of the design in terms of dominant perceptions and lighting patterns. The representation of the visual dynamism, represented by the direction of arrows, is certainly minimal is certain composition, but it contributes to provide a synthesis of concerted actions of elements in the field of view. The strength of certain images is mainly due to the mutual reinforcement between light and objects whenever two components are morphologically coinciding. In the left image of figure 8 (corresponding to enlarged image of figure 3), the angle of the lighting pattern is directed towards the object, symmetrically oriented. The linear aperture also coincides with the linear dominant lighting pattern. The circular aperture of the central image of figure 8 (also illustrated in figure 1) is projecting a luminous cone around the object, which is also occupying a cylindrical volume. In other images of figure 8, light and objects are creating distinct accents, which can also be interesting but it produces a much different effect, creating diversion in the field of view. The determination of the reinforcement of light with objects or other spatial features should therefore become an integral part of the creative process.

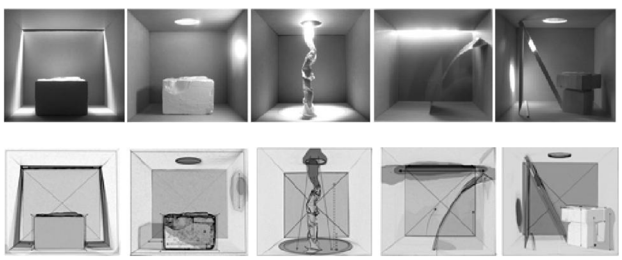

Figure 8: Light-objets-space design process illustrated with the graphical synthesis to represent, identify and discuss interactions between light and architecture.

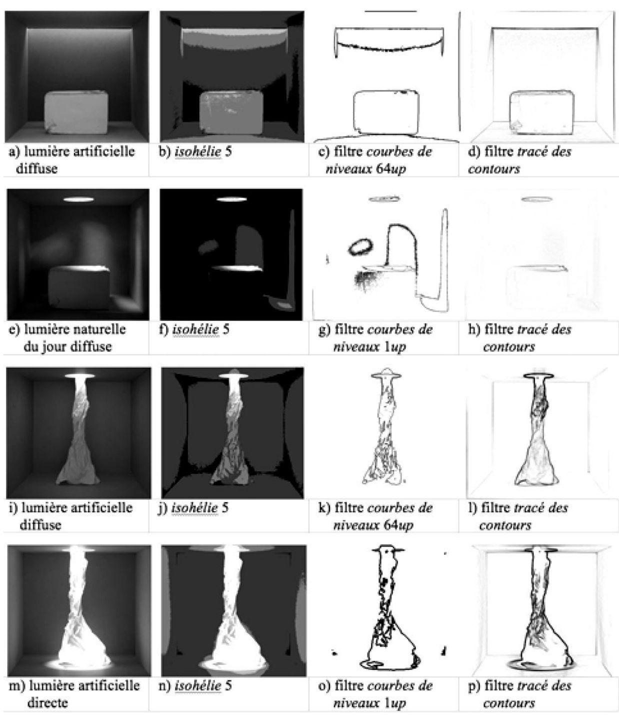

Figure 9: Digital image analysis. a, b, c) diffuse light, d) direct light

The most part of previously discussed images were obtained under direct light, associated with a dynamic perception that emphasise the sense of direction and the effects of the zones. These characteristics are greatly related with high brightness and high contrast, some of the most *active* variable of the visual environment, contributing to well-defined volumes, lighting patterns and strong shadows [13] [14]. Under a diffuse light, interpretations using the vocabulary of directions and zones are also possible, but results show that the morphological language associated with objects is dominant as light is more uniform and contrast very low [8]. Indeed, lighting patterns that are less identified, without perceptible limits and uniformly distributed produce more emphasis on the space as a whole instead of identifiable area that capture the visual attention of an observer (figure 9). Under diffuse light, the dynamic relationship between light and object is reinforced by the association of an aperture, perceived as bright and dominant in the visual field, with a contrasting in reflectance, well-defined object. For both types of light, direct and diffuse, spatial composition relates with the cohesion existing between the importance of sharing visual attention between objects and lighting patterns to reinforce and share the visual forces attributed to each architectural element.

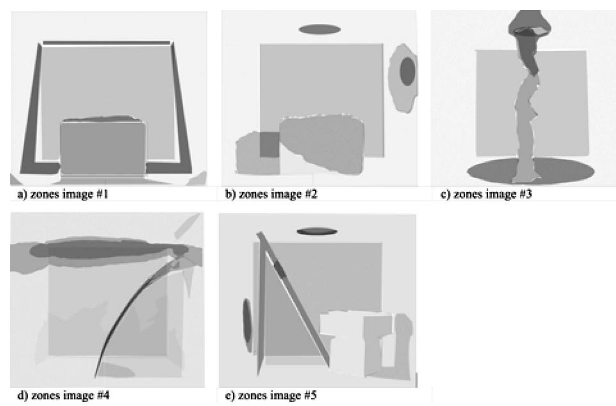

Figure 10: Graphical interpretations using the concept of light-form zones.

Lighting effects The proposed graphic representation enables the identification of lighting zones. In figure 10a, the darker grey triangular zone on each sides of the image reinforces the symmetry of the composition and the rather linear pattern produces a lighting frame intersected by the parallepided object. The dense lighting pattern, distinct from the object, provides a high contrast with the darken object, lighted from behind. In figure 10c, the symmetrical composition of objects and light show patterns that reinforce each other. The dark background produces high levels of contrast between object and space. The superimposition of the graphical representation of the object and its lighting pattern contributes to a high concentration of the visual attention of an observer on this highly contrasting composition. Directions of light and form of the object are also corresponding.

CONCLUSIONS

Through the analysis of directions and zones, the methodology relates notions of visual centers of attention that associate to the character of space in terms of dynamism and visual interest. Observations on the many elements contributing to the perception of a space are identified and listed in several tables such as Table 1. Architectural theory enables the dynamic evaluation of each element using concepts of light-form directions (figure 11), which can be modified by other concepts such as light-form zones (figure 10).

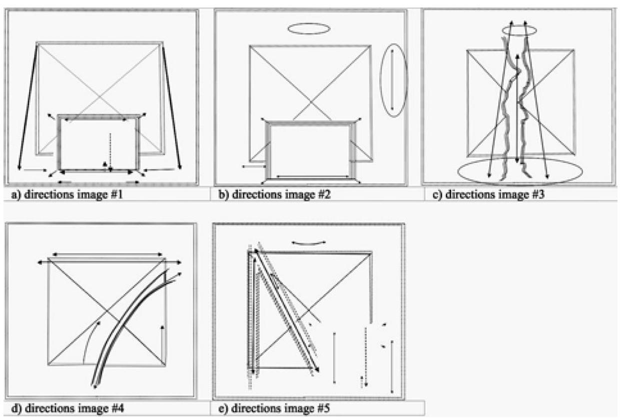

Figure 11: Graphical interpretation using the concept of directions.

The vocabulary and interpretations developed through this paper consists of detached variables, providing a clear understanding of the visual environment. It should however be remembered that the perception of space, form and light is a comprehensive and global phenomenon. Despite the minimalism of images obtained in the physical models, the research demonstrates the richness of simple spatial configurations. The discussion reveals the necessity to equally consider dynamic axis, centers of attention and forces that relate to directions and zones. Two concepts emerge from the analysis of the spatial configurations relating objects and light: competition and reinforcement. Competition is defined as a division of visual attention between several *active* elements that are not physically or morphologically related. Reinforcement of a concept appears whenever there is a connection between the graphical relation existing between object and lighting pattern. The graphical representation using concepts of direction and zones provides the necessary design tool to interpret and assign a vocabulary to such connection. During the design stage and especially for the strategic viewpoints of a space, the architect can use the methodology to respond to needs of visual attention of a space. A division of the visual attention between light and object will provide graphical representations that cover a larger area of the space whereas concentration of attention on a single object will provide converging patterns that often superimpose themselves. This detailed methodology provides the necessary basis for the design stage of architecture, using rough physical modelling that relate matter and light to study a space at its simplest expression. The methodology provides a global insight of a space whereas dominant visual elements are clearly identified. This approach reiterates the richness of physical model experiments as sources that nourish the imagination rather than simple representations. Moreover, it designates the graphical interpretation of the light-object relation as a privileged creative act allowing the understanding of dynamism and effects on the overall perception of a space. These graphical interpretations should therefore be considered as contributions to a vocabulary that develops the creative acuteness.

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