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# Evaluating Human-AI Design Interaction From the Perspective of Cognitive Abstraction

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## ABSTRACT

Together abstraction and iteration are two foundational cognitive processes used to expand intellectual experimentation, realize innovation, and construct theoretical models. This research study interprets how the semantic structure of prompts and images (input and output) change through iterative Human-Artificial Intelligence (AI) design workflows. In speculative design practice, the semantic structure of prompts are modified in the iterative Human-AI workflow in order to change concepts, explore nuances in conceptual formation and application, and control consistency of output quality when working with generative AI tools. The research questions examined in this study are; i) how do prompts and AI visualization transform through iteration? and ii) how is the construct of abstraction used in the development of a conceptualization? The historical-cognitive methodology is applied in the analysis of design workflow to structure prompts and AI output visualizations. Using the ontological categories of domains, scoping-contextual (scopal) conditions, constraints, relationship and technical-function the semantic structure of prompts is reassigned to distinguish patterns across iterations. Content interpretation analysis of generative AI conceptual materializations (outputs) distinguish the presence of qualities of specificity and/or non-specificity, and presence of shared semantic meaning. The research aim is to identify the presence of non-specificity, a characteristic of abstraction in the Human-AI input and output conceptual formations.

**Keywords:** Space configuration, Artificial intelligence, User experience, Workflow, Visualization, Speculative design

## INTRODUCTION

Together abstraction and iteration are two foundational cognitive processes used to expand intellectual experimentation, realize innovation, and construct theoretical positions and test scientific models. In this paper, I examine how the semantic structure of prompts apply abstraction as a method and control consistency of output quality in the Human-Artificial Intelligence (AI) speculative design conceptual production. The research questions examined are i) how do prompts and AI visualization transform through iteration? and ii) how do Human-AI speculative design workflows engage the construct of abstraction in the development and change of a conceptualization? Findings highlight how iterative testing of semantic constraints (non-specificities) by the designer to create inputs, is further advanced by the AI tool through

the semantic reference of shared meaning. The methodology tested in this study may be useful to further explore structuring properties of H-AI iterative conceptual development and change.

## LITERATURE REVIEW

### On the Ontology of Abstraction in Conceptualizations

Ontology present an interesting interactive dynamic by which to examine the semantic structure of Human-AI (H-AI) interaction. Ontological specifications act as the approximate of an intended model of a logical language that reflects a conceptualization (Oltamari, 2019). The definition of an ontology by Gruber is 'an explicit specification of a conceptualization of the world by means of a given language, a formal specification that may also be a shared conceptualization.' Conceptualizations are language independent abstractions containing different degrees of specification that may hold shared or negotiated meaning (Oltamari, 2019). Domains are inherently part of conceptual spaces that may be characterized by a number of qualitative dimensions related to its [morphology] perception (temperature, brightness, weight and spatial dimensions of height, width depth) (Gärdenfors, 2017). Grasping the understanding of a domain requires referent to its characteristic distinctions and specificities, communicated through words, gestures and icons that refer to different regions of the domain. Concepts may be understood by their collection of properties contained with intention, expressing how their properties are corelated, typically expressed by adjectives (Gärdenfors, 2017). These properties may identify a single domain or a complex of properties may form a number of domains are expressed typically as nouns (Gärdenfors, 2017). Iterative semantic structure may indicate change or transformation in the noun phrase reflecting a loss of domain and relational specificity, which may indicate abstraction or the way the noun phrase uses determinacy of reference, indicated by degree of constraint in specificity (Farkas, 2002).

### Abstraction and Specificity in Generic (Conceptual) Models

Research on conceptual change highlights abstraction and the role of nonspecificity in the formation of generic models, understood to be mental abstractions of a system or relationships seen in objects and dynamic processes (Nersessian, 2005). Generative AI systems are useful to rapidly perform cognitive abstraction tasks and construct a synthesis of new patterns that are presented as the output materializations of a concept (visualization artifacts). Designers engaging in reflective analysis of AI artifact outputs may further extract specificity features that achieve greater levels of abstractions in the input sematic language in order to clarify the expression of design ideas. Nersessian (2005) notes a generic model should satisfy the abstracted domain constraints that constitute the domain field. The generic model will ideally represent the class of phenomena in each domain that are capable of producing specific configurations. The aim of this study is to evaluate how designers integrate or revise semantic structures to change design concepts

in prompts for Human-Artificial Intelligence (AI) integrated workflows that aim to improve design visualization outcomes as a type of generic model. The goal of this study is to establish an evaluative tool that is able to assess consistency and change in conceptualizations between Human-AI systems. Two case studies included in a recent exhibition showcasing the speculative design workshop "The Quality That Lights Up" are examined.

## METHODOLOGY

In this study prompt semantic structure is categorized through an ontological schema that distributes the phrase elements according to ontological aspects. The goal is to align the semantic structure of inputs (prompts and sketches) to AI materialized visualizations (outputs) in order to establish the continuity of transformation of the image through iterative development. Table 1 outlines the aspects examined in this study. Text prompts (inputs) are deconstructed to identify their semantic structure aligning to ontological categories of domain, condition relationship, constraint, technical-functional. Interpretations of the AI materializations of conceptualization, as individual images are aligned to patterns identified in the semantic structure of prompts. The visual interpretation of AI conceptual materialization distinguishes three aspects; i) the presence of specificity and non-specificity (abstraction) in the visualization, ii) the presence of a shared semantic reference (interpreted meaning), iii) the presence and distinctiveness of semantic continuity of spatial and social references seen in the composition of object/subject and in the phenomenal aspects of individual and iterative AI output visualizations. The presence of distinctions in the prompt and AI materialized image are identified referring to how variables are introduced by the phrase or assigned values. In the case examples presented, iteration is used by designers to rephrase prompts with new semantics. The maintenance of non-specificity [in the prompt input during iterative testing with AI tools] may establish the development and continuity of structuring logic for a generic model. Two case studies shown in an exhibition of AI-Designer interface as examined. As the speculative design workshop aimed to develop futuristic conceptualizations of lighting, I assume an architectural categorization in phrase structure based on its domain morphology and scopal condition characteristics.

## ANALYSIS AND FINDINGS

This section presents the analysis of two Human-AI project cases in order to illustrate the presence of abstraction and non-specificity in conceptual artifacts of prompts and sketches (inputs) and AI conceptual materialization (outputs).

### Case 1 Overview

In case 1 the designer uses the generative AI software *Vizcom* to iteratively develop the conceptual materialization as a visualization output. The designer input consists of text prompts and hand drawn sketches. Light and space are the main focal elements abstracted in the structure of human input. In concept

A the AI visualization presentation is highly abstract. Through the iteration the aspect of light is seen to materialize a spatial form rather than provide source of illumination. The light sources are not defined. The spatial form is presented as planes and interior volume (cube).

**Table 1.** Aspects of semantic structure in H-AI conceptualization.

| Aspect | Sub-category | Definition |
|---|---|---|
| **Domain** | Morphology | Attributes of shape, line, point, dimensions, scale etc. (Farkas, 2002). |
| | Scopal Configuration | Structure and configurational properties, that are in dependency on scope, temporal aspects or reflect relationships to typology specificity such as context (Farkas, 2002). |
| | Quality Distinction | Spatial, atmosphere, and social qualities, that illicit distinctions and specificity (Gärdenfors, 2017). |
| **Condition Relationship** | Assigned Value | Precision succinct linking value to objects, people, space (Farkas, 2002). |
| | Quantification | Assignment of value, quantity (Farkas, 2002). |
| | Connection | Relations in the introduction of variables and their assigned values (Farkas, 2002). |
| **Constraint** | Restriction | Rules for operation or assignment of value or quality (Farkas, 2002). |
| | Ordering | Evidence of formalization, classification in topological relations (Farkas, 2002). |
| **Technical-Functional** | Operational | Performance oriented attribute or brand technological indicator (Farkas, 2002). |
| | Tasks | Indicators of activity and action, doing (Farkas, 2002). |

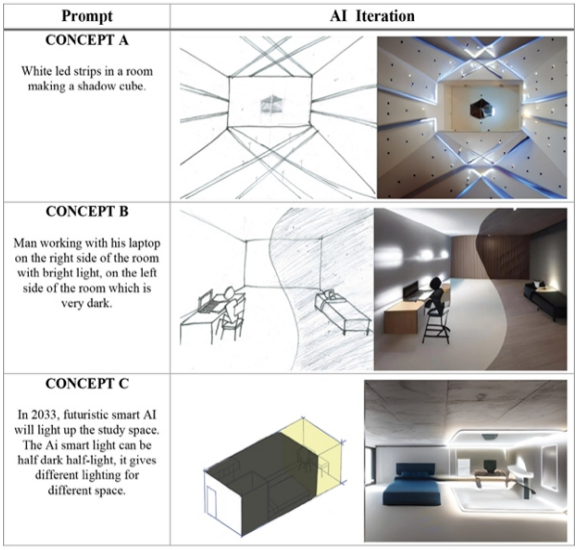



**Figure 1:** Case 1 Human input (prompt – sketch) iteration and AI output (visualization).

## Case 2 Overview

In case 2 the designer uses the AI tool *Midjourney*. The semantic structure of the domain reflects a spatial room in the early visualizations with ambient colour mask to indicate differentiations of light with an exception of the rear wall plane. This has a specific element of window that is assigned the role of scopal configuration referencing light source in the AI interpretation of meaning of human input. Window is understood to be a sources of light even as this is not incorporated in the semantics of the human prompt. In the second series of iterations the frame of the window maintains continuity in the output visualizations but is interpreted in two different ways. The distinctive specificity in the visualization image references the mood as experssions of colour, curving lines and which modify the shape and form of the window frames. The aspect of colour is not specified in the prompt sequence.

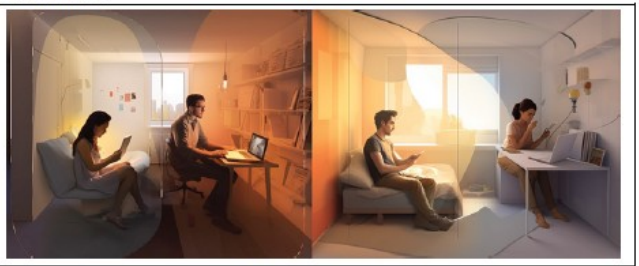
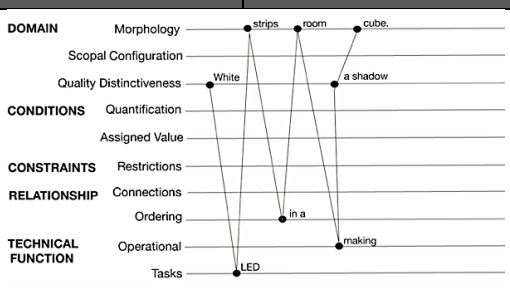
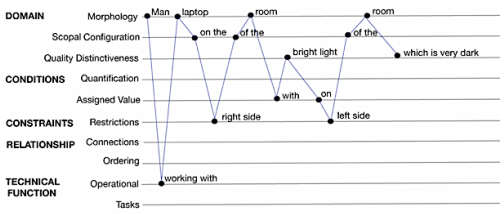
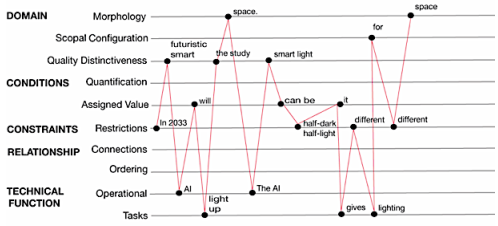
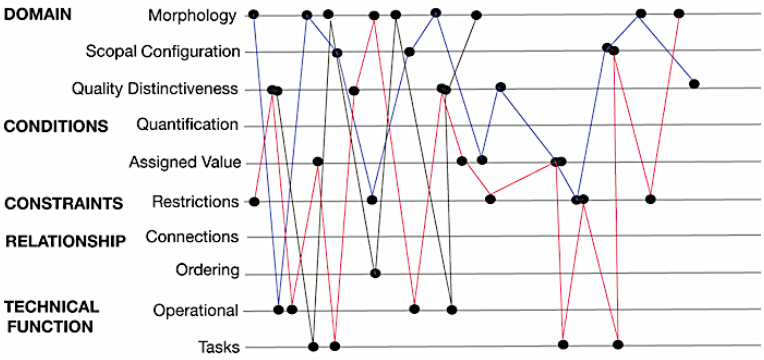
| Prompt | AI Iteration |
|---|---|
| Making partitions with light to divide living spaces to increase small living spaces |  |
| Light partition system to adjust its lighting to improve user's mood and wellbeing. |  |
| 2 people working in the same room doing different activities divided by a partition emitting 2 different kinds of light. |  |
| An apartment room with people doing different activities and a partition made of light separating their spaces and shining lights of different colors. |  |

**Figure 2:** Case 2 Human input (prompt – sketch) iteration and AI output (visualization).

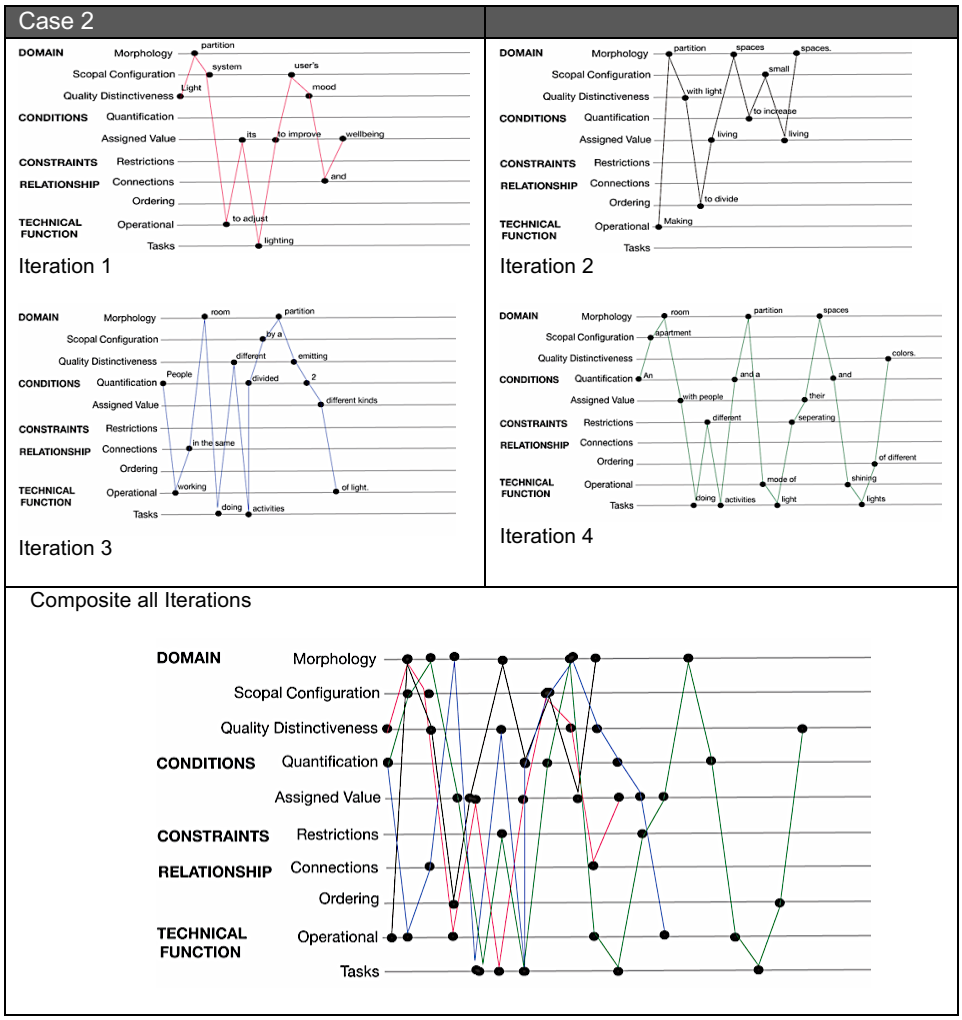
**Table 2.** Analysis semantic structure (prompts) Case 1.

| Case 1 | |
|---|---|
| Iteration 1 |  |
| Iteration 2 |  |
| Iteration 3 |  |
| Composite all iterations |  |

The colour palette in AI output images relate to mood through the different colour assignment to spatial elements of furniture and partitions (Wexner, 1954). In the third iteration, a frame of coloured light encapsulates human activity, with layering and shape configurational differences aligned to mood. To reflect a change of mood, the AI system tranfers blue and square shape to warmth and soft curving partition in the foreground. This is then scaled up

with AI distributing human activity throughout a further abstracted structure of frames and dematerialized spaces. The final visualization is a conceptualization and generic model of space within a space. The AI visualization constructs a structural grid scaffold system with possibilities for multiple spatial domain definition but it is maintaining an abstract visualization. The AI tool applies non-specificity to compose the materialization, scales up the concept to indicate the formation of a generic model. The image is abstract in many aspects, from the level of domain, scopal conditions, and relational structure. Aspects of technology, task and function are not distinct in the visualization.

**Table 3.** Analysis semantic structure (prompts) Case 2.




The analysis of semantic structure aligned to ontological categories (aspects) reveals a clear non-specificity at the domain structure, with quality distinctiveness and quantification highlighted as specificities operating in the prompt in case 2. Patterns are noticeable in the composite for both case 1

and case 2 and highlight the designers strategy to vary deployment of words to express variety of to clarify the different concepts to be visualized.

## CONCLUSION

This study examines how generative AI tools may be used to develop generic modelling processes through representations of the general dynamical properties of prompt and visualization semantic structure. As seen in the transformation of prompt semantics structure and AI materialization visualizations in Case 2, the the AI system process involves the extrapolation of a shared meaning from the prompts for specific words and phrases ex. mood, light. Together these become expressed in the window frame, and are carried forward as a spatial distinctive quality materialized through application of opacity and color to the required partition that gives light. This was a construct that are not intended by the designer in their formation of a concept through the prompt composition aiming to elucidate a design direction of vision. The extrapolations of physical features in the materialization by generative AI achieves an idealization of the human conceptualization input. Idealization is a cognitive process need to reduce and simplify phenomena to form a model to which mathematics can be applied as an ideal model. Cartwright notes that the point of constructing an ideal model is to establish an abstract law, where abstraction is extrapolation beyond the ideal model.' (Cartwright, 1989, P 187 in Nersessian, 2005) This study of lighting atmosphere through manipulations of AI materialization and prompts, present us with different degrees of abstraction across iterations to provide a general description that is in some way common to all.

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