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SUBSTANCE VARIATION IN DESIGN APPROACH

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1. Introduction

In the process of designing, substantial consideration and effort are applied to the formulation of ideas and solutions. Attributes, properties and qualities are specified towards design solutions and results. Attention has been placed to this course of action with the purpose to understand how do designers' activities enhance the value of the design process and deliver value to the design results. Attempts in design cognition have been made to augment the processes of giving substance and materializing design solutions. Design has been recognized as an appropriate field for cognitive studies and advancement of cognitive theories. The study of designers' cognitive characteristics and behavior became an important aspect to understand the mechanisms of the design process also in the context of teamwork. Complex design problems involve designers from different disciplines and make them blend and converge to one purpose. In these situations, different designers share the creative process and the problem context. Collaborating and sharing the design process became tasks that ask for management skills.

The purpose of the present research is to identify how designers' characteristics and behavior ascertain different approaches to the design process. The identification of transdisciplinary commonalities and differences between design approaches can lead to understand design processes underlying mechanisms with the aim to identify effective design practices on the perspective of the Lean management philosophy. These outcomes might derived in practice and educational application. The present paper reports a case study providing insights on the characteristics and behavior of designers from different disciplines that share the same working environment and contribute to the creation of interactive design solutions. The content of the designers' statements are analyzed to identify variants and invariants of designers' approach.

2. Literature review

Despite various research attempts in the past to understand the mechanisms of design cognition, the center of the design domain remains without an organized and solid body of knowledge difficulting the task. Research in design has been suffering from the following difficulties: design is generally referred as a way of thinking therefore a broad set of tasks has been called design activities; design is specifically referred to the knowledge and resulting artifacts of the core design disciplines creating ambiguity; purposeful research has not been developed in cross-disciplinary or interdisciplinary approaches; the core knowledge of the design domain does not have more than partial responses rather than structure. These circumstances contribute to design ambiguity and ensuing difficulties in framing and structuring the central knowledge of the design domain.

A major attempt is the Goel and Pirolli (1992) generic design hypothesis regarding the study of design as a subject matter in its own right. The study presents findings of commonalities in the structure of design problems and tasks across some design disciplines, as well of significant differences in the structure of design and non-design problems [Goel 1994], and represents a contribution to structuring the design core knowledge domain. Other paired studies were assert through empirical research [Visser 2009, Akin 2001, Eastman 2004, Cross 2006] on diverse design domain concerns. These concerns derive from the following assumptions: a) different design disciplines share major commonalities; b) different design disciplines show variation in similarities; c) designers approaches vary across design disciplines; d) design situations frame design approaches creating variance in designers cognition.

One notion of design became generally recognized: design is a cognitive process, or a cognitive frame that can be acquired and embedded through personal development and experience and is extensive to all the fields of human action. In spite of this, the Latin origin of the word design "designare" (de + signare) which means 'to designate', make things "be a sign of", stresses an essential aspect of the design nature and a characteristic of a design result.

Moreover, design results evolve under designer approach set of elements that comprise independent constant variables and dependent variables. These variables have been addressed as invariants and variants in design [Akin 2001]. Invariants have been identified as variables of a conditional character, variants have been identified as dependent or even uncontrolled variables. Both influence designers perception and analysis of design problems context and play an important role in the designers behavior framing the result through an individual and/or team process.

Moreover, design situations can vary significantly requiring different creative approaches. The core of a creative approach lies in the ability to mold experiences into new and different organizations and to communicate the resulting experience to others [Taylor 1959]. This process is characterized as a communicative task of transforming implicit experiences into objective symbolic form, and additional skills in translating subjective notions into objective form. To completely specify solutions, designers need to characterise elements and attribute qualities that give substance to their mental representation, deriving in tangible artefacts or intangible results as the feelings provided by a design experience. Studies with relevance for design demonstrate that the factors governing the visual perception [Metzger 1936] are inherent in the visual system and the organization of the visual field occurs essentially without our involvement. These rules hold that stimuli organize themselves in the simplest and most balanced manner, complemented by a set of perceptual constancies or invariances that enable us to recognize objects and form experiences for what designers have increased sensibility.

Inherently, design involves mental models and a rich set of semantics [Goel and Pirolli 1992], and is appropriately qualified as the construction of representations [Visser 2006, 2009]. The characteristics of the mental models also depend on invariants and variants of each designer approach and set of design elements and tools in dayly work. Working more commonly with design elements such as abstract representations as the alphanumerical, or schematic representations of mechanisms and architectures, lead to more abstract concerns on structural relation while more vivid mental models as more accurate external representations of final appearance, allow the designer to characterize the solution in a closer approach to the final result, framing the assessment of what will become physical artefacts [Visser 2009] and its intangible results.

Besides influencing the designer, the process and the result, variants and invariants of designers approach also influence the teamwork that similarly to the individual process, involves a perceptual act and a cognitive strategy and in addition, a co-development of problem and solution [Cross 2009].

3. Research procedure

The present paper reports an example from a transdisciplinary empirical research in four design disciplines, namely, architecture, industrial, graphic and interaction design. The research strategy adopted is based on the case study method. Its use is justified since the research reported investigates contemporary events within its real-life context [Yin 2003]. The study presented here refers to a piece of data collected during the periods of observation in a company that provides interaction design solutions, more specifically in the design department. The current example comprises six of 27 interviews. For further enlightment on the characteristics of the six design actors, a detailed analysis of the six interviews is presented. The selection of interviews was made on those who exhibit more distinctive profiles and represent essential roles of a typical team. The data releases common characteristics across the interviewees: sharing the same task environment; contribute to the creation and development of design solutions. Each designer represents an essential and distinct role in the teamwork and naturally differ in background as shown in Table 1.

Table 1. Background and activity of the sample

Designer	Background	Activity	Period of interview
A	Software Architecture	Programmer	0:53:30
B	Graphic design	Interaction designer	1:41:43
C	Literature	Copywriter	1:22:58
D	Mechanical engineer/Management	Product development	2:15:54
E	Industrial designer	Industrial designer	1:14:28
F	Environmental engineer/Arts	R&D Artist and Engineer	2:44:17

The study refers to data collected by means of a structured interview addressing 11 main topics regarding the designing context, such as designers motivations.

With the purpose to study characteristics and added value of different designers' activities as well as gaining insights on the structure of each one approach to design problems the study aims to answer to the following research question:

Do designers sharing the same design environment show the same design approach characteristics?

3.1 Coding procedure and dimensions

The search for a transversal categorization system to the main research goal led to a sequence of steps. In a first stage data were analyzed in three main dimensions namely, the designer, the process and the result. In a second stage each dimension content was distinguished on the light of a more detailed identification of the structure of the assortment [Saldana 2009]. The structure that emerged from the data has been compared with literature and showed similarities with theoretical insights of the Aristotle categories of substance. The interpretation of these categories in the designing context matched with the structure that emerged from the data and the identification of other dimensions namely, management, performance, team and environment. Each dimension emcompass categories of substance to which sub-categories are addressed as shown in Table 2.

Table 2. Structure of the categorization system

Coding dimensions	Categories of Substance	Sub-categories
Environment	*Place*	Structure, Values, Vision
Team	*Relation*	Role, Collaboration, Communication
Designer	*Essence*	Purpose, Concerns, Values, Type of problems
	Passion	Motivation, Emotion
Management	*Time*	Planning, Happening, Decision
	Situation	Client, Resources, Complexity
Process	*Quantity*	Design elements, Design tools
	Quality	Procedure, Strategy, Finding direction, Flow Solution conceptualization, representation and materialization
Performance	*Habit*	Attitude, Learning processes, Cognitive processes
	Action	Cognitive retrieval mechanisms, Heuristics

4. Results Analysis

Interviewees' statements were analysed and grouped in codes to each sub-categories. Statements content gave meaning to the codes and to the identification of invariants, which conditional character is stated by the 6 interviewees, and variant characteristics, which dependant or uncontrolled character is specific or shared by some of the interviewees. Predominance of variants and invariants in each dimension is shown in the discussion. Further analysis of the characteristics is presented.

4.1 Invariant characteristics

Design problems and cognitive retrieval mechanisms emerged from data as the most shared characteristics between designers, followed by structure and values of the environment as shown in Figure 1. Furhter analysis of invariant characteristics to each dimension sub-categories is described.

Environment

Place – The category 'place' addresses the working place and its environment characteristics, cultural values as well environmental issues in a broad and societal sense. Interviewees show invariant characteristics regarding: structure such as, *Horizontal approach to people, Challenging risky company, Space to give and exchange ideas and to do a good work, Provides personal accomplishment in teamwork, Keep the person active and aware*; and values, such as, *Liberty of saying, Freedom to think, to explore and express, Opinion recognition, Responsabilization, and More engagment.*

Team

Relation – The category 'relation' addresses the teamwork and designers' individual and team roles. Invariants regard: team role, such as, *Add suggestions as user and professional, competence recognition, Contribute to define the value of the result;* collaboration, such as, *Sharing, Personal and team engagement, Converge to the same objective,* communication, such as *Willing to listen, Discussing, and Focus*.

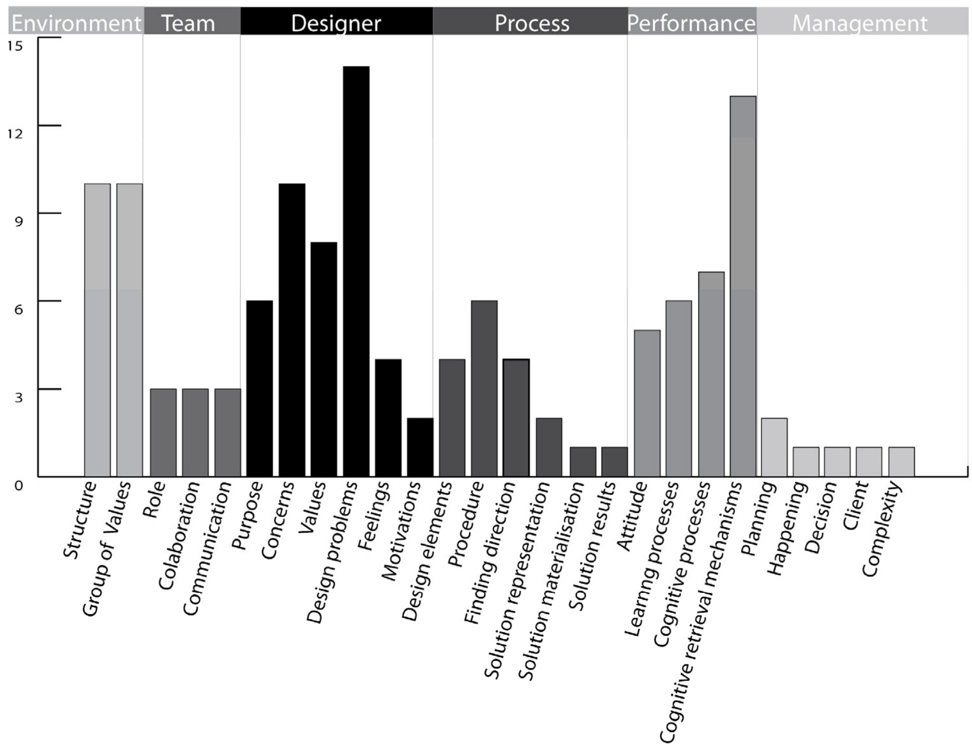

Figure 1. Assortment of invariant characteristics to each one of the main dimension

Designer

Essence – The category 'essence' addresses the designers essential aspects such as, purposes, concerns, values and the type of design problems they deal with. Common purposes relate with *knowing the problem context, project objectives and target group, learning from the process, quality and reliability in final result*. Concerns regard *project feasibility* and *knowing each one team role*, *planning* and *solution improvement*. Values hold on *cooperation, experience, integration, inclusion* and *simplicity*. Common problems refer to *structuring the problem or the solution* and situations that influence the work of all.

Passion – The category 'passion' addresses feelings, motivations, emotions and beliefs. Designers share contrasting feelings such as *Enthusiasm* and *Tiredness*, and motivations, such as *Learning* and *Personal interest* for projects.

Process

Quantity and Quality – The categories 'quantity' and 'quality' address design elements, methodology and solution. Example of invariants are, *Alphanumeric representations, Structural relations,* as design elements, *Mental scheme* in finding direction, *Mental and Physical sketch,* in solution representation.

Management

Time – The category 'time' relates to aspects of planning, happening and decision during the design process. Example of Invariants regard: planning, such as, *Know planning information from the project manager*; happening, such as, *Not possible to have everything clearly defined early;* and decision such as, *Commit to the decision on the final solution.*

Situation – The category 'situation' relates to aspects of the problem situation, such as client, resources and complexity. Invariants regard: the client, such as, *Inform on project feasibility;* Resources, such as, *Cope with available elements and persons,* and complexity, such as, *Complex projects that require more work, time in structuring*.

Performance

Habit – the category 'habit' relates with permanent actions of designers. Examples of invariants regard: attitudes are such, *Being positive, being flexible, Experimenting, Clarify doubts, Open mind;* Learning processes, such as, *Learning through mistakes, Reuse of knowledge and solutions, Discussing;* and Cognitive processes, such as *Thinking, Analysis and Imagining*.

Action – The category 'action' relates with designers transitory actions to solve more persistent and difficult problems. These actions are related with cognitive retrieval mechanisms. Examples of invariants are, *Awareness, Questioning, Proposing, Ask what is missing, Risk assessment, Opportunity recognition, Control recognition, Limits recognition and Give time*. Designers share several cognitive retrieval mechanisms to improve personal and solution performance.

4.2 Variant characteristics

Variants are dominant in three main dimensions namely, Designer, Process and Management as shown in more detail in Figure 2. Variant characteristics related to *The client* and *Solution conceptualization* emerge aligned as the most prevailing variants.

Other not so prevailing sub-categories characteristics but that more evidently distinguish designers approaches are also given as example. A thorough analysis of the three main dimensions is presented.

Designer

Designers show variant characteristics in the categories of *Essence* and *Passion*. *Motivations, Design problems, Concerns for improvement* and *Values* emerge as the most variant sub-categories. Some characteristics are shown in Table 3.

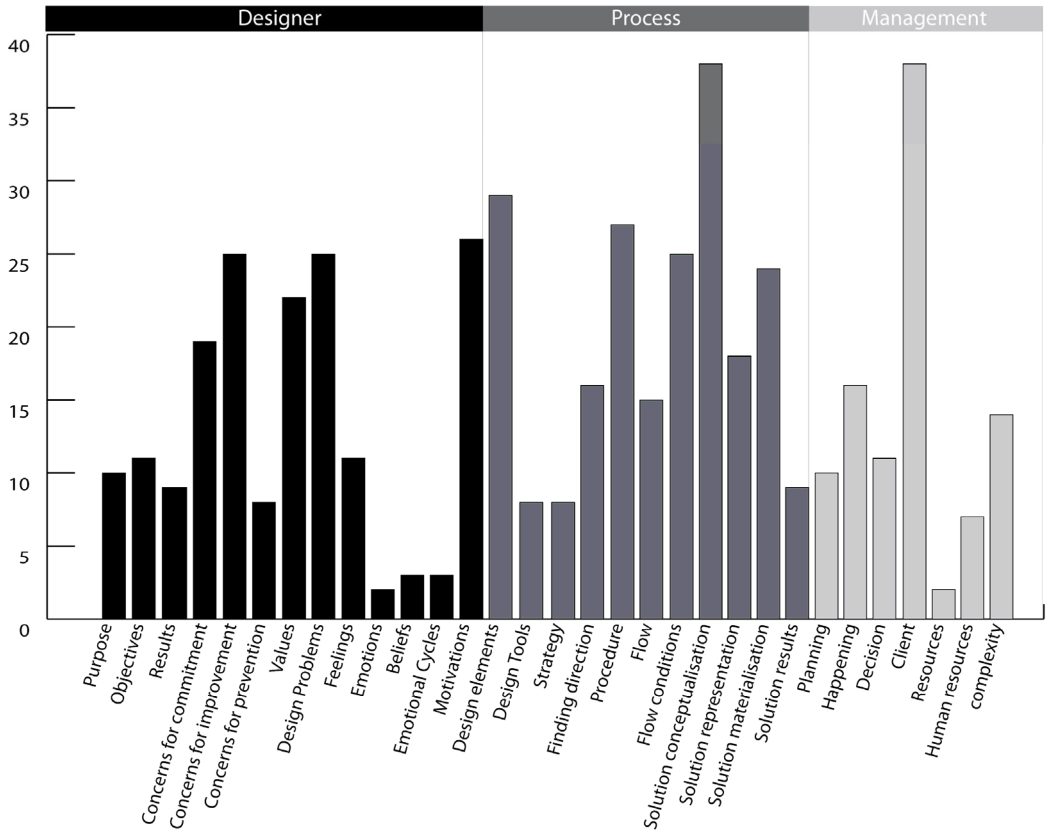

Figure 2. Assortment of variant characteristics in the most dominant dimensions

Table 3. Example of variants regarding designers essential aspects

Purpose	**A**	**B**	**C**	**D**	**E**	**F**
Create something standard that can be reused by others	▨					▨
Do significant work, new and innovative solutions, Improve life's quality		▨			▨	▨
Best solution for lowest cost				▨		▨
Transmit a message to the public and users		▨	▨		▨	▨
Comply a function with a pleasant use					▨	
Concerns for commitment	**A**	**B**	**C**	**D**	**E**	**F**
Unambiguous specifications	▨					
Have a physical vision of what to make people feel or interpret or understand		▨				▨
Balance between meaning and sell-out. Identify effective valuable outcome of ideas						▨
Adequability of solutions, Mental validation of the solution		▨			▨	▨
Problems	**A**	**B**	**C**	**D**	**E**	**F**
Experience context		▨				▨
Communication structure		▨	▨			▨
Interactive problem	▨	▨				▨
Identify opportune technology				▨		▨
Functional problem structure				▨	▨	
Conceptual structure		▨			▨	▨
Problem architecture	▨					
Motivations	**A**	**B**	**C**	**D**	**E**	**F**

See things working	▨			▨		
See things happening, matching, fitting		▨	▨		▨	▨
Discovering, experimenting, Project relevance	▨	▨	▨		▨	▨
Users happiness with our solutions		▨		▨		▨
Go beyond project objectives and goals		▨			▨	▨

Designers A, D and F purposes and concerns hold on pragmatism, and designers B, C, E, F hold on aspects of final results. Designer F shares both. Designer B shares problems with designers A, C and F. Designer E shares problems with designers D, B and F. Designer F shares problems with all the others. Designers B, E and F are more motivated and more demanding.

Process

Variant characteristics on the categories of *Quantity and Quality* concerning the process dimension have major incidence in sub-categories such as, *Solution Conceptualization*, *Design elements, Procedure, Flow conditions, Solution Representation* and *Solution Materialisation.* Some variants are shown in Table 4.

Table 4. Example of variants in the design process

Design elements	**A**	**B**	**C**	**D**	**E**	**F**
Hardware and software components	▨			▨		
Digital visual representations		▨	▨		▨	
Narrative	▨	▨	▨			▨
Time and Scale, Interaction, action/reaction, Audio		▨			▨	▨
Movement and Relative dimensions		▨		▨	▨	▨
Finding direction	**A**	**B**	**C**	**D**	**E**	**F**
Know what will remain, the project mark, the project flame		▨				▨
Choice is made on priority, available elements, feasibility and level of important		▨	▨	▨	▨	▨
Explore all the alternatives				▨		
Economical constraints		▨	▨			▨
Balance what we have, what we know, newness and public attraction						▨
Solution Conceptualisation	**A**	**B**	**C**	**D**	**E**	**F**
See it as the best one	▨					
Have a 1st fuzzy vision, Immediate senses, perception of 1st vision characteristics		▨				▨
Identify immediate sensation on users 1st impression to assure people attention		▨				
That people recognize themselves in the concepts, Use of metaphors			▨			
Number of units to build, Different options				▨		
What message to transmit, Theme, Approach to the theme		▨	▨		▨	▨
Feasibility of concept materialisation, Usefulness of the concept						▨
Solution Materialisation	**A**	**B**	**C**	**D**	**E**	**F**
Effective communication of tangible and Intangible effects such as feelings		▨	▨		▨	▨
Provide performance, Protect hardware from environment agents	▨			▨		
Colour, Esthetic, Light, Sound, materials		▨			▨	▨
Budget			▨	▨	▨	
Being specific, precise in solution materialisation, Detail		▨				
Be aware of the change in how ideas are perceived when thinking in pragmatic terms						▨

Designers differ in several aspects of the process. Designers A, C and D regard tangible design elements while designers B, E and F regard tangible and intangible design elements. Designers share design tools to solve common problems, still, are dependent on each on competence and domain of different softwares. Strategies relate to own purposes, project course and client. Designers B, C, D and F deal more with uncertainty that designer A, thus, recognize a process of choice made on the feeling of balance towards final result. Designer A and D have more straight forward procedures, while designers B, C and E have similar procedures. Flow breaks are related with each one main concerns. Flow conditions are related with each one motivations. Approach to solution conceptualization differs in the same relation as designers purposes. Solution mental and physical representations are more frequent among designers B, C, E and F. Designers A, C and D have a more programatic approach to solution materialization, while designers B, E and F are concern with the characteristics of the experience. Thus, the same designers show much more concern with final result appearance and experience than designers A and D.

Management

Variant characteristics concerning the categories of *Time* and *Situation* show more incidence on the sub-categories of *Client*, *Happening, Complexity* and *Decision*. Some variants are shown in Table 5.

Table 5. Example of variants in management

Planning	**A**	**B**	**C**	**D**	**E**	**F**
Respect time	▨					
I'm not much structured in planning		▨			▨	
I plan to execute			▨	▨		
Periodic meetings to review and register deliverables and sales pipeline				▨		
Planning strategy to prepare the future, Be ready to review and reschedule						▨
Happening	**A**	**B**	**C**	**D**	**E**	**F**
Be able to skip the plan	▨					
Perchance, time and words influence in having sudden ideas		▨				
Find something more interesting to substitute other, Find new things			▨			▨
Reformulate according to things that were not taken into account				▨		▨
Errors that turn into a good thing and you can take advantage of					▨	▨
Client	**A**	**B**	**C**	**D**	**E**	**F**
Answer to client request/need	□			▨		
Find an approach to cope with the type of client and project, and client real wishes		▨	▨		▨	
Bother the client with questions for what he doesn't know the answer		▨	▨		▨	
Interpret client request, Objectivate the client request, User as final user, not the client		▨			▨	
Team with the client, complicity, empathy working in the same direction and bearing		▨			▨	
Manage client expectations		▨				▨
Mark necessary positions, Make the client aware of the value of the given experience		▨				
Know what the client wants to say and to communicate			▨			
Complexity	**A**	**B**	**C**	**D**	**E**	**F**
Difficulty in keeping method			▨	▨	▨	
Unpredictability of doing technological artisan					▨	▨
Manage expectations, workflow, respect, deadlines, stress, priorities and significance		▨				
Colleagues resistance to correct, adjust details and finishing		▨				
Manage mixing conceptualization with production phase, timings and type of suppliers					▨	
Lost of quality and rigor in complex situations					▨	

Designers show significant variance regarding planning concerns. All refer unpredictable situations that happen during the processes and compel to change or review planning and project. Designer A is confortable with *not making decisions*, while designer B needs to have the *control of decision*. Designers C, D, E and F contribute to *collective decision*. The designers B, C and E are more concerned in building relations with the client. While designers A, D and F have more pragmatic approaches. Managing complex situations relates with aspects such, *different methods, motivations, priorities, timings and unpredictability.*

Other variant characteristics found in the dimensions of environment, team and performance also with management implications, are worth of reference. For example, Designers B, E and F show more diverse aspects regarding *motivations*, gathering *experience*, opportunity to *deliver innovation* and contributing to the *society and country evolution*.
Individual roles differ. Designers A, D and F are more focus in project materialization while designers B, E and F show more emphasis in project creative stage and characterization of final result. Designers D and F share both streams of the process although with different intuits. Designer B has a leading team role in design management.
Concerns regarding attitudes and performance also differ. For example, designers C, D and E *cope with pressure*, while designers B and F *work positively with pressure* and designer A does not.
Designers also differ in semantic reference to cognitive processes that frame similar actions in different ways. Examples of variants are, *Interpreting, Pursuing* for designers B, E and F, *Structuring, Restructuring,* for designers B, C, E and F, *Decomposing,* for designers A, D and F.
Designers B, C, E and F share some cognitive retrieval mechanisms, such as, *perchance recognition* as well *perception of sensations from the recreation of the solution*. B, E and F are concerned with *Recognizing quality* in their performance, and in the results of the process.

5. Results and Discussion

The present research illustrate characteristics of designers with different background that ascertain distinct approaches to the design process. Although the data is gathered from a minor sample, the content and distinctive character of each interviewee makes it a piece of knowledge on the identification of variant and invariant characteristics in designers' approaches from what insights emerge such as, guidelines for the identification of transdisciplinary commonalities and differences between design disciplines.
Invariants show design problems and cognitive retrieval mechanisms as the most shared characteristics, jointly with aspects relating the design working environment, followed by concerns, values, cognitive processes, purposes, procedure and learning processes. It can also be infer that less shared characteristics can relate with working struture constancy or clear divergent behavior as can be observed in the dimensions of Team and Management (see Figure 1). More specifically the sub-categories of motivations, solution materialisation and solution results show less shared characteristics. These aspects can relate with designers' different interests in solving parts of the same general design problem and just the necessary level of concern with the final result of the interactive experience. This shared concerned with final result just regards the software and hardware performance, tasks of the software designer and the mechanical engineer. This concern is stated in the common expression "make it work". Although a considerable amount of invariant characteristics are shared by the six interviewees, variant characteristics are dominant in general results as shown in Figure 3.

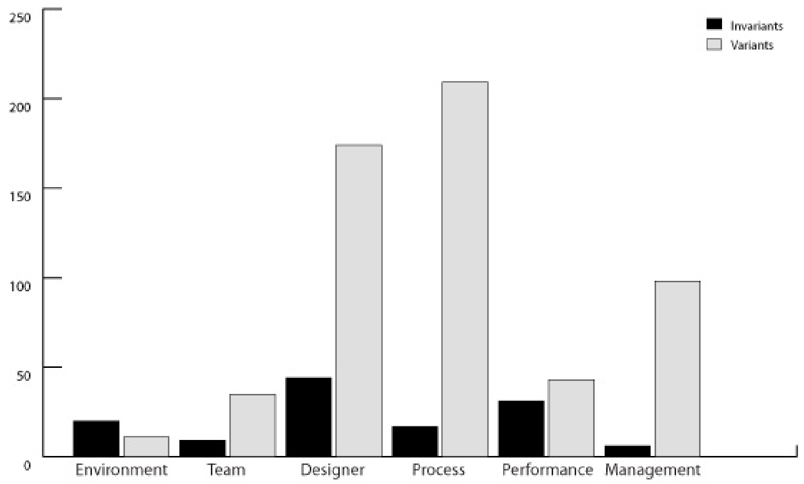

Figure 3. Predominance of Variant and Invariant characteristic to each dimension

The dimensions of Designer, Process and Management are the most dominant in variant characteristics. Environment, Designer and Performance are the most dominant in invariant characteristics, although just prevailing in the Environment dimension, which is understandable once the cultural values and structure of a company considerably frame a working environment. Thus, the dimension Designer is strong in both, variants and invariants. A central value system for designers seems to be possible to delineate. The dimensions of Process and Management show more discrepancy in a low amount of invariants and a higher amount of variants. In between variants and invariants intermediary features are found relating with sub-teams of designers sharing characteristics, as concerns, values, design elements, problems and procedures. In addition, each designer refers specific variant characteristics that relates directly with their background and concerns (see Table 6).

Table 6. Example of specific variants of each designer

Specific variants	**A**	**B**	**C**	**D**	**E**	**F**
Code application	☒					
Mental or physical scheme of project architecture	☒					
The total project		☒				
Fuzzy mental vision, Immediate senses, perception of 1st vision characteristics		☒				
Know what the client wants to say and to communicate			☒			
Identify communication tone			☒			
Hardware development				☒		
Providing scenarios and options for discussion				☒		
Comply a function with a pleasant use					☒	
Being in touch with the users					☒	
Come out with the next big things, technology innovation						☒
Products life cycle						☒

Results show variation of content in designers approaches refuting the research question, once that characteristics of designers approach sharing the same design environment are not the same. Although some characteristics are common, others are just partially shared or specific of each one.
In more detail, the research infers from the study that designers A and D do not concern final solution appearance, but only functional performance and differ from designers B and E in the absence of some characteritics such as, mental recreation of the context and users interaction experience, which are characteristics that represent core designers, as well concern with communication of intangible results such as feelings, also shared by designers C and F as shown in Table 7.

Table 7. Sample of variants in designers approach to solution

Solution Representation	**A**	**B**	**C**	**D**	**E**	**F**
Mental recreation of users interpretation, perception mechanisms and usability		☒			☒	☒
Mental recreation of the narrative context		☒	☒			☒
Written representation of the communication chain			☒			
Written description of solutions, drawing a small model with persons						☒
Solution Materialisation	**A**	**B**	**C**	**D**	**E**	**F**
Effective communication of tangible and Intangible effects such as feelings		☒	☒		☒	☒

Core designers differ from the others, and in particular, in the context of the present case study, once they are the ones that create the physical representations of final solutions regarding final experiences.

Aspects such perception and communication are crucial to core designers in framing design experience, information content and message communication. In spite of this designer F differs from all the others showing characteristics of an inventor, being the one that represents the delivery of technology innovation, regarding social education and evolution concerns, as well commercial purposes, usefulness and value of results, characteristics not noticed in the core designers. Once one of the design cognition purposes is to understand how do designers activities enhance the value of the design process and deliver value to the design results, the business aspects are worth to integrate in core designers education focusing their creativity to a sustainable and innovative business orientation.
Results show that varying characteristics of purposes, concerns, design elements, among others, comprise scopes such as, value systems, cognitive structures and patterns of action, that characterise each design approach making them varying in substance.

7. Conclusions

From the knowledge derived from the present study the following set of statements can be drawn:

a) there are invariant characteristics across the actors of a design environment;
b) there are variant characteristics across the actors of a design environment;
c) there are specific characteristics of each design actors of a design environment;
d) there are specific characteristics of core designers of a design environment;
e) there are specific characteristics of non-core designers worth of integration in core designers' education.
f) designers' variant characteristics frame each one design approach differing in substance.

Further studies on value systems, cognitive structures and patterns of action, can lead to augmenting the variables of designers process with focus on how and what value is delivered to final products. A thoughtful study of these aspects can contribute to the body of knowledge of the design management field, where, as shown in this case study, core designers have central role. These outcomes might derived in practice and educational application. The research continues with further work on how do designers deliver value to final results regarding the perspective of the Lean management philosophy.

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