ENHANCING CREATIVITY IN THE CONCEPT GENERATION PHASE: IMPLEMENTATION OF BLACK BOX AS A TOOL FOR ANALOGICAL REASONING

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ABSTRACT

ENHANCING CREATIVITY IN THE CONCEPT GENERATION PHASE:
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FOR ANALOGICAL REASONING

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In recent years, the field of design has met new grounds with the growing awareness among design researchers of the potential relationships between cognitive studies of creativity and computational modeling. The turn of the studies has given rise to the emergence of a new paradigm of modeling and understanding mental processes in creative design. This study tries to gain further insight into the *creative occurrence* by blending virtual experiences with designer actions in a model of creative thinking in concept generation phase based on the Geneplore Model by Finke *et al.* (1995) and supported by analogy construction incorporating the implementation of a computer based tool (Black Box) running on PC platform as a potential immanent part of the concept generation phase.

Black Box is devised in such a way that the core of the constructive process of the analogy relies on the designer's expressional, perceptual and conceptual actions which are presented in the traditional methods of sketching and writing, whereas the change and expansion of the design space is realized through the virtual worlds the tool offers via the computer screen.

The research method is based on the development of Black Box tool and its subsequent implementation in a study with eight experienced design consultants, utilizing a procedure composed of preliminary interview, observational protocol analysis, questionnaire and retrospective interview. Through encoding actions of individual designers by means of their maps in the computational tool, the study yields significant results in revealing differing thinking maps of different designers which have been used to propose a general creative thinking map of concept generation in Black Box presented in a way to be adapted for further studies. Moreover, the study provided insight on the methods used to assist creativity in concept generation by different designers, on the selection of inspirational material and on the integration of analogies as knowledge transformers to evoke design concepts.

Keywords: Concept Generation, Creativity, Creativity Methods, Analogical Reasoning, Computer Generated Virtual Spaces.

ÖZ

KONSEPT GELİŞTİRME SÜRECİNDE YARATICILIĞI ARTTIRMA:
KARA KUTU'NUN ANALOJİYE DAYALI DÜŞÜNME İÇİN
BİR ARAÇ OLARAK UYGULANMASI

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Son yıllarda tasarım alanı, tasarım araştırmacılarının yaratıcılıkta algıya/kavramaya yönelik çalışmaları ve bilgisayar modellemesi arasındaki potansiyel ilişkiyi keşfetmeleriyle yeni bir zeminle tanıştı. Söz konusu çalışmalar yeni bir paradigmanın doğmasına sebep oldu: *Yaratıcı tasarımda zihinsel ve algısal süreçlerin modellenmesi ve anlaşılması*. Bu çalışma, sanal deneyimlerle tasarımcı hareketlerini konsept geliştirme sürecinde, Finke ve çalışma arkadaşlarının (1995) geliştirdiği Geneplore modeline dayanarak ve analoji kurgulama ile desteklenmiş bir yaratıcı düşünme modeli içinde, PC platformunda çalışan bilgisayar tabanlı bir araç olan Kara Kutu'nun konsept geliştirme sürecinin potansiyel doğal parçası olarak dahil edilmesi ile *yaratıcı oluş'a* daha detaylı bir kavrayış getirmeye çalışır.

Kara Kutu öyle bir geliştirilmiştir ki; analojinin kurgulanmasının özü tasarımcının eskiz yapma ve yazma gibi geleneksel medya ile sunduğu ifadesel, algısal ve kavramsal hareketlerine dayanmaktadır; Öte yandan tasarım uzayının değişimi ve genişlemesi aracın sanal dünyaları sayesinde bilgisayar ekranı aracılığıyla sağlanmaktadır. Araştırma metodu Kara Kutu aracının geliştirilmesi ve hemen ardından sekiz tasarım danışmanı ile gerçekleştirilmiş çalışmanın ön mülakat,

gözlemsel protokol analizi, anket ve retrospektif mülakattan oluşan bir prosedür izleyerek uygulamasına dayanmaktadır. Farklı tasarımcıların hareketlerinin bu bilgisayar tabanlı araç içerisinde izledikleri harita aracılığıyla belirlenmesiyle, bu çalışma farklı tasarımcıların birbirinden farklılaşan düşünce haritalarını ortaya çıkararak önemli sonuçlar elde etmiştir ki bu çıkarımlar konsept geliştirme sürecinde genel bir düşünce haritasının ilerki çalışmalara adapte edilebilecek bir şekilde önerilmesinde kullanılmıştır. Ayrıca, çalışma farklı tasarımcıların konsept geliştirme sürecinde yaratıcılığı destekleme amaçlı kullandıkları metodlara, farklılaşan esinlendirici medya seçimine ve analojilerin tasarım konseptleri uyandırmada bilgi dönüştürücü olarak sürece entegre edilmesine provizyon sağlamıştır.

Anahtar Sözcükler: Yaratıcılık, Yaratıcılık Metodları, Konsept Geliştirme, Analojilere Dayalı Düşünme, Bilgisayar Tabanlı Sanal Alanlar

To my parents …

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CHAPTER 1

INTRODUCTION

1.1 Motivation for the Study: Spatial Relativity in Design

Special relativity proclaims that observers in relative motion will perceive distance and time in a different manner meaning that identical watches worn by individuals in relative motion will tick at different rates resulting different amount of times to pass for each of the individuals. After a century of Einstein's dramatic discovery, if we are to take the intuition of relativity into design grounds we may say that a theory of *spatial relativity* defined in terms of design space would proclaim that, individual designers acting in relative cognitive abilities will perceive and construct the design space in a different manner meaning that identical design problems worked by individual designers will evolve in a different rate and into different resulting designs.

The rate of meeting a creative solution during the design process occasionally decreases when conceptual blocks appear in the design space. Especially, at the very beginning of the design process, it is to be admitted that the landscape of design is a relatively rough and irregular one. So, the concept generation phase aiming to meet a creative idea is experienced by and large in a *not smooth* design space which calls for knots in this design space that enable change by the shifts they offer in the path of a concept generation. Based on this observed phenomenon and on the fact that changes in the design space will cause a mutation for emergence of a creative design as stated by Gero and Hun (1995), it becomes important to relatively define a design space.

A peculiar trait of designing is that it is self-reflective (Schön, 1983) remarked by the fact that conceptual shifts occurring within the design space are canalized again by the acts that are carried out in the design space itself. From this, it can be inferred that creation of concepts heavily relies on designer performances in design space

which can be enhanced either through an agent to orient designer actions or through an expansion of the design space.

The relative construction of a design space is observed and realized through mapping, exploration and transformations (Boden, 1991) that concurrently occur during a design process and creativity is expected to be prompted through an agent that causes mapping, exploration and transformation of the knowledge base of the designer.

A theory of spatial relativity in design with the mentioned descriptions of it makes us realize that it can only be modeled in the virtual world of computer codes. This thesis tries to form an alternative that accommodates a design space and a transformative agent for the landscape of the concept generation phase.

1.2 Aim and Scope of the Thesis

The demand for creativity has reached considerable concern in all kinds of design areas. The balance of forces between routine and creative designing has shifted towards the creative invention with an emphasis of novelty. While it is understood and very well known that design is a process of a series of phases that appear in shifts, and creativity is of utmost concern in all of these phases, this thesis will focus only on the concept generation phase and the ways to improve designer's creativity at this very phase as concept generation is considered to be a focal aspect of creative design in a design world of increasing claim for novel concepts.

The key ingredient of concept generation phase is taken as the design concept space; A space which entails all knowledge related to the design problem and also all knowledge of the designer's self; related to his/her background and experiences. In science fiction films such as Stanley Kubrick's 2001: A Space Odyssey (1968), we are also presented with another conception of space, not just infinite but also involving the space of the spaceship itself containing a whole minuscule world within its multiple spaces. The *microcosmos* that is tried to be implied with the spaceship is similar to basics of the construction of a design concept space.

Designers are to construct the design concept space like a microcosmos of the design space as the concept is the designative key that holds together the subsequent processes of design. The construction of a microcosmos/space for each design concept is important as much as it is a problematic issue that designers are faced in designing. This thesis actually seeks for ways of expanding the concept design space through drawing upon and reviewing relevant literature on new directions of assembling and defining space and in particular design space.

In this thesis, the quest for creativity in the concept generation phase is taken as an underlying concern which will be attained through the expansion of the concept design space and the inquiry of resolving the creative occurrence is tried to be met through investigation into different descriptive and cognitive models of creativity. If design can be seen as "effective recycling of real data into buildable matter" (Salazar, J., 1999:13) then analogies can be seen as the agents that makes the transformation of the data into a concept, possible. The study implemented in the thesis makes use of analogical mapping to make the designer meet a creative concept and additionally it is based on a pursuit of understanding of how designers approach a design concept, make decisions and search for ways of getting over conceptual blocks which is significant for both theoretical and practical purposes. As a matter of fact, it is aimed to understand the *cognitive process underlying creative occurrences* through *designer's responses within the tool* that is implemented. It is believed that a successful demonstration can be generalized in one aspect. A model of the creative thinking path in concept generation phase can be considered as a vehicle to see the creative design thinking process more effectively.

The aims of the thesis can be pointed as given below:

- to construct a computational/virtual design space that would plausibly fit the observable behaviors of the designer
- to examine in a relative study the role of analogy transfer used in designing in search of an appropriate raw model suitable for further development.
- to develop a viable model of creative thinking path in concept generation devised within a paradigm of virtually expanded design space
- to evaluate how designers correspond to the predicated nature of design

The hypothesis that has been formed in the light of the aims can be stated as follows.

Hypothesis: Black Box, as a virtual tool for promoting analogical reasoning may assist designers during concept generation phase, for enhancing creativity. This tool may be used in identifying design paths and patterns of behavior.

1.3 Research Questions

The study aims to answer to the following questions with the help of the literature review and the evaluation of designer performances in the Black Box Tool.

1. What do designers prefer to do to enhance their concept generation phase and support their creativity?

2. To what extent do designers rely on externally provided media such as images, words, representations causing them to recall any past experience or previous design data for improving creativity during concept generation phase?

3. What types of mentally simulated paths do designers with various skills and background form during concept generation?

4. In what ways should a virtual tool/media enhance designers' divergent thinking during concept generation?

1.4 Structure of the Thesis

The main theme of this thesis focuses on proposing a virtual expansion to the design space. Based on the notions that changes in the design space through a transformative agent like analogy can cause a sudden creative idea in designer's mind giving way to novel concepts of design, Chapter two presents the implications of a virtual expansion of the design space that is explored through an analysis of the current state on concepts of design, creativity and analogies as knowledge transformers.

In the third chapter the architecture of the constructed and implemented tool *Black Box* is explained and the methodologies, proposed models, methods of evaluation are discussed in detail, both for the pilot study carried out with design students and for the main study carried out with experienced design consultants.

In the fourth chapter, which is based on the analysis of empirical research through the implementation of *Black Box*, the eight case studies of the design consultants are analyzed in depth and the outcomes are revealed. In this chapter, detailed information on the process based observations of the designers is given and a raw model of a creative thinking path of concept generation in Black Box is composed.

In the final chapter, a summary of the findings and the discussions that are addressed accordingly are given. Going over the research questions once again, the last section is dedicated to further implications of the study especially in education.

CHAPTER 2

THE VIRTUAL EXPANSION OF DESIGN SPACE: DESIGN, CREATIVITY AND ANALOGIES

2.1 Design Meets Digital Space

Four decades ago, the design research community was working intensely to develop a design methodology, in that design practices should be made to follow rigorous methods. According to their theories, design should be "following the principles of logical deduction and mathematical optimization techniques" (Gedenryd, 1998:1) which made the idea of an analytic science of design most appropriate for them (Goldscmidt, 2002). This is especially evident in most of the design theories that emerged in the early days of the design methodology movement, indicated by an analysis-synthesis model involving logic, rationality, abstraction, and exacting principles (Gedenryd, 1998:1; Darke, 1979:37). But after half a century of surprises in terms of both technological and ideological advances, regarding the innovations in communication technology of the second half of the 20th century and new directions in design research involving even models of artificial creativity, now it seems quite obvious that, in most if not all design domains, strict design methods based on well defined algorithms do not yield the expected improvement in design quality and that they just may not reflect what is actually taking place in today's design practices.

Today, design era has met the development of an unprecedented form of global and digital space which has been altering the ways to conceive the formation of the world for designers and non-designers as well. Virtual Reality (VR) and cyberspace have entered our social consciousness with the force of a revelation, exercising an immense fascination on the extra world-space they present.

In articulating a notion of virtuality, it is important to conceive that our lived experience today involves spaces that were quite unimaginable with respect to those of half a century ago.

> *"VR is shared and objectively present like the physical world, composable like a work of art, and as unlimited and harmless as a dream. When VR becomes widely available, around the turn of the century, it will not be seen as a medium used within physical reality, but rather as an additional reality. VR opens up a new continent of ideas and possibilities"* (VPL Research at Texpo 89, in Rheingold, 1989:154)

In as much as the new digital world -the net- represents the matrix of connectivity and a corridor of seemingly limitless freedom with VR standing for an enrichment of the world-space, the blind spot of the preceding design methodology remains with its limited and limiting conception of the design space. Indisputably, design methodology and the ways of conceiving design have to change to compensate for the delay that caused segregation between design methods and today's design.

On the basis of these primary thoughts, in a climate of exponentially accelerating change, in architecture and industrial design, catching up with the past does not amount to leading oneself into the future anymore, considering the fact that mere analytics in design is completely impotent in arresting the trajectories of the cognitive ways of approaching the design task. Space, understood as multiplicity that brings together externality, simultaneity, contiguity or juxtaposition, differences of degree and quantitative differentiations according to Deleuze (1988), should be defined once for the design realm and as "design space". The design space, accordingly, has to be one that corresponds to the externality of the design, it has to read over what has been written so far and add upon them, it has to grow simultaneously with the technology and has to be product of a simultaneous representation of the inner world of the designer and the outer design realm.

As a consequence, the new design space is to be perpetually verging on to the next "new" design space, by changing itself and opening itself up to a reconsideration of

the promise of it holds for newness, otherness and divergence from what currently prevails.

2.1.1 The New Virtual Space and the New Variables in Design

As change accelerates, different technologies become assimilated into the design milieu, which in fact requires the designers to approach them daringly with the urge to acquire ways to meet the day's needs. Nevertheless, there exists still an understanding of industrial design which articulates its concepts, design decisions, and processes almost exclusively by means of a series of rationalizations that puts the discipline of design into a kind of learned and applied process within itself, forcing the designers to conform to their sets of normalcy instead of challenging them (Goldschmidt, 2001). The demand to present "unique" in today's conception of design requires designers to reject the predictable and rational interpretation of the "winning scheme" and escape the pressure of rationality that is streamlining the theory of industrial design towards a compelling logic.

In the field between the poles of the "rational-winning scheme" and the "unique", there exists still the ubiquitous phase of design where the designers mostly get stuck; the concept generation phase, which by and large requires the dismantling of the rationalizations put forward by the discipline, expecting the designer to challenge even his own capabilities, his own norms in addition to the ones he has been taught during his education.

It seems clear that *to challenge* requires being up to date; being capable of coping with the advancements. However, the impact of the emergence of new technologies does not change the idea that design is an activity that requires both logic and creativity (Alexander, 1964; Archer, 1969). Yet again, the above stated dichotomy – the rational versus the unique- of the design of our times is likely to be challenged by VR which fundamentally involves the replacement of all constants with variables, suggesting a deconstruction of the way we build the design grounds in terms of both cognitive and visual ways. VR as not just an abstract medium but as a technological component of the design of our times offers a reconciliation between

the *routine rational* and the *creative unique.* VR forms a language, syntax and even a variable topology considering that the virtual proposes a re-representation through conversion of the known set of relations. As for the spatial practice of modern design society, the topology, defined as the study of relationships that are invariant under transformations and deformations, of the *routine design* may be replaced by the variable topology with a move into the virtual giving way to *creative* design (Novak, 2000; Grosz, 1998; Rajchman, 1998).

The routine design process has been regarded as "a form of design that is regarded to be basic and not necessarily innovative" by Akın (1998:2). As far as we are concerned for the post-CAD approaches to design, it might be said that computational studies to a degree, have tried to support the routine design process while not being able to transcend the role of just a representational tool for the creative design process (Akın, 1998). Still, there is agreement that unless computational tools are contemplated in a more innovative manner, including the contribution of the VR, the scene for creative design seems melancholic. In this respect we can paraphrase Walter Benjamin's portrait of the *allegorist* to further indicate that a virtual corrective for a contingent design space can not be made unless the designers of the codes and variables of the system attribute an alternative meaning to it.

> *"When things are exposed to the allegorist's glance, the force of life flows out of them and they are surrendered to his mercy or disfavor; the thing is given meaning only to the extent that the allegoricist attaches meaning to it"* (Benjamin, 1972: 204)

Surrendered to a new understanding of codes and variables, computational tools can be used far beyond constructing the relationships between variables but also for introducing variables. Along the same line with this, Gero and Maher (1991) explain the difference between routine and creative design through the concept of search spaces and with respect to the set of variables the design context entails. Accordingly, in *routine design*, designers make decisions where all the decision variables are known without any investigation or further exploration, acting within a

closed state of possible designs where only the values set into the variables change the end design solutions. However, in *creative design* the designer acts within an altering state space of possible designs; "*a state space which increases in size with the introduction of each new variable*" (Gero and Maher, 1991:1). *Creative design* involves the exploration and transformation of the search space of design by introducing new variables.

The concept of introducing new variables into design space, put forward in the computational model of creative design by Gero and Maher, may be taken as a starting point for attributing a new meaning to the computational tools of supporting creative design through a variable topology which may transform and re-define the relationships between *the designer-the design world-the design concept* all over again. This transformation may change the design space by adding or substituting areas and is equivalent to 'conceptual expansion' (Ward, 2001). In the added or changed areas with each variable, a creative solution is expected to be presented inherently. Provided with a nomadic freedom of interchangeable boundaries initiated by the transformation of the design space, *the designer* is to break up with the static norms of the taught *design world*, and the uncomfortable boundaries the designer has been set into collapse. Sense of freedom for the designer here, can simultaneously be understood as a breakdown of the formulas for a contingent *design concept*.

As long as our sense of this symbolic freedom is a sense of layout change from residence to nomads, it may be seen as a thriving ingredient of the design process, especially of the concept generation phase.

2.1.2 Introduction to New ways of Conceiving the Design Space

Design has always been mentioned with an acceptance of a *space*. At first glance, there exist the problem space, the design space, the solution space, and the designer's space etc., all of them appearing not only figuratively but also spatially. The interwoven spaces confirm that design meets the world's grounds within a certain kind of radius. The decomposition of this radius reveals that it entails the

defined problem, the designer, the designer's inner and outer radii and intruders of external media such as factual, actual, informal, experiential, procedural, tactile, auxiliary, auditory and fictional representations. The search for a dynamic structure of these aspects has been a very ancient subject of dispute (Eastman, 2001). Indeed, it is presumably accepted that better understanding of the structure of this space, the radii that design brings about, may allow further insight into the design process (Simon, 1973; Akın, 1986; Eastman, 2001)

Today, as a global medium, VR opens spaces for hybrid discourses like design, developing a new dynamics of space. Chesher (1992) claims that VR proposed a paradigm shift: that computers can be *reality generators*, not just *symbol processors*. This shift allowed VR to become associated with creativity in design and cognitive science through the introduction of a multi-faceted space (Langley *et al.*, 1987; Partridge and Rowe, 1994; Boden, 1999).

In "The Production of Space", Henri Lefebvre (1991) states that within the spatial practice of the modern, the architect establishes himself in his own space. He has a representation of this *conceived space* which is thought by those who make use of it to be *true*. Opposed to the architect's *conceived space* described by Lefebvre that can be said to be distantly related to the linear perspective of Renaissance, Giedion (1941) mentions of a multi-faceted perspective of space.

> "*Space in the modern physics is conceived of as relative to a moving point of reference, not as the absolute and static entity of the Baroque system of Newton. And in Modern Art, for the first time since the Renaissance, a new conception of time leads to a self-conscious enlargement of our ways of perceiving space*" (Giedion, 1941: 112).

Gideon's account of perceptual enlargement is actually what Einstein calculated, Picasso painted. Having a cubist painting in front, one might say that vision is no longer subordinated to a single view of an external image which suggests that new ways of perceiving the visual surroundings have given way to new ways of perceiving the space. Crary (1994) emphasizes at this point the new status of the

new observer through Turner's work. Turner's work explores the observer's confrontation with the sun and shows how an object defined in classical mechanics can be described through new notions of heat, time, and entropy. Just as Turner's works displayed a new way of perceiving light and *space through light* and just as a cubist portrait may show simultaneously the side and the front of a face, the space that VR offers, is a distinct multiplication of the constants that have defined our space so far. Papers, plans, elevations, sections and perspectives may have dominated our design space so far but the code of VR is to confront the core of design space by expanding it, bombing it with variables, elevating the nodes of the traditional cognitive mechanisms of seeing and perceiving.

It is for all these reasons that design reasoning via computational models and Artificial Intelligence (AI) by means of the virtual medium has become a potentially intriguing topic (Davies and Goel, 2003Sosa and Gero, 2002, 2005; Yaner and Goel, 2003; Davies, Goel and Nersessian, 2003) not just because "the virtual" has expanded the boundaries but also because it made possible the experience of a different perspective to see the territories around us (Jensen; 2000). Here, we are talking of a different perspective that will remind us of the understanding of space of many scientists or mathematicians. Let us think of Gauss' curvature or Lobachevksy's hyperbolic or *imaginary geometry*. Their ability to see the space in a more non-actual way has never been grasped by us, nor did it cure our arithmetic, just because the scale at which these conceptions apply is outside the range of everyday experience that we are used to.

It is the same in design; we, most of the time, can not realize what we might see in a single drawing, in a single picture, fragment of happening and unconsciously we miss the 'idea', the 'A-h-a!' (Akın and Akın, 1996; John and Steiner, 1987). It is an undeniable truth that unexpected discoveries during design have governed the main scenes on many grounds ranging from molecular chemistry to mathematics. The main reason behind our unconscious avoidance of the potential realities can be explained in our readiness to accept things *as they are*, without the need to change them. However, the reason for this acquired laziness may remain a question of the new post-VR poetics of industrial design opposed to the post-war poetics.

When compared to the post-VR advancements, the post-war industrial design era in the 60's witnessed the emergence of design methodology rather to create a systematic way of performing design to unload the designer from engaging with creative aspects of design (Cross, 1984). That is why, a notion of a design methodology of post-VR space is to engage in creativity as today what we are bound to respond is a "quotidian assemblage" rather than a "military need". Following that, today, the "day" and the "space" of each day is conceived and perceived in a diverging manner, having no single focal point. The architecture of the virtual is offering the chance to mend the rupture between how we know the world and how we conceive and execute design, hoping that we are becoming more and more accustomed to a new awareness of space and overcoming the new handicap of altering it over and over again.

The above mentioned handicap of altering the design space recurrently can be conquered by pushing the boundaries of the way we picture the world by changing the way we construct it.

> *"Once we allow ourselves to view the world as not assembled, as incongruent, made up of many divergent paths out of the domain we are inhabiting (...) it then becomes possible to move out of the familiar system of representation and think in terms of still unactualized realities –in terms of virtualities- and thus be able to perceive the multifaceted and unpredictable potential of all things and to see the other (hi)stories in other grounds"(Rajchman1998:42)*

Rajchman assumes that spatial revolution in the virtual starts with representational revolution. The familiarity of the grounds we act always gives a feeling of trust which is one of the major reasons of our laziness for reforming our conceptual space but as Rajchman asserts, it is only then possible to realize the potential in our surroundings when we leave the common grounds for good.

To recapitulate, it can be said that the three main aspects that have been emphasized so far: *the new virtual space, the new variables in design and new conceptions of the space and design-space* have radically altered the ways we conceive design today.

2.1.3 Introduction to New Ways of Conceiving Design

Materially, the design of our times is one that is conceived algorithmically, prototyped rapidly, fabricated robotically; it is a design that is inherently intelligent and interactive. Visually, the space of our times is characterized by a fundamental shift from an Albertian fixed viewpoint to a condition of interactive presence. The designer's horizon of our times is expected to have shifted to another level of presence. If we are to take a wider view, since the age of reason, reality had been identitical with the physically present world as sensed by man. So, the 18th century witnessed a lively discussion on optics and how the man could perceive and sense his surroundings. Organity started to rise as a new phenomenon leading geometry to be abandoned as a structuring principle which ended in organic definitions of sight. And so the perspectival mode of sight lost its impetus. The cubists' weak attempt, on the threshold of the previous century, to accomodate the swiftness of changing visual impressions produced a multiperspectival scheme, marked its end as a means of grasping reality. The re-construction of the sight has made it possible for the exercise of a new opportunity to conceive design which presumes that reality is not just what we see but also what we might see in the same line with what actually designers are to do; to change in order to bring about change through the ability to see and perceive differently than non-designers. However, the change of the virtual into the actual is not the same as to realize the possible (Deleuze, 1968). That is why for being able to handle the virtual, the designer is expected to be freed from seeing just from one point or in just one direction. Besides, designers are thought to be visual thinkers (Cross, 1986; Tovey, 1986; Goldschmidt, 1991, 1994) and according to McKim (1980), visual thinking includes 3 kinds of visual imagery: the kind we see, the kind we imagine, the kind we draw. The virtual has already altered the three of them: the new understanding of sight as an organic sense, the new medium to bring imagery to real and the new ways to represent an idea through computation as an alternative to the traditional representing media drawing and sketching.

2.2 Design, Concept and Fixation

The following section tries to formulate a general basis for understanding the design process and the design concept from the designer's point of view in that s/he is set into different roles as the *Reflective Practitioner*, the *Bricoleur* to furtherly investigate designer behaviors in concept generation phase.

2.2.1 A Perspective of Design as Situated Action

Clancey (1997) claims that every human thought and action is adapted to the environment meaning that it is situated. Presenting the basis for the theory of situated cognition, he asserts that the things people perceive, the way they conceive of their activity, and actions they physically do develop together. *"In short, situated cognition is the study of how human knowledge develops as a means of coordinating activity within activity itself." (Clancey, 1997: 4)*

In a view based on situated cognition, design can be seen as an activity or set of actions which develop within a setting that can be defined with two aspects: an environment independent of the agent (designer) and a conceptual context (design space) established by the agent (designer). In terms of the design space, the external environment is structured through domain knowledge composed of the design task related database, the social database of the designer's surroundings and the client needs with financial and time constraints. On the other hand, the conceptual context is formed by the agent (designer) itself and involves the agent-relative conception of the external environment. It is actually, the agent's subjective representation of the external data in terms of variables of the design space. In this view, the changing state of designer's perception of his/her external environment will be effective in determining the course of actions that s/he is to take in design environment as well as the end design.

A more phenomenological perspective has also been favored that a designer mentally constructs a design world beyond the external givens (Schön, 1988). However, the

issue is: what is the "mechanics" of the inherent process of designing composed of real time designer actions during designing.

2.2.2 Reflection in Action

Schön (1983), in one of his studies, was observing students during design studio in the action of designing and explaining the design acts and decisions to each other. One important thing he realized was that when a student was reading his/her representation of his/her own design sketch s/he perceives points that have not crossed his/her mind during the sketching phase. This phenomenon was defined as "reflection in action" by Schön (1983; Schön and Wiggins, 1992). The term defines the essential connection between perception and action, i.e., intertwinement of these two processes. Moreover, the ability to perceive latent things in one's own actions can be seen important in its emphasis on the possibility to read the design space through designer actions and perceive the latencies that it employs which can be considered as the *virtualities* (potential *actualities*) of the design space.

2.2.3 A Perspective of the Designer as "Bricoleur"

Today, a great deal of the design literature is discussing design thinking as a way to attain a map of the design space to view into the intertwinement of perception and action during design. Inquiring deeper into the implications of design thinking, Lawson (1980:6) asserts;

> *"Design involves a highly organized mental process capable of* ***manipulating*** *many kinds of information,* ***blending*** *them into a coherent set of ideas and finally generating some realization of those ideas*"

As indicated also by Lawson, in structural means, designing is an intertwined mental process. In order to see the fine grain of the transformations an idea is about to go through, we have to be able to realize the designer's conception of this world. There are a variety of values, purposes, measures and procedures concerning the problem. The designer is asked to bring them together like a "bricoleur", a metaphor used by

French anthropologist Claude Lévi-Strauss. In Lévi-Strauss's point of view, the designer makes do with what is there, with everything that he has around.

> *"The bricoleur is adept at performing a large number of diverse tasks;...; his universe of tools is closed, and the rule of his game is always make do with 'what's available', that is a set, finite at each instance, of tools and materials, heterogeneous to the extreme, because the composition of the set is not related to the current project, or, in any case, to any particular project, but is the contingent result of all the occasions that have occurred to renew or enrich the stock, or to maintain it with the remains of previous constructions or destructions"* (Levi Strauss, 1962:31).

Accordingly, the designer is endowed with the knowledge he has built so far, with the events he has met so far, with the experiences he has been through. Those are all, his primary tools to invent anew. Eastman (2001) proposes that a designer's conception of a design and its context is built up over time, using information from the designer's already gained knowledge and experience, and from external sources of information. These external sources can be other designs (examples), the client, or visually or verbally encoded sources like books, drawings, pictures, etc. But another source also applies, that is, the information generated (inferred) during the design process (Ullman *et al.,* 1988).

However, in order to stimulate the designer to produce novelty, more will be needed beyond personal knowledge or more will be asked than the *available*. Novelty that is sought in design is due to *atypical stimuli*, which means that it is unlike any previous experiences (Berlyne, 1960). As a matter of fact, this is the part of designing where, 'what's available' should just exceed what it truly means giving way to the latent. The latency that the available serves, brings about the actual-virtual debate. As "*actual is endowed with a potentially 'objective presenc*e', there is also the *virtual corresponding to the subjective and to duration"* (Bergson, 1917:121). So, it is a matter of time for the designer to recognize the *subjective implications of the available*, thus being able to produce something that will not be like any other thing.

We may say that, there is always a radius around a designer that contains his perceptions, desires, experiences, attempts at effecting change, his personal cultivation. The personal cultivation of the designer is referred here as involving designer's background, the implications of his/her education, the life experience which in a way defines his/her potential sources of producing. The *latent*, *the subjective available* or *the virtual* in a designer's present radius only then becomes apparent to his/her perception if s/he becomes accustomed to the notion that space can be conceived in many ways different than those that have dominated our thinking so far. Similarly, the design problem always thrives within a radius that entails designer actions, designer's perception of the problem space, designer's desires. If the designer can also conceive this space in a different way than s/he is used to, s/he will be eased at coping with the early phases of design where the construction of the design space is of utmost concern.

2.2.4 Design Concept

The idea of a design concept as a holistic approach to designing has been adapted by many practicing designers who insist on carrying through a design concept with no regard of the obstacles they might face during the exploration or implementation of the concept (Lawson, 1990, Rowe, 1987). The design concept has been identified as the primary generator by Darke (1978) referring to the initial idea that appears to be most appropriate at first glance for further development. The concept generation phase is therefore considered as an essential part of the design process. This attitude is not only connected to the emphasis on questioning creativity, but is also strongly influenced by the mentioned holistic approach to design.

2.2.4.1 Concept generation phase

Traditional systematic procedures prescribe several phases such as analysis, synthesis, evaluation, refinement and development for design process (Cross, 1991; Ullman, 1986, Jones 1981). A recent approach of Cross (2000) can be said to form a three phase model which tries to typically detail the process. (1) The initial phase focuses on the motivation of the creative design process in order to generate early

design concepts which is followed by the design phase as the second phase of the process. (2) The design phase aims at the development and refinement of the design concept followed by the (3) finalization of the design process through working drawings.

Taking the initial phase for further investigation, it can be inferred that concept generation phase happens to be in this initial phase of design. Concept generation phase, as the name signifies, is the part of the design process where the design idea is expected to emerge; *the concept*. Novel design concepts are often considered to arise as sudden illuminations. As mentioned before, this idea of a 'creative leap' has for some time been regarded as a key element to the design process (Archer, 1985).

> "*The discovery of a creative solution occasionally corresponds to the sudden attainment of a mental insight*" (Akın, 1996:1)

The cognitive phenomenon of sudden mental insight as presented by Akın is related with the ability of designers to find the right set of *frames of references* for a design concept (Akın, 1996). Moreover, Poiesis, -bringing forth-, of a creative solution with the right set of *frames of reference* to a design problem is always favored whereas there might be other solutions that have emerged during concept generation. That is why concept generation phase is highly regarded as the *key frame* of designing.

As anticipated through the fact that it bases itself on the grounds of Poiesis, concept generation phase can be regarded as the phase in which designers mostly get stuck. As a matter of fact, supporting designer performance during concept generation phase is quite crucial as this phase requires substantial product knowledge, vision and inherent creativity. Coming to the core issue of creative concept generation, it is to be stated that individual creativity is a critical factor, which can be enhanced through a set of effective tools and attitudes providing a better motivation for the designer.

However, development of a support requires better understanding and modeling of the space of concept generation. As mentioned before, the space for the concept

generation phase is not a smooth landscape. The concept generation space is to be rather blended with additional conceptual spaces in order to promote creativity. A conceptual blend like this is described by Fauconnier and Turner (1994, 1998) as a selective merging of two or more conceptual spaces to form an expanded, newly instantiated space. This blended space often directly supports inferences which are not readily apparent from a disjoint consideration of both inputs giving way to unexpected discoveries during concept generation. That is why such a blended sense of landscape is a sense of other methods of reading than the linear or hierarchical reading of a space.

2.2.4.2 A Literary Space for Concept Generation Phase

Offering a non-linear reading of the design space of the concept generation, Deleuze tries to delineate the design plane forming the design space with a reference to Proust's novels. Through Proust's novels run, for instance, long lines of musicality, passion, picturality, and other narrative lines that coil around black holes within the story. The black holes are a literary construction that enables change. If there were no black holes for the protagonist to fall into, the landscape of the narrative would be an unrealistically smooth and timeless plane, which would make it impossible for the hero, whose character and adventures are formed by this landscape, to evolve.

Similarly, design process involves long periods of silence and then sound, a tremendous flow of ideas, hundreds of variables, bombardment of visual, verbal, auditory and even tactile media, all curling around the black hole of the design process- the concept generation phase. Just like the black holes of Proust's novels, concept generation phase is the part of the design process that brings forth "change". The designer is the hero of the design story and once fallen into this black-hole, it is hoped that he will come out of it with a creative idea that will save the day. In fact, all designers do fall into the situation that is anecdotally described here. The lines that coil even become so dense that the landscape of the design space during concept generation seems to be intransient. To be more clarifying, designers do get stuck mostly at this early phase of the design process. That is in many ways like the writer's block, namely: the designer's block.

2.2.4.3. A Literary Dead-end: The Designer's Block or Design Fixation

The emphasis to pursue design novelty and change is often so strong among designers that they find themselves in living a block-out during the concept generation phase. In some cases, the ideas themselves bring about difficulties that hamper the design process which is called design fixation (Lawson, 1990). Design fixation actually can be seen as a readiness "to re-use features of known existing designs, rather than to explore the problem and generate new design features" (Cross, 2001a: 86). However, the major fixation is defined as the fixation that exists among designers to be different through novel design solutions (Cross, 2001a).

Actually, the search for a novel and creative idea puts such a pressure on designers that it becomes unfeasible to fight the landscape of the concept space. Standing still, in between a set of ideas and sketches within a literary black-hole, the individual designer finds himself in a state of block-out. The design behaviors begin to demonstrate a cyclic nature where each action repeats itself throughout the process. Most designers, even the exceptional ones experience this kind of block-out especially in the concept generation phase. What designers actually need to dissolve such blockade turns out to be a question that is mostly tried to be answered by means of research in assisting creativity.

> *"It is always six o'clock now," the Hatter said mournfully.*
> *A bright idea came into Alice's head. "Is that the reason so many tea-things are put out there?" she asked.*
> *"Yes, that's it," said the Hatter with a sigh: "it's always tea-time, and we've no time to wash the things between whiles."*
> *"Then you keep moving around, I suppose?" said Alice.*
> *"Exactly so," said the Hatter: "as the things get used up."*
> *"But what happens when you come to the beginning again?" Alice ventured to ask.*

According to Boden (1994), Alice's question in Wonderland points out that she has noticed that the conceptual space of the Mad-Tea party was repeating itself in a

circular way which will come to a point where a change would be inevitable; a point where "something" new would have to happen. Either "something" like they are going to be out of clean things and the party will stop for a while or they will clean the plates and cups with some grass and keep on.

Boden acclaims that if such limitation occurs in a conceptual space, the thing that should be done is trying to give a new way to the flow of things, just by changing "something" of it, in it, about it, beyond it, etc..

Change can occur in many different ways. Though, when we refer to the bricoleur in that case, we see that Lévi-Strauss chooses to explain the designer actions through an analogy. The means of the bricoleur are concrete, having an objective existence but they are also abstract as they can stand for other things that they are not. They are signs and the designer's exploration of new ideas in these signs is a matter of the dialogue he carries with the design world.

> *"His first practical step is retrospective: he must turn to an already constituted set, formed by tools and materials; take, or retake, an inventory of it; finally, and above all, engage into a kind of dialog with it, to index, before choosing among them, the possible answers that the set can offer to his problem"(Levi Strauss, 1962:134)*

Lévi-Strauss' bricoleur appears to involve in a dialogue with the design world that contains his design input, to find an exit out of the unproductive state he is in. Indeed, a dialogue of this nature is not the first. In the same line with the "bricoleur", "the reflective practitioner" of Schön (1983) works instinctively, drawing on previous similar experiences using a mixture of knowing and doing. The reflective practitioner also carries out a dialogue between his internal representation of the problem and external references.

If we are to combine the bricoleur's and the reflective practitioner's approach in one, we may say that, the designer living a block out would search for the relief within his experiential knowledge or he would try to experience new things to awaken new

ideas or to recall again some unreachable past experience. The designer would avoid acting in a kind of amnesia; rather he would try to gain an "other insight" (Mayer, 1995) in that what he once stored and now recalls. Furthermore, he would make himself open to any intrusion of novel figure with an aim to awaken curiosity and then creativity.

Hence, the designer's conception of the design world will develop with every additional recall of experience and with entrance of every other stimulus. The components of the design world are the parts that make up a designer's "repertoire" (Schön, 1983). The notion of repertoire is a key aspect of Schön's reflective practitioner approach. Practitioners build up a collection of images, ideas, examples and actions that they can draw upon.

Necessarily, the repertoire is fed with multiple sources; the external world and observations of it, the internet, books and magazines, personal experiences, interactions with the outer-world, social events, images, designer's self-imagination, the physical world with all its factors. Schön proposes that professional practice involves the use of knowledge-in-action. Therefore, the repertoire of the designer provides the useful source to escape the block-out. However, as mentioned before, the repertoire needs to be widened and enriched externally as much as it needs to expand internally. The designer, internally, may be open to perceive things in a different way but the external world that he has been provided with also has to be open to deviations which would mean openness to acceptance of addition or replacement.

So, during a block-out, if we do not want to end up with a lame *anything goes* conclusion, why on earth wouldn't we let ourselves to the chance of *anything may happen*. Akın's sudden mental insight (SMI) concept explains what has been tried to be expressed with the *chance of anything may happen* in the preceding lines. As sudden is defined in Oxford Dictionary (Oxford University Press) "done or occurring unexpectedly or abruptly", the concept as SMI may be arrived at as a result of planned actions or it may not be planned at all.

2.3 Creativity in Design

This section casts a concise look on current and past definitions and ways of explorations of creativity and creativity in design, stressing the cognitive mechanisms underlying the creative process and the importance of the design space in causing the creative occurrence.

2.3.1 Towards a Theory of Creativity in Design

"Understanding the nature of things to be able to act on them" (Guallart, 1996: 211). This is a holistic approach which runs through the history of research in design, architecture, art, social sciences and any other discourse where a critic approach is necessary. The same holds for creativity and its implications such that they have been a popular area of inquiry in design discourse. Yet, the need to render the definition of creativity has haunted most attempts to develop models and theories of it. As a matter of fact, creativity still remains a non-lucid subject in the literature of design (Lawson, 1997) and the apparent unpredictability of creative act with its contingent nature indicates that it is hard to establish a systematic explanation of creativity (Boden, 1999). However, the "mysteriousness" of creativity is starting to be reduced as new explanatory descriptions of creativity have emerged from empirical studies within both design domains as well from other fields (Cross, 2001).

2.3.1.1 Creativity, Novelty and Interestingness

Generally, creativity has been defined along two lines: creativity as an individual trait (Koestler, 1964, 1975; Boden, 1991; Gero and Maher, 1992, 1993; Akin and Akin, 1996; Kim, 1990; Sternberg, 1988; Tovey, 1988) or creativity seen as a systems property focusing on the interaction between individuals, social groups and knowledge (Csikszentmihalyi, 1988; Sosa and Gero, 2002). Both perspectives have provided many interpretations of creativity and creativity in design in particular, whereas the former approach has resulted in models of creative thinking and the latter in relatively more socio-cultural studies of creativity.

The term creativity refers to make or bring into existence something new (Liu 2000; Sternberg 2001). Yet, novelty is essential but not sufficient to define creativity (Liu 2000). Some ideas are considered creative a long time after their introduction and therefore are not strictly novel which indicates the paradoxical nature of the act of introducing a "new" into the design milieu.

Boden (1991) emphasizes that the act of creation itself is paradoxical as defined in Oxford Dictionary "to bring into being or form out of nothing" which makes creativity simply impossible. Yet, beyond divine intuition, there have been many descriptions of creativity which led to many other paradoxes.

Taylor's (1988) (cited in DasGupta, 1996) definition of creativity as "the ability to produce work that is novel and appropriate", conveying the idea that creativity is not pure novelty, has been one description upon which there has been agreement among a number of researchers (Boden, 1991; Partridge and Rowe, 1994; Rosenman and Gero, 1993; Sternberg, 1988). Alongside with Taylor's definition, Cropley (1999) has stated that creativity requires novelty and utility. However, there is a clear difference between the subjective evaluations of novelty and appropriateness where the creative product may remain appropriate for a long time but looses its novelty as soon as it is experienced, revealing another paradox of the efforts to define creativity with respect to the concept of novelty.

That is to say; creativity is not just concerned with the introduction of something new into a design, even though that is an essential need for anything to be considered as creative. Rather, the introduction of 'something new' should lead to a result that is unexpected and valuable (Gero, 1996).

Many theorists of a scientific approach have defined creativity as "novel combinations of old ideas". Koestler (1964) has referred to creativity as "*the bisociation of unrelated matrices*" describing Gutenberg's invention of the printing press as combining the idea of seals used to press letters into wax with a wine press to print many letters simultaneously onto paper. However, Boden (1992) has insistently pointed out that just a novel combination alone could not be the origin of a

creative idea. Moreover, Boden has argued that to call an idea creative indicates that it is not only new but also "interesting". None the less, it might have escaped many theorists who mention of a "combination", that novel combinations are not always interesting.

The concept of interestingness with respect to its relation to creativity, is studied based on its being objective or subjective (Silberschatz and Tuzhilin, 1996). Objective interestingness makes use of relationships that are found entirely in the object that is considered to be interesting whereas subjective interestingness compares properties of the object with respect to some user's beliefs. To go further, subjective interestingness includes "unexpectedness" which depends on a designer's ability to predict an as-yet unseen event. An interest in the unexpectedness of novel artifacts is what Boden takes on saying that the creativity of a novel idea lies not in the fact that it *did not* happen before but in the fact that it *could not have* happened before.

In order to make clear the distinction between '*did not happen'* and '*could not have happened'*, Boden (1990: 76) gives an example of a novelty that could have happened before through language. A sentence, such as "The pineapples are in the bathroom cabinet, next to the oil paints that belonged to Machiavelli" is novel regarding to the combination of the chosen words but it is not creative as it can be generated by anyone knowing the rules of English grammar. The combination may be novel and interesting too but the fact that it has been produced according to a set of generative rules makes it replicable and "could have happened" before.

Generative systems like English grammar, mathematical equations or computer programs do describe a certain set of possible structures but the design of our times should be kept aside from those when the notion of "radical originality" is favored more than "mere novelty" (Boden, 1990). As mentioned before, in order to free design from the "learned and applied process" label and in order to promote creativity, the idea that "could not have happened" has to be underlined.

Based on the above assumptions and within the context of its relationship with novelty and interestingness, creativity has been defined by Boden (1994) as more than just novelty-producing thought, but rather of novel exploration of and creation of mental representations.

2.3.1.2 Creativity and the Design Space

According to Boden (1994), there are two types of creativity: *improbabilist* and *impossibilist.* Improbabilist creativity involves novel combinations of ideas that are known or recognizable and it assumes that through establishing new connections between existing elements, creativity can be sought without the need for anything to be created de novo. The impossibilist creativity, on the other hand, involves the mapping, exploration and transformation of conceptual spaces causing a change within the design space and therefore producing ideas that could not have been generated if it was not for the change. It does favor for exploration not just combination.

The distinction between these two types of creativity can be made according to their mode of creative thinking. Improbabilist creativity stipulates thinking in the *associative mode*, adhering to rules and boundaries of the current *conceptual space* which has been defined as "a space to understand and act" (Fauconnier, 1985). Impossibilist creativity on the other hand, depends on the *bisociative mode* of thinking, in which the conceptual space is transformed, yet often without a consideration of the existing rules and firmly set boundaries. Therefore, it is assumed that impossibilist creativity can not occur without the existence of a transformation and/or change within the conceptual space of design.

To explore and to change being the basic principles of the impossibilist creativity, Boden presumes that the ability to understand the impossibilist creativity lies in the definition of the conceptual space of design itself. "The more clearly conceptual spaces can be defined, the better we can identify creative ideas" (Boden, 1994:519-520).

She moves from her definition to argue that since creativity is the investigation and transformation of conceptual spaces, the mechanism of creation must be a sort of search through and between conceptual spaces,

> "*A generative system defines a certain range of possibilities... (...)…These structures are located in a conceptual space whose limits, contours, and pathways can be mapped, explored, and transformed in various ways…(...)…probably the crucial difference between Mozart and the rest of us is that his cognitive maps of musical space were very much richer, deeper, and more detailed than ours*" (Boden, 1995; 2-3).

In this context, design is considered to be a creative activity. Additionally, it is also considered a source of innovation. So, according to Boden, creativity in design is by and large related with our cognitive maps of the conceptual space of design. Through the mapping, exploration and transformation of this space, the designer may wind up with the creative idea, if he has the necessarily complex inner structure of representations. As indicated before, the structure of the conceptual space of design is of great importance to gain insight into the creative design process.

2.3.2 Creativity and Cognition

Definitions of creativity vary between researchers and across research fields. Turmoil is inevitable once looked at the diversity of the explanations but to understand the creative design process it is necessary to understand what goes in the designer's head which leads us to the realm of cognitive psychology (Lawson, 1990).

When taken as a cognitive construct, creativity has been a subject that cognitive psychologists have been deeply interested in studying, to understand what kinds of mechanisms underlie creative activities (Finke *et al.*, 1992; Mayer, 1995; Guilford, 1967; Sternberg, 1988).

Two important approaches that have resulted from these studies are the 'Creative Cognition' approach and the 'Gestalt' approach. Among the two, the 'Creative

Cognition' approach proposes existing; universal 'pre-inventive' (imaginative) cognitive structures that are used in creative thinking (Finke *et al.*, 1992). Finke's Geneplore[1] Model based on his Creative Cognition approach, involves a generative phase where one constructs pre-inventive structures, or mental representations having various properties that promote creativity which are then exploited and interpreted during an exploratory phase. Examples of pre-inventive structures include symbolic visual patterns, mental blends of basic concepts, exemplars of novel or hypothetical categories, and verbal communications that give rise to new associations and insights (Finke *et al.*, 1992) .Through studies addressing the phases of the Geneplore model, Tang and Gero (2002) have observed that novelty and unpredictability increase when cyclic shifts occur between these generative and explorative phases This alternation is also assumed by the Geneplore model itself (Finke *et al.*, 1992)

The 'Gestalt' oriented view, on the other hand, attributes creativity to insights associated with recognition of specific underlying structures (Mayer 1995). Obviously, the designer's ability to 'see' (interpret) the underlying structure outlines the creative act (Liu, 2000). The Gestalt approach accounts for creativity to rest in the ability to define the not-instantly recognizable 'latent', making explicit meaningful visual patterns, which were not explicitly indicated, by grouping explicit or implicit structures of objects in defined ways (Gero and Jun, 1995) that signifies 'visual emergence'.

Actually, visual emergence has been a phenomenon studied by Gestalt psychologists and a paradigm observed in creative designing (Schön and Wiggins, 1992). Fundamentally, visual emergence allows the designers to look at unexpected or emergent visual structures from what they see in front of them. The search for the 'hidden', 'latent', 'unexpected' in visual emergence plays a significant role in introducing new variables into a design space.

Despite differences in relation to their structure and process, both of these theories acknowledge sudden, unexpected restructuring of a creative idea that emerges during

[1] The Geneplore Model of Finke *et al.* is further investigated in Section 2.3.5.2.4

a generative phase, referred as the *big idea*, *primary generator*, *creative leap, sudden mental insight etc* (Cross, 1997; Akın and Akın, 1996; Darke, 1976) either through a refurbishment of a pre-inventive structure or through an insight of a latent structure.

2.3.3 Creativity as Sudden Mental Insight

Solitary creative process is referred to be a myth (John and Steiner, 2000). However, implicitly or otherwise, the individual creators as in the examples of Darwin, Pasteur or Einstein are supposed to have experienced a sudden illumination beyond this myth. Akın and Akın (1996) cite Mozart's words trying to explain the "magical" burst of an idea to an exceptional composer:

> *When I am, as it were, completely myself, entirely alone, and of good cheer, say traveling in a carriage, or walking after a good meal, or during the night when I cannot sleep; it is on such occasions that my ideas flow best and most abundantly. Whence and how they come, I know not; nor can I force them.*

The readiness to the flow of unexpected, or shall we say indirectly expected, idea for Mozart has been a characteristic of many creators of the modern era. Such a moment when the creative flash arrives, is referenced as the "a-ha!" response which corresponds to a sudden mental insight (SMI) in the design process (Akın and Akın, 1996). The sudden sparkle, a flash or a lightning may appear exaggerated but they designate a creative idea behind a creative product.

The insight experience is the sudden emergence of an idea. Without the company of the *experience*, the notion of *insight* is defined as *an understanding* (Smith, 1993) which refers to an understanding of a mechanism, an analogy or a re-conceptualization. Beyond experimental research that had been conducted on insight by Gestalt psychologists such as Koehler (1925) and Maier (1931), in the early 1980's Robert Weisberg and colleagues have reviewed the subject to expose what Weisberg (1986) referred to as the "myth of insight". However, anecdotal accounts of dramatic insights have drawn attention to the unconscious connections beneath these sudden insights. A famous example would be Kekule's insight into the

molecular structure of benzene which was arrived after his daydream of coiled snakes within ring-shaped structures. It is to be noted here that insight experiences do not need to lead historic tremendous discoveries; the essential elements of insight experiences are that the ideas are sudden and unexpected. Boden would define this understanding of –unexpectedness- through her impossibilist creator where exploring and transforming would cause the creative act. Boden makes use of the unexpected, just playfully made change by dropping Euclid's fifth axiom about parallel lines meeting at infinity, which resulted in the emergence of Non-Euclidian geometry to explain the transformation of the geometrical space in this case, but the design space in general. As a matter of fact, dropping a constraint here is a general heuristic for transformation which could be substituted by an analogical transfer, mental transformation or re-contextualization mentioned as generative models for Finke et al.'s Geneplore model, when it comes to design. Boden (1990) with this, in fact, emphasizes that creative design involves transformation and exploration in addition to a radical originality encompassed in the unexpected and sudden idea in saying that just daydreaming would not have caused Kekule to transform a string to a ring to explain the benzene structure but that some underlying thought had been already processed under the name of "transformation" within his mind. He had an association of snakes and molecules, the topology of open and closed curves in mind and a transformative tool –the negation- , so this is also accepted today by many researchers that the creative impulse originates through a cognitive preparation.

Other than the Gestalt psychological view, the sudden mental insight has been referred in design as the "creative leap" by Archer (1965). The occurrence of the so called "creative leap" has been seen as a characteristic of the design process (Dorst and Cross, 2001). From 1994 on, Cross has produced a series of studies in industrial design to demystify the creative leap by assuming that a set of pre-conditions should exist to lead to that leap (Cross, 1997; Dorst and Cross, 2001). Most of these studies have relied on protocol analysis also in retrospective accounts (Cross and Christiaans, 1996; Suwa and Tversky, 1997; Gero and McNeill, 1998). Cross has also suggested that creative event in design is much more like a "bridge" between the solution and problem spaces of design rather than a jump or leap between them. Dorst and Cross (2001) have also stated that design involves an exploration phase

where both the problem space and the solution space, are subjected to transformation instead of being static just as it could not have been for Boden's (1990) impossibilist creator to meet the creative idea without the transformation of the conceptual space.

Yet, Koestler (1989) suggested that conscious thought, might actually inhabit the unconscious forming of connections that underlies insightful leaps. If creative insights occur in sudden ways and if conscious thought might inhibit insights, how could they ever be studied through observational studies under controlled conditions?

2.3.4 Approaches to Exploring Creativity

The outcome of research in creativity for the last fifty years has been partly tentative in that it came up with a vague level of theorizing and inconclusive empirical evidence (Sternberg, 1999). However, the "mysteriousness" of creativity is starting to be reduced as new empirical intra-domain and outer-domain studies give way to new explanations of creativity (Cross, 2001).

The main approach to studying creativity has been to find out characteristic traits of creative people, designers, based on the idea that creativity is an isolated capacity or process (Eastman, 1969; Schön, 1983; Sternberg, 1988; Gardner, 1993; Lawson, 1994; Roy, 1993; Cross, 2002).

For the last two decades, there has been a growth in architectural and industrial design research, and accordingly, a varied range of research methods have been adopted and deployed within the design domain (Cross, 2001). These methods include both participant and non-participant observation methods which have tended to study real as well as artificially-constructed design projects (Cross, 2001). Research subjects have included both inexperienced designers, usually students, and experienced architects and industrial designers (Cross, 2001). Even so, the number of the conducted researches remains small with respect to the studies in other domains. Additionally, subjects to take part in the studies are generally restricted with a small number and repeat studies are even harder to be carried out to test the results (Cross, 2001).

Based on a classification made by Cross (1998), methods that are used to understand design thinking and in particular creative design thinking can be listed as such:

- *Interviews with designers*. Generally, outstanding and experienced designers which are known for their competence have been selected and the studies involved a series of interviews, mostly retrospective. The studies aimed at reaching patterns schemata or maps that revealed whether creative genii have something in common or whether some provisional data can be arrived at to gain insight into the designer's conception of the design and its conceptual space. Cross (2002) has carried out a study on three exceptional designers, where the two of the three have been retrospectively interviewed and the other one was subjected to a protocol analysis. The interviews were based on examples of specific designs of the designers which were counted as radical achievements with respect to the conflict to be resolved between the designer's conception of the problem and the criteria for the solution. Including the protocol analysis which was based on a novel task given to the designer through the process of which he was videotaped and asked to think aloud, Cross produced a general model of creative process by underlining common features in the three designers' actions and strategies for creative act. Examples of interviews to understand the creative design process include Darke's (1979) interviews with architects and later Lawson's (1994) studies.

- *Observations and case studies*. These studies have favored the inspection of a specific design task given to the subjects during the performing of which they are observed and occasionally recorded. Both participant and non-participant observation methods have been included, and varieties of real, artificially-constructed and even re-constructed design projects have been studied.

- *Protocol studies*. Protocol analysis has been the primary empirical method to study creativity as a cognitive activity. Protocol analysis inherently includes small design tasks to be given to the subjects and observation of their design behavior. In relation with the data captured during the design process such as

verbalizations, drawings and gestures, the design thinking map of the designer is induced (Ericsson and Simon, 1984).

However, whilst design is seen as an ill-defined creative problem solving activity (Newell, 1969; Eastman, 1970; Simon, 1973) that can be decomposed and analyzed through protocol analysis and via external representations of the designer (depending on behavior and on drawing), it did not escape design theorists (Chi, 1997) that the ambivalence between the internal and external representations was not even close to be attended.

Consistent with this concern, Winograd and Flores (1987) stated that designers mentally construct their view of the situation as well as actions taken within it. Going further through a phenomenological perspective, designer mentally constructs a design world (Trousse and Christiaans, 1996; Schön, 1988) beyond the entities, attributes and relations that are generally involved in the state space of design. Actually, this is the conceptual space of design that Boden emphasizes, which will witness the emergence of a creative idea going through the mapping, exploration and transformation of it.

To overcome such challenges as many of the important aspects of design are hidden in designers' heads rather than being visible (Lawson, 1997) think-aloud protocols have been conducted in architecture and industrial design where designers were asked to describe what they are thinking of during the designing process. Yet, of course, such analyses have been quite time-consuming and as some designers find "it difficult to describe a non-verbal process in words" (Darke, 1979: 37) and some have difficulties in recall and as architects and industrial designers are more likely to impress rather than explaining (Lawson, 1997), implementation of this technique has been also limiting.

- *Reflection and theorising*. Schön and today many other design researchers indicate that they see empirical research to have a limited contribution to architecture and design that is why theoretical analysis has been a significant feature to comprehend the creative design process. Mostly dating to 60's and

70's, Koestler (1964) and Schön (1983) have studied design theories based on reflections.

- *Simulation trials*. Today, neural network simulators are allowing us to program what we have no explicit description for, and artificial life techniques are allowing us to create programs that simulate creativity. The aim of artificial creativity has been to "provide insights into the nature of creativity –as-it-is by studying creativity-as-it-could-be" (Saunders and Gero, 2002).

While the empirical studies in research of creativity, based mostly on protocol analysis, have been successful in identifying what designers do, they have been less so in identifying how they do it. In addition to that, it has been proved to be true that it is difficult to get a single or a set of characteristics that are all so common in creative designers.

Besides the vague and questionable results of empirical and theoretical studies, little information is available about how creativity actually works. Assuming that we can recognize creativity when we see it, how come is it that we can not explain how it comes about. What makes the designer experience such creative spark? How can we model a creative act or can we reach to the trajectories that mind follows? On the basis of this view, the state space of design has to be explored and analyzed to reach more evidence on creativity as it is the playground of the designer.

2.3.5 Modeling Creativity in Design: Descriptive and Cognitive Models

This section is based on the different models of creativity which have been produced to present a prescription or description of behaviors during creative design process.

2.3.5.1 Descriptive Models of Creativity

There have been several descriptive models proposed to explain the creative process (Wallas 1926; Poincare, 1924; Rossman, 1931; Torrance,1988; Barron, 1988; Osborn, 1953; Koberg and Bagnall, 1981; Isaksen and Trefflinger, 1985). The terminology that have been used to describe the different stages vary but there is a consensus among researches for the following four stages of creative design, a model first proposed by Wallas in 1926 (cited in Plsek, 1997:2).

Preparation is the stage where the person tries to understand the problem and collects relevant data. Even at this very first stage there may be attempts to solve the problem, with a high possibility of being unsuccessful. In the *Incubation* stage, the person does not actively attempt to solve the problem. There is supposed to be an unconscious work going on in the persons head. In the third stage, *Illumination*, a possible idea surfaces to the consciousness and makes the 'a-ha!' moment come true. Finally, *Evaluation* is the stage where the designer/thinker assesses his idea which will be decisive on whether the process is going to be repeated or concluded with the supposed idea.

Wallas' model has been found interesting in that it implies that creative thinking is a sub-conscious process which is not easily understood nor directed and also involves analytic thinking at the first and last stages not opposed to it but as a complementing feature of creative thinking. (Plsek, 1997)

Some models have favored the notion of "chance" in creative design process as Simonton (1988) and Campbell (1960) (cited in Plsek, 1997). Chance configuration models imply that "variations on ideas and concepts come about through random chance" (Plsek, 1997:6). The chance event is followed by the random selection of the surviving idea and the third and last stage is where the survivor idea is made to get a concrete form.

Apart from the chance models that give emphasis upon subconscious mental processes and uncontrollable happenings, there have been much more modern

models produced. Fritz (1991) for instance, has proposed a modern model of creativity. His 'Process of Creation' is remarkable as it identifies the beginning of the design process with the creative acts of conception and vision.

Plsek (1997:6) has given concise explanations of Barron's Psychic Creation Model, Rossman's Creativity Model, Osborn's Seven Step Model for Creative Thinking, Koberg and Bagnall's Universal Traveler Model and Robert Fritz's Process for Creation which according to him, do share some commonalities in their approach to framing the creative process in design:

- The creative process involves purposeful analysis, imaginative idea generation, and critical evaluation, the total creative process is a balance of imagination and analysis.
- Older models tend to imply that creative ideas result from subconscious processes, largely outside the control of the thinker. Modern models tend to imply purposeful generation of new ideas, under the direct control of the thinker.
- The total creative process requires a drive to action and the implementation of ideas. We must do more than simply imagine new things; we must work to make them concrete realities (Plsek, 1997:6).

Through an analysis of the models that have been mentioned above, Plsek provides us with an integrative model of creative design: "The Directed Creativity Cycle". According to this model, **everyday living** is a creative activity which is fed with the **observations** one makes throughout the course of everyday from the beginning till the dawn. Observation is followed by **analysis** of the things happening in our surroundings, how they work and fail. All of the events and entities that have been experienced are transformed into a kind of knowledge base and recorded in the memory which will be then used as associations to form and **generate** novel concepts. Building associations leading to novel concepts rely mostly on analogical reasoning. The generated ideas are then harvested and enhanced before they are subjected to evaluation. Implementation as the final node of the cycle is also the point where the cycle starts to repeat itself. Four phases define the four quarters of the cycle: preparation, imagination, development and action (Plsek, 1997).

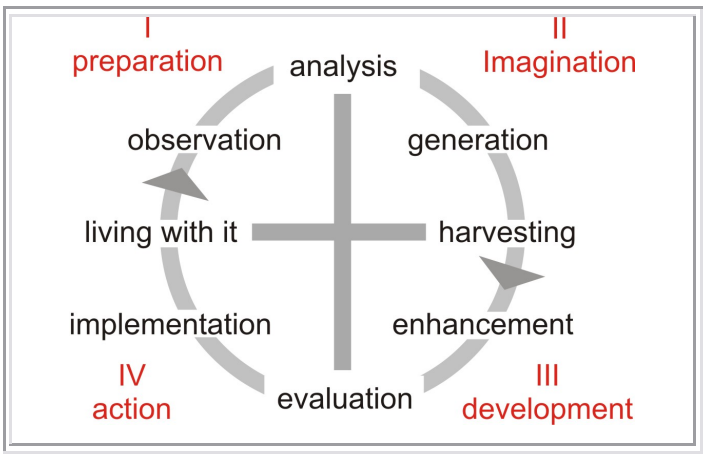


Figure 2.2 The Directed Creativity Cycle (Plsek, 1997:3)

These descriptive models of creative design are important from the aspect that they enable designers to understand the creative design process based on the similarities and differences between different viewpoints. As a matter of fact, as human beings with distinctive intelligent capabilities, designers have different cognitive mechanisms which are triggered through different stimuli and which are directed differently throughout the course of creative design.

2.3.5.2 Cognitive Models and Theories of Creativity

Cognitive models of creativity consent to the existence of a series of knowledge transformers to trigger a change through which the opportunity of meeting a creative idea is increased. This section covers some of the basic knowledge transformers and their application in the cognitive models that have been proposed.

2.3.5.2.1 Introduction to Knowledge Transformers

In order to derive new knowledge from an existing domain or given input, knowledge transformers act as operators realizing the transforming action. Sim and

Dufy (1998) identify seven pairs of knowledge transformers which are thought to be explanatory in creative discoveries of design and science (Table 2.1). Knowledge transformers are important in the way they define how different theories underlying different models of creativity make use of knowledge which is essential for an understanding of the basic mechanisms that lead to creative acts in different models.

Table 2.1 Knowledge Transformers (adapted from Sim and Duffy, 1998)

Knowledge Transformers	**Description of the way the knowledge is transformed**
Abstraction/ Detailing	Using abstract concepts, abstraction forms a new version of the knowledge less in detail more in generic. Through detailing, on the other hand, knowledge is more elaborated in its descriptive quality.
Association/ Disassociation	Association between the visual structural primitives and the causal primitives enables adaptation and transfer of causal knowledge based on a notion of dependency. The opposite is disassociation, which is based on the omission of dependency.
Derivations/ Randomization	Derivations transform the knowledge through deriving piece of information from another knowledge into the base one. Randomization however, transforms segments of knowledge into others through random changes
Explanation/ Discovery	Explanation derives supplementary knowledge based on the domain knowledge. Discovery derives brand new knowledge with no reference to the domain knowledge.
Group Rationalization (Clustering)/ Decomposition	Group rationalization includes similarity based grouping of past designs and examples with respect to considered criteria. Decomposition removes any groupings.

Generalization/ Specializations	Operating on inductive inference, generalization characterizes related concepts based on different specializations of that concept. Specialization increases the specificity of the description.
Similarity comparison/ Dissimilarity comparison	Similarity comparison is based on retrieving design knowledge from similar past designs. It is based on analogical inference. Dissimilarity comparison being the opposite derives knowledge from dissimilar aspects from the two designs at hand.

Table 2.1 (continued)

2.3.5.2.2 Bisociation

In his book *The Act of Creation*, Arthur Koestler (1964) defines *bisociation* as the combination of ideas of two often incongruous domains which fuse and blend into each other and expresses that the source of creativity lies in the combination of these *far apart* domains.

The ability to synthesize a wide range of concepts which might have been thought to be unrelated at first plays central role in bisociation which is considered as a cognitive faculty typically defined as a mapping process between *matrices* (Koestler, 1964). An example of Gutenberg's invention of the printing press was mentioned in a previous section which combined the ideas of two unrelated domains resulting in a dissimilar juxtaposition of concepts in an innovative idea. The idea of seals when combined with a wine press, appearing to be subjects of unrelated domains, has lead to the emergence of one of the most important inventions of the media culture. As operating on linking unrelated or incompatible knowledge from different domains, the knowledge transformers that can be inferred from the bisociation theory are that of disassociation.

2.3.5.2.3 The Darwinian Model

The creativity of nature has inspired Donald Campbell to propose a Darwinian account of creativity which relies on the generation and growth of knowledge (Campbell, 1960). He proposed that creativity depends on the random generation and

selective retention of ideas where the more creative the outcomes happen to be the more they depart from that what's been preceding them. The Darwinian model provides a perspective in understanding creativity by its three mechanisms. The first one is the need for the generation of variations having a blind quality, meaning that their consequences can not be guessed or anticipated, in order to produce genuinely new knowledge. Second, through a selection process, the variations are diminished to the ones which fit to the problem at hand. Third, the fact that without retention, a selected variation can not lead to an acquisition of a new knowledge, calls for a mechanism for the retention and propagation of the selected variation (Campbell, 1960). The knowledge transformers in this model can be identified as randomization which allows generation of blind variations with no respect of the end results they may produce.

2.3.5.2.4 Geneplore Model

Geneplore Model proposed by Finke *et al* (1995) consists of two phases: a generative phase which is followed by an exploratory phase. In the generative phase, the designer constructs mental representations called pre-inventive structures. Pre-inventive structures have various properties that promote creativity during designing which are then tried to be interpreted in an exploratory phase.

The pre-inventive structure can be seen as the core concepts which are trying to be developed into creative product concepts through generation, regeneration and modification in their exploration during the exploratory phase. Actually, Geneplore model makes use of different knowledge transformers in the generative and exploratory phases which are thought to be happening in cyclic shifts.

Some of the common ***Generative processes*** in the generative phase can be defined as the retrieval of existing structures from memory and the formation of associations among these structures or combinations of them. Through mental synthesis or mental transformation of existing structures into new forms by the re-arrangement and reassembling of them mentally, new pre-inventive structures may be attained. An important type of generative processes in the generative phase is analogical transfer

which is based on the construction of relationships between two different domains and the transformation of the relationships from one context into the other, resulting in pre-inventive structures of high value.

Exploratory processes in the exploratory phase of the Geneplore model include the search for novel or desire attributes which can be considered as a systematic search for finding emergent features in pre-inventive structures. The exploration of emergent structures resulting from conceptual combinations and metaphors can also be supported by attribute finding. The search for metaphorical implications of the structures or the search for potential functions of the structures can be interpreted in the way they present solutions to the problem space, the former referring to finding an abstract, metaphorical interpretation of a pre-inventive structure whereas the latter refers to the exploring of potential uses of a pre-inventive structure (Finke *et al.,* 1995).

In the generative phase, the knowledge transformers identified are association, analogical transfer and abstraction while in the exploratory phase they are abstraction, discovery through attribute finding, finding abstract, metaphorical, or theoretical interpretation of concepts, functional interpretation, contextual shifting(.

The mentioned knowledge transformers so far, as also cited in the three cognitive models of creative design can also be considered as the basic ideas that form different tools for supporting creativity by suggesting the actions to be carried out during a search for a creative concept.

2.3.6 Supporting Creativity in Design: Creativity Assisting Tools and Methods

The potential for enhancing human creativity has been a chronic theme of visionary thinkers such as Edward De Bono (1986) whose idea of Lateral Thinking shows an unusual approach towards design thinking in its basis on the fact that problems are the results of obstacles and in order to get over those obstacles and to arrive at the destination, it is required that the regular direction of the approach is to be replaced by an unexpected direction that moves around the obstacle. As a matter of fact,

creativity methods attempt at bringing different perspectives to the design environment than the available ones. The ability to see things differently than they appear to the eye and thought in normal is seen as a source code for creative occurrence and that's why methods to support creativity have tried to help the designer to get over the designer's block by suggesting alternative approaches to the problem at hand.

1980's being the beginning; there have been numerous attempts to systematically support the creative processes of design, called creativity methods. Whether to escape a mental block, a fixation or just to improve creative skills of average and exceptional designers, creativity methods are asked for assistance during the design process. These formal concept generation/ideation methods are classified into two; *intuitive* and *logical* where intuitive methods aim at breaking mental blocks based on their alternative routes within the design environment and logical methods include systematic analysis of the problem based on science and engineering principles.

Intuitive Methods can be sub-classified into five categories: Germinal, Transformational, Progressive, Organizational, and Hybrid (Shah *et al.*, 2002). Germinal methods like Morphological Analysis and Brainstorming aim to produce ideas from scratch. Transformational Methods like Checklists, Random Stimuli generate ideas by transformation of the existing concepts through addition or replacement of some regions. Progressive Methods are based on a cyclic nature where ideas are generated through repeating same steps many times. Examples of progressive methods are Method 6-3-5 and Gallery Method. Organizational methods on the other hand, operate on the grouping and generating of ideas in a meaningful way among which The Affinity Method, Storyboarding, and Fishbone Diagrams can be shown as examples. Finally, hybrid methods like Synectics merge different techniques in themselves to be operated in different phases of design (Shah *et al.*, 2002).

Logical methods, alternatively, can be categorized into two in themselves: History based and Analytical. History based methods aim to create a data-pool of past design examples. TRIZ, Theory of Solving Inventive Problems, as proposed by Altshuller

(1984), provides a coherent method through invention principles by examining patents from different domains. Analytical methods concentrate on the first principles, analyzing basic relations and causal chains.

Recognition of the fact that there are multiple dimensions of creativity and many different approaches to the research of creativity requires that these various aspects are to be set into an n-dimensional classification. In other words, the decision of in which intersection of the n-dimensional classification the tool is to operate is prior to a development of a creativity support tool.

Taking the intersection of the use of analogies as creativity support agents and the phase of concept generation as the coordinate space for the agent to act, the following section is based on the investigation of analogical reasoning in design and how it can serve as a creative and inventive design strategy for supporting the design process.

2.4 Analogy and Metaphor in Similarity Based Reasoning in Design

For a long time, theories on the systems of reasoning have designated two types of reasoning which are supposed to develop into one cognitive system following a trajectory of evolution from *reasoning based on similarities* in early childhood to *rule based reasoning* in adulthood. Of the two, similarity based reasoning is largely visual, depending on figurative qualities whereas rule based reasoning signifies the ability to form abstract concepts and the use of language as a tool for symbolic representation (Goldscmidt, 1997). However, in recent years studies have shown that we are endowed with the two cognitive systems; similarity-based and rule-based, acting in a parallel and interactive manner to operate in problem solving (Gentner and Medina, 1998).

Gentner and Medina (1998) single out analogical reasoning as a similarity based mechanism, for its being a particularly important strategy in problem solving regarding its ability to form also rule-based structural relationships in addition to visual and figurative similes. In its basis, an analogy is a mapping of knowledge from

one domain (the base) into another (the target) which conveys that a system of relations which holds among the base objects also holds among the target objects constructing a one to one correspondence based on the identification of relations relying heavily on cognitive abilities of the one who makes use of analogies. That is why analogical reasoning has been presented as a cognitive ability as frequently occurring and highly valued in both problem solving and understanding and has been studied both by arts and sciences in order to understand the basic mechanisms underlying human cognitive and creative abilities. In this respect metaphors can also be seen as structure-preserved mappings between conceptual domains requiring an abstract mapping to be established between two domains based on their common structure rather than implying only a linguistic construction. Like analogies are part of a mechanism through which different domains are mapped into each other, metaphors are also part of a mechanism through which abstract concepts are understood and abstract reasoning becomes possible (Lakoff and Johnson, 1980).

2.4.1 Analogical Reasoning

Reviews of the current cognitive and computational theories of analogical reasoning generally distinguish two main approaches, Gentner's (1983) 'syntactic', and Holyoak *et al.*'s (1985) 'pragmatic' approach. In Gentner's syntactic model of analogy-making, the structure of the source and the structure of the target determine if there is an analogical relationship between the two and these structures guide the mapping which allows this relationship to be exploited. In the pragmatic approach of Holyoak (1995), the structure of target and source is important, but the causal nature of the relations between the corresponding elements in these structures is determining element in the definition of the analogy and in triggering analogical reasoning. Because causal relations depend on the context and/or the use of target and source, this approach is called 'pragmatic'. Transcending Gentner and Holyoak, Keane *et al*. (1994) have proposed, in their "solution generation theory", a common meta-theoretical framework in which the two different theories can be unified and distinguishes the main stages of analogical reasoning as retrieval, mapping, adaptation and side-effects (i.e. learning through induction, and/or other updating of memory). Visser (1996), on the other hand adds *representation construction* to the

common stages of search and retrieval, mapping, adaptation and side-effects defined by other researchers.

However different models appear to focus on different combination of sub-processes. Processes that analogical reasoning involves can be gathered as representation building, retrieval of a base for the analogy, mapping this base onto the target, transferring of unmapped elements from the base to the target, making inferences, evaluating the validity and applicability of these inferences, and learning from the experiences which includes generalizing from specific cases and developing mental schemas (Kokinov and French , 2003).

Theories on analogical reasoning have been followed by a series of studies with students and designers to understand the underlying mechanisms. The effect of expertise on the ability of analogical construction has been a subject of investigation for Goldschmidt and Casakin (1999) who have tried to elucidate the skill to use visual analogies in design through a series of empirical studies with expert and novice architects. As the use of analogy requires the identification of abstract knowledge structures that correspond to the similarities between known and unknown situations, the accumulation of knowledge and the practice of methods become vital variables of assessing the capability to use visual analogies in design. This is therefore supposed to be true to state according to research of Goldschmidt and Casakin that experts have tended to come with better results than the novices.

Building an analogy, aside from the structural or experience-based perspective, can be a means for artistic expression of concepts or it can provide a problem solving strategy or maybe a part of a method or the method itself for creating novel design concepts. With no regard of its area of implementation, making analogies inherently relies on the ability to combine different sources of information through representing different domains *as if* they were *the same.*

2.4.2 Analogy as an Inventive Design Strategy

Analogy is ever-present in most intellectual endeavors as a matter of which reasoning by analogy has been recognized by scientists, philosophers, and psychologists as a mechanism that has the potential to bring forth prior knowledge that can support the acquisition of new information.

Studies with students designing through analogical reasoning have shown that analogical mapping and transfer is a two-way process. The first way is mapping from a known example to abstraction and the second is from abstraction to a new candidate in the realm of the given design problem (DeJong, 1989; Goldschmidt, 1995). Novices exercising analogical reasoning become apt at using abstractions causing them to gain in knowledge and in the ability to use knowledge in design reasoning (Gentner and Medina, 1998). Therefore, analogical reasoning brings similarity-based and rule-based reasoning close together, providing an interaction between the two which leads to an enhancement in design problem solving. Especially, in the early phases of design where the designer searches for ideas or concepts, reasoning by similarity is helpful as a triggering tool whereas reasoning by rules is much more proper in the next phases of the design process (Goldschmidt, 1995).

Reasoning by similarity is a popular inventive design strategy making use of knowledge transformers like analogy and visual metaphors. Metaphor and analogy play a key role in many cases where a creative occurrence is of question based on a 'seeing as' mechanism. Examples can be drawn from instances like Kekule's seeing benzene's carbon ring structure as a snake that bites its tail or Faraday's seeing the universe as patterned by *lines of force* leading to the invention of the electric motor (Koestler, 1964). The use of metaphor and analogy in design is correspondingly encouraged especially in architecture as well as in industrial design. For example, Broadbent (1973:35) states that "Analogic design is the most potent source of creative ideas in architecture". Examples from architecture include Santiago Calatrava's BCE Place Gallery where palm trees are converted to the columns of the gallery, Utzon's Opera House, the shell shapes of which are shaped in association to

the yachts in Sydney Harbor which can be classified as shape reminding through reasoning by similarity.

A famous example of an inventive design based on reasoning through similarity and analogical mapping to be drawn would be Le Corbusier's design for the roof of Ronchamp chapel. According to the architect's own indication, the shape of the roof was first captured as an image of a crab's shell which had been lying on his desk for quite a long time. Le Corbusier, transferred the structural principle of the double-membrane shell to the structure of the roof giving the building its special silhouette (Broadbent, 1973).

The underlying cognitive strategies of creative designs are often not so lucidly described as the one of Le Corbusier's. Yet, the rationalized description of such an occurrence of a creative idea is considered to be the basic aim of investigation into the design process with an expectation of the ability to extract laws to be re-applied in other design problems. This pragmatic objective has given way to the emergence of a number of strategies and methods to increase creativity in design. One of these methods is Synectics proposed by Gordon (1961) which uses analogy as its basic strategy.

2.4.3 Synectics

Synectics (Gordon, 1961) aims to introduce new and different viewpoints into the concept generation environment. The ability to use preconscious mechanisms for conscious use has made the theory to be grounded in two stages: making the strange familiar and making the familiar strange. The first stage is the part where the problem is understood in an analytical way, going down into its basic principles. Subsequent to the analysis of the problem, the creative part starts where the problem is tried to be perceived in an unusual way through the use of analogies as the de-familiarising agent. Analogies allow the extraction of the problem from the boundaries it has been set into and bring about a different perception of it.

Actually, Gordon's Synectics relies on designer's creativity seen as a "black box". There is no evidence on how the transformation happens resulting in creative occurrence whereas at the other end of the spectrum of creativity increasing methods based on analogical transfer, the Structure Mapping Theory of Gentner (1983) attempts to model the underlying mechanism of analogy making in order to define rules for transformation (Kulinski, 2002). While synectics can not provide further insight for an analogy based computational modeling, most of the computational models operating with analogy agents are based on Gentner's Structure Mapping Theory.

2.4.4 Structure Mapping Theory

The Structure Mapping Theory (SMT) proposed by Gentner (1983) relies on the central idea that an analogy is a mapping of knowledge from one domain (the base) into another (the target), which conveys a system of relations that holds among the base objects, also holds among the target objects (Gentner, 1983). This theory emphasizes the importance of structural similarity between base and target domains, defined by the common systems of relations between objects in the respective domains. The target objects do not have to resemble their corresponding base objects. Objects are placed in correspondence by virtue of corresponding roles in the common relational structure.

Two major principles of SMT are;

- the relation matching principle: good analogies are determined by mappings of relations and not attributes (originally only identical predicates are mapped) and
- the systemacity principle: mappings of coherent systems of relations are preferred over mappings over individual relations. (French, R.M., 2002:202)

Gentner (1983) in SMT, categorizes the types of similarities into five, based on the mapping processes' being of relations or of attributes (Table 2.2). In this respect, in analogies only relational predicates are mapped whereas in mere appearance it is mainly object attributes that are mapped. In literal similarity both relational

predicates and object attributes are mapped whereas in abstraction relational predicates are favored in mapping process with respect to the object attributes just as in analogies. On the other hand, in anomaly both the object attributes and relational predicates are set aside and the similarity is basically independent with no respect to the constraints of the relational formula or visual properties of the object. Finally, in mere appearance, object attributes regarding rather visual properties are mapped with not much care for the relational predicates.

Table 2.2 Kinds of similarity (adapted from Gentner, 1983)

	Attributes (object)	Relations (predicate)	Example
Literal Similarity	Many	Many	Pitcher is like the house
Analogy	Few	Many	Time is like water
Abstraction	Few	Many	The atom is a central force system
Anomaly	Few	Few	Coffee is like the solar system
Mere Appearance	Many	Few	The glass tabletop gleamed like water

2.4.5 Analogy in Design: Case Studies of Computational Models

The systems presented in this section are some of the computational models of analogy based problem solving including two case-study based systems and a system based on constraint satisfaction.

2.4.5.1 STRUPLE

Struple is developed by Zhao and Maher (1988) based on Carbonell's theories on analogical mapping where he proposes that "analogical problem solving consists of transferring knowledge from past problem solving episodes to new problems that share significant aspects with corresponding past experience and using the transferred knowledge to construct new solutions to the problems" (Carbonell, 1986). Struple is a support system for structural engineers where designs are represented as recorded in a database based on information like floor system type, foundation type etc. The retrieval from the past source is done according to the description of the new problem in terms of predicated index cues (Kulinski, 2002).

2.4.5.2 SYN

Based on a model of conceptual analogy, Börner *et al.* (1996) propose a case based approach in their system of Struple which actually solves problems of mechanical ventilation in architectural projects. In order to make it possible for the retrieval of a case, topological graphs are formed which include nodes corresponding to outlets and pipes corresponding to arcs. The analogical retrieval of cases is based on identifying classes and assigning them concept descriptions. Then, analogical reasoning is based on these concepts. When a new problem is given, it is first coded in terms of the most appropriate and definitive concept which is followed by the search of analogical case (Kulinski, 2002).

2.4.5.3 CYCLOPS

Navinchandra's (1991) CYCLOPS system finds innovative solutions through an enlargement of the search space which is seen as a basic for innovation in design. In computational terms Cyclops is grounded on the structure mapping theory, in which the system operates by relaxing constraints and by retrieving and adapting previously stored designs using a three-stage strategy in problem solving: search, exploration and adaptation. The first two stages are based on constraint satisfaction whereas the

third stage is the stage where analogical search is conducted through the encoding of causal relations between a problem and its cause (Kulinski, 2002).

In addition to the computational models of *analogy-based reasoning*, there are also computational models of *analogy-making* following different approaches and differentiated from the first series of the computational models in their approach to analogy making as a high level perceptual process. Seeing the two situations at hand as *the same,* is the main idea of analogy making Furthermore, analogy making is mostly dependent on constructing an appropriate domain representation, "a view" that can be successfully coupled as the famous model of analogy making COPYCAT (Mitchell, M., 1993) relies on this premise in its basis: to copy a quality/order/attribute into another (Hofstaedter, D.R.; Mitchell, M., 1995).

CHAPTER 3

BLACK BOX: A TOOL FOR SUPPORTING CREATIVITY IN THE CONCEPT GENERATION PHASE

The main aim of this chapter is to describe the method of the Black Box Project with regards to its goals, implementation and performance. Black Box was developed as a tool for a design support system that would help the designer use analogy transfer in the conceptual stage of designing. System architecture, world categories, knowledge (pictorial and verbal) representation and methods of controls of various modules of the system are described. The system was implemented in Macromedia Flash running on PC platform and then embedded into HTML for ease of use and operation on any computer.

3.1 Theoretical Framework of Black Box Study

Creative design, while being regarded important and valued is not much supported by computer programs that are used during design. In fact, most of the CAD programs usually aim at visualizing the idea at hand and re-structuring it to the extent of the possibilities that 3-D transformations allow. A number of studies (Coyne and Snodgrass, 1993; Tovey, M.,1992) have commented on the disadvantages of current CAD systems for creative idea generation.

Nowadays, potential improvements for understanding creative design involve research in computational models and artificial intelligence. However, according to Gero and Maher (1991), research in computational processes for design has been mainly concerned with what they call ‘routine design’ and escaped providing further insight into ‘creative design’.

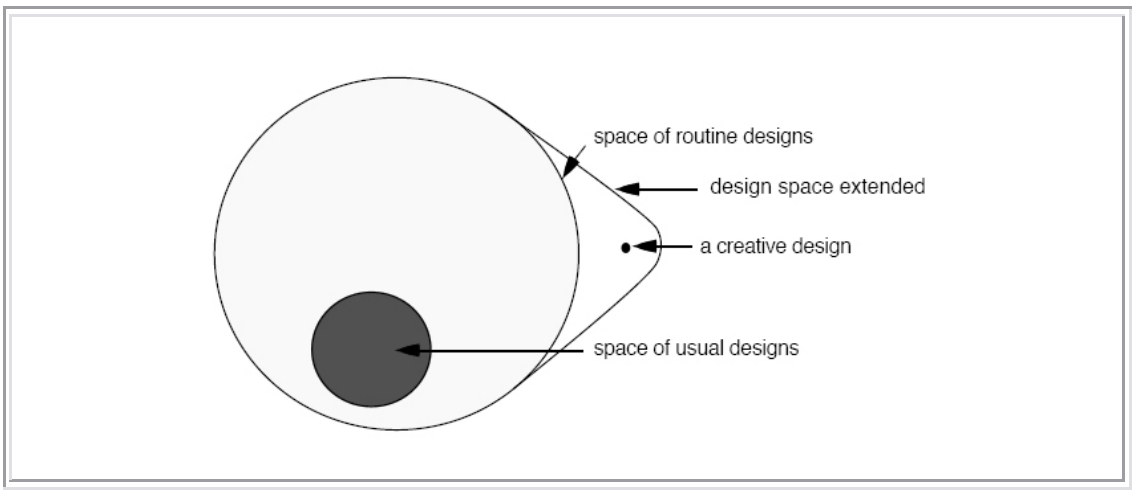


Figure 3.1 Creative and Routine Designing

(Figure from Gero and Maher, 1991: 2)

Routine design, as defined by Gero and Maher, happens through the acts of the designer where he operates within a closed state space of possible designs (1991). In routine design, the design variables are set beforehand and the only thing the designer has to do is to change the values and attributes for the variables. In short, routine designing is the design activity where all the necessary knowledge is available. On the other hand, creative design requires the introduction of new variables into the state space of design; it presumes some kind of an extension within the design space which leads to a changing state for the design space (Figure 3.1). The act of changing causes a mutation in the design space. Such processes do not guarantee that the end design is judged to be creative; rather these processes have the potential to aid in the design of creative objects. Thus, creative designing, by introducing new variables, has the capacity to produce novel designs and as a result extends or moves the state space of potential designs.

In order to provide further insight into the "Creative Design" that Gero and Maher have defined, Black Box study concentrates on the “Creative Occurrence” at the concept generation phase by blending virtual experiences with actual designer

actions through the implementation of a computer based tool which assists designer actions by expanding the creative design's design space.

Apparently, a change or a new combination of "unusual" causing the expansion of the design space does not appear out of the blue. The change actually, calls for an agent or a knowledge transformer to make the change happen and to cause a sudden mental insight (Akın, 1996) which is to be followed by the creative occurrence. Such agents that can extend the design space have been defined by Gero (1995) as combination, transformation, analogy, emergence, and first principles. Furthermore, Sim and Dufy (1998) categorize knowledge transformers under: abstraction, associations, derivations, explanation, decomposition, generalization, etc. Black Box, aiming to assist creative occurrence during concept generation, makes use of analogies as the space extension and changing agent aiming to let the user make use of knowledge transformers as associations, and structural or surface derivations.

Analogies are selected as the transformative agents acting in the design space considering the fact that 'the phenomenon of analogy' appears ubiquitous, playing an important role in essentially all modes of reasoning. In the case of creative design, analogies can serve as an algorithm that builds a bridge between subject and object, between eye and shape, observer and observed and provide a means to reach beyond the provided design space by altering it (Greiner, 1998).

The transformative agent being analogies and knowledge transformers as associations and derivations that are used to construct analogies, it then it is time for the design space (Boden, 1992) to be constructed. Based on the Geneplore Model of Finke *et al.* (1995), in this study, the design space is divided into two experiential subsequent phases which are adapted from the Geneplore model. The first one is the **Generative Phase** where the designer builds pre-inventive structures with the assistance of Black Box tool so as to promote creativity. The second phase that the designer is going to experience in the constructed design space is the **Exploratory Phase** where the designer is expected to search for emergent features in the pre-inventive structures which refer to concepts s/he produces.

3.1.1 The Generative Phase: Memory and Knowledge Organization

The Generative Phase experienced in the navigation of Black Box calls for the notion of 'constructive memory' proposed by Dewey (1986). Through the perspective of constructive memory, memory must be seen as a process rather than a fixed state. The basic idea of constructive memory is that memory has to be re-constructed each time a new memory is to be created instead of having static qualities at a fixed point of time of the original experience. So, recalling a memory is related with the events that have happened after the original experience and every added experience kind of defines the original one. The features of the scenes of Black Box are based on the assumption that any type of data, pictorial or verbally coded, may retrieve different events and entities from the memory. As the memory is constructed again and again with the addition of each new variable for defining a certain event, the worlds of Black Box are constructed upon concepts that are placed next to each other aiming to recall and retrieve data.

The fact that the designer is going to see and act according to what he associates with the perceived data or derives from the perceived data corresponds to Schön's *see and move* cycles of the *reflective practitioner*. Black Box provides and surrounds the designer with a series of worlds of varying content which will be seen and perceived and which will tease corresponding memory levels to produce new directed and reflected actions (moves) based on the experience promoted with data diversity in Black Box worlds. It is expected that the possibility of the emergence of a creative idea increases as shifts occur between the see and move actions. At some point of the see and move shifts, the emergence of a sudden and unexpected creative idea within the predicated verbal and pictorial data can be better explicated through the *flashbulb memory* concept of Brown and Kulik (1977). Trying to define flashbulb memory they claim that "it is very like a photograph that indiscriminately preserves the scene in which each of us found himself when the flashbulb was fired" (Brown and Kulik 1977: 74). Those memories are incomplete and the missing parts are only activated context dependant. That's why it is presumed that context plays an important role in awakening feelings and senses and thus making one remember something that would

not cross his mind normally which is the main reason behind the divergent themes used in the contexts of Black Box worlds.

3.1.2 The Exploratory Phase: The Concept Generation

The Exploratory Phase makes use of the exploration of a hypothetical design scenario used in the designing of an artifact with the help of analogies. It does not aim at replicating the actual design process but rather it is a concise experience of the concept generation phase of the given design problem.

Based on the visual or verbal associations, derivations and references which arise as pre-inventive structures, the designer tries to define conceptual combinations or metaphors.

3.2 Aim and Scope of Black Box Study

Black Box intervenes in the concept generation phase in order to enhance the creative ability of the designer and her/his performance with respect to pre-inventive structures s/he produces in the generative phase and develops into concepts in the exploratory phase of the study. As for analogy making provides a bridge between seeing and moving caused by recalling events and/or entities that have been at an unknown memory level as a consequence analogies are used as triggering agents to construct pre-inventive structures. Black Box offers to help find analogies that are going to be used to transfer data from one source to the target and a code that might set the designer free from the routine evaluation of still images, everyday images, surrounding images and animated contexts in a computer based virtual space. According to Novak (2000), the most important change brought about by digital tools, the alliance between line and digit does not imply space through the representation by lines, planes and volumes anymore. The digital world has provided the designer who sees and moves with the symbolic meaning of building an algorithm in that the impressions and expressions might free the designer from the three dimensionality of his usual perception as well as from the determinacy of the sign.

Black Box proposes one algorithm and code that is developed into a virtual environment that progressively evolves from a state of latent potentiality to a complex evolutionary stage through the interaction of memory and the predicated knowledge base of the computational tool, through a law of interactivity between the designer and Black Box.

3.3 Objectives of Black Box

Black Box as a tool has arisen out of the concepts of Boden (1994) that impossibilist creativity happens through exploration and change of the conceptual space of design and of the need of an agent to cause change as stated by Gero (2002) and of the possibilities of the moves that are to be produced by the designer as a result of the changes in the act of *seeing* (Schön, 1983). In short, Black Box expands the design space by attaching itself to it, changes the perceived data through analogies and aims at the creative occurrence by changing the way the designer sees and acts.

The tool is not a computational engine but rather a virtually organized set of windows that open to different perspectives after which the designer will form a concept in traditional media through sketching or writing. Thus the system's main focus is representation not computation.

The tool requires various types of knowledge which have been encoded procedurally. Below is a list of objectives that have been taken into consideration in the design of the tool.

- The tool should be simple and ergonomic in use but also unpredicted and multi-faceted at the system level so as to support creativity.
- Since rigid compositional order can be understimulating, unpredictability has been used as a driving force in the arrangement of visual and verbal knowledge represented within the tool.
- There is no effort to provide the tool with the capacity of long term learning since the main objective is the analysis of a single phase of the design process.

- The tool is to use high level concepts in arranging low level graphical data which means that the segments of the tool, the worlds, have been based on singular concepts.
- The main focus of the implementation is to provide as much visual data as possible for the given problem definition and the amount of time.
- The rationale behind the selection of the knowledge base and the content is along with the existence of selection of content ranging from irrelevancy to relevancy for the design problem.
- The fact that the content of the tool is adequately varied is the consequence of the aim of coping with the different styles of the potential users and of course of divergent approach taken to support creativity.
- The tool does not require facility for the user to extend/modify the design base interactively.
- The tool is basically constructed on user manipulations such as stopping, playing and randomly picking.
- Themes and variations aim at expanding the conceptual space of design.
- The ways that have been used to introduce (non-random) variability are not based at the level of program codes nor through software definitions of an n-dimensional space but through employing lexicons of images variously modifying and combining them according to a set of rules analogous to the rules of morphology and syntax.
- Given the vastness of the potential images that may be used, effective search strategies have been based on the concepts that may awaken curiosity and on the concepts that are related with the design problem.

3.4 Black Box Architecture

Black Box is constructed via Macromedia Flash MX and common lisp where needed. At the level of program source code, Black Box is rather easy to define as it is not interactive software that responds to user actions. Unlike CAD software that makes even untrained individuals create shapes and drawings, Black Box is a system of experience, letting the user sketch in traditional ways later in the process; it is not a

drawing medium. It is a surface-bound medium where all the interaction is based on the single point of contact of the mouse.

The kernel of the generated tool is that it is case-based and the types of data structures are defined accordingly. For another hypothetical design scenario, type of data has to be defined again. As for this study, data structures are organized according to the integration of themes related with *time* considering the fact that a *clock concept* is going to be designed. Additionally, in order to provide ease of use, the tool has been reformulated through the HTML code and presented in an arrangement of a web-page.

Black Box is a compilation of virtually designed worlds which are loaded with images, words and animations or a combination of those. The content is to be changed, redesigned and extended according to the design problem at hand or the hopes are towards the tool's improvement to such a degree that the content can also be extended with the user's own intervention.

Basically, the virtual tour that is to be taken in Black Box is based on visual and audio experiences that appear and disappear one after the other in sequential worlds. As soon as the user clicks the icon and the web-page like interface welcomes him/her into the virtual experience, he is let into a virtual tour.

3.4.1. The User Interface

Black Box provides the user with a shape based interface. There are no menu-driven operations but navigational actions are executed through buttons defined with texts according to the content of each point of the navigational map (Figure 3.2).

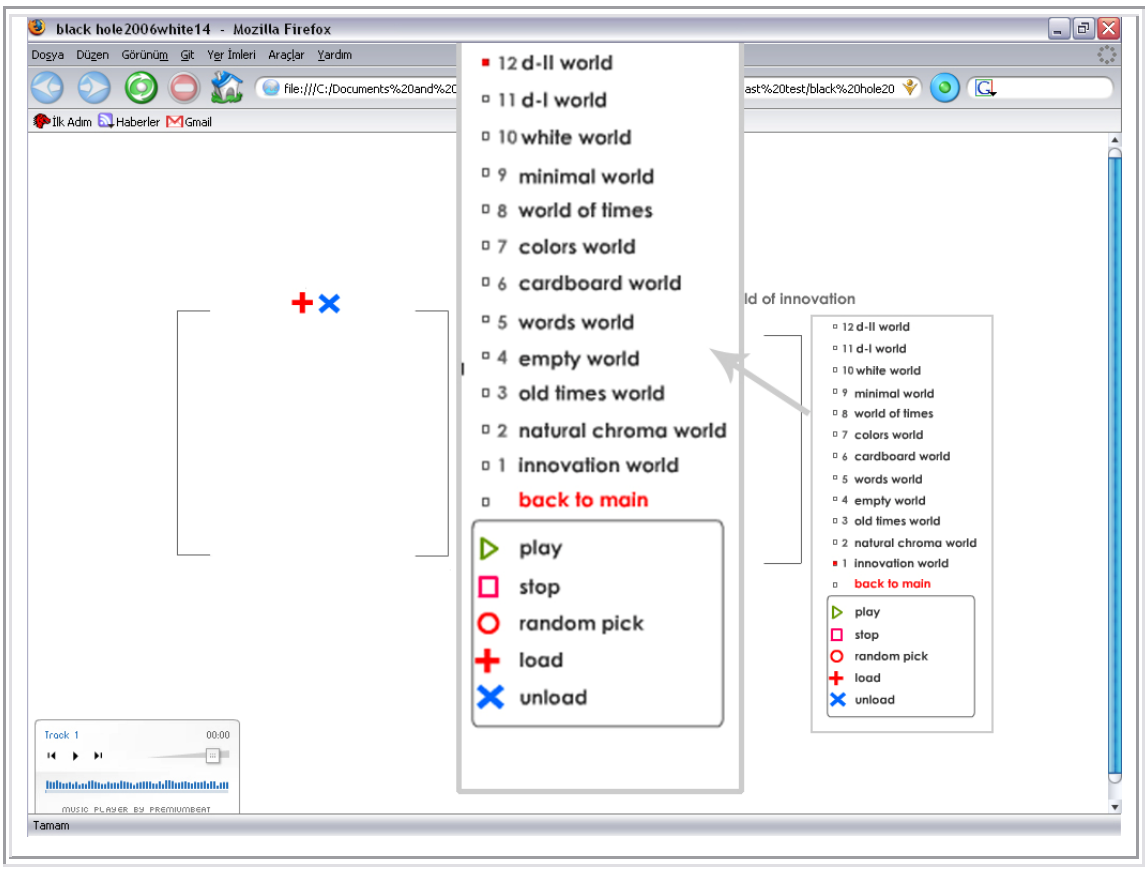


Figure 3.2 Main Interface of Black Box

As the interface stays static, the set-up of each point of the navigational map (by point, a specific world of the tool is meant) shows a deviating design. Phenomena of self-organization which claims that hierarchical, 'top-down' planning may not be the only way of producing interesting structures (Bruton, 1999), has been taken as organizing principle in modeling the scenes of Black Box tool. So, the differing set-ups of the worlds have followed intuitional self-organization rather than a hierarchical one, designed by the author through selection of differing graphical computing, in the same line with that what Stephen Wolfram states: "...nature must follow the laws of our particular universe. Yet programs can follow whatever laws we choose" (Wolfram, S. Graphica Defined. URL:www.graphica.com/defined)

3.4.2. Design of the Worlds of Black Box

There is an assumption that a divergent thinking is considered to be the most important capability of a creative intelligence (McCrac, 1987). Providing the setting for such divergent thinking, the virtual environment the computer provides us with, has been of great importance in the design of the tool. Unlike people, computers can perform masses of complicated arrangements of symbols and images to offer for the selective nature of the human vision. But we are outperforming computers in memory retrieval as we are able to retrieve salient information almost instantaneously from our long term memory (LTM) which accounts for our astonishing powers of recognition superior to those of any computer. As a matter of fact, Black Box aims at the encounter of the computer's ability to bring together a vastness in terms of collected data and the human capacity to select and retrieve and also recognize which may provide divergence and lead to an unexpected act evaluated creative regarding to its novelty and suddenness.

Springer (1998) has stated that thinking processes can be assigned to one of the brain hemispheres which are specialized in specific functions. Zdenek (1998) describes the thinking of the right hemisphere as introverted, complex and perceiving symbolically, metaphoric, imaginative, closer to affective states, competent for spatial perception and Gestalt perception. In one of his studies, Zdenek has shown that creative persons partly use techniques that ease access to right-hemispherical thinking making use of associations and perceptions. To go further, Wermke has claimed that creative persons prefer complexity over simplicity. He has also pointed out that creative persons have a different type of perception defined as *synesthesy* meaning the ability of experiencing something with several senses (visual, acoustic, haptic) simultaneously (Wermke, 1994).

As a consequence of the above statements, the contents of the worlds of Black Box are designed to be associative, indeterminate, imaginative, metaphoric, giving way to flexible and unusual thinking and also stimulating acoustic senses with an embedded music-player.

Apart from the descriptive factors in the design of the worlds, the main reason behind the selection of the singular concepts for each world component was based on the design brief.

3.4.2.1 Design Brief

Please design the initial concept for a tool that shows time (a clock), for either personal use or for uses at home/office. There are no limitations set for place of use; it can be wall mounted, desktop or a watch or something that you might offer.
Please, aim that the end idea will be novel and able to compete in the market.

As indicated above in the design brief, the concept of time and related concepts in addition to the other various concepts to support analogical reasoning have been used in the selection and formation of the content of Black Box.

3.4.3 Black Box Worlds: A Classification on Content

The content of the worlds have been constructed in order to promote the designer's use of analogical reasoning based on the listed occurrences.

Similarity effect: Semantic similarity between word lines, images, properties, and possibly relations in both domain related data and intra-domain related data is essential for analogical reminding and reasoning.

Structural effect: Structural correspondence (similarity between the inherent organizations of two systems) plays a very important role in analogical reminding and the operation of such a structural analogy requires the construction of high level correspondence between the two systems.

Schema effect: The ability to generalize certain aspects of a previous design experience into a scheme assists analogical reasoning.

Random context effects: Perception of accidental elements from a diverse set of contexts plays an important role in analogical reasoning and association.

3.4.3.1 World 1: Innovation World

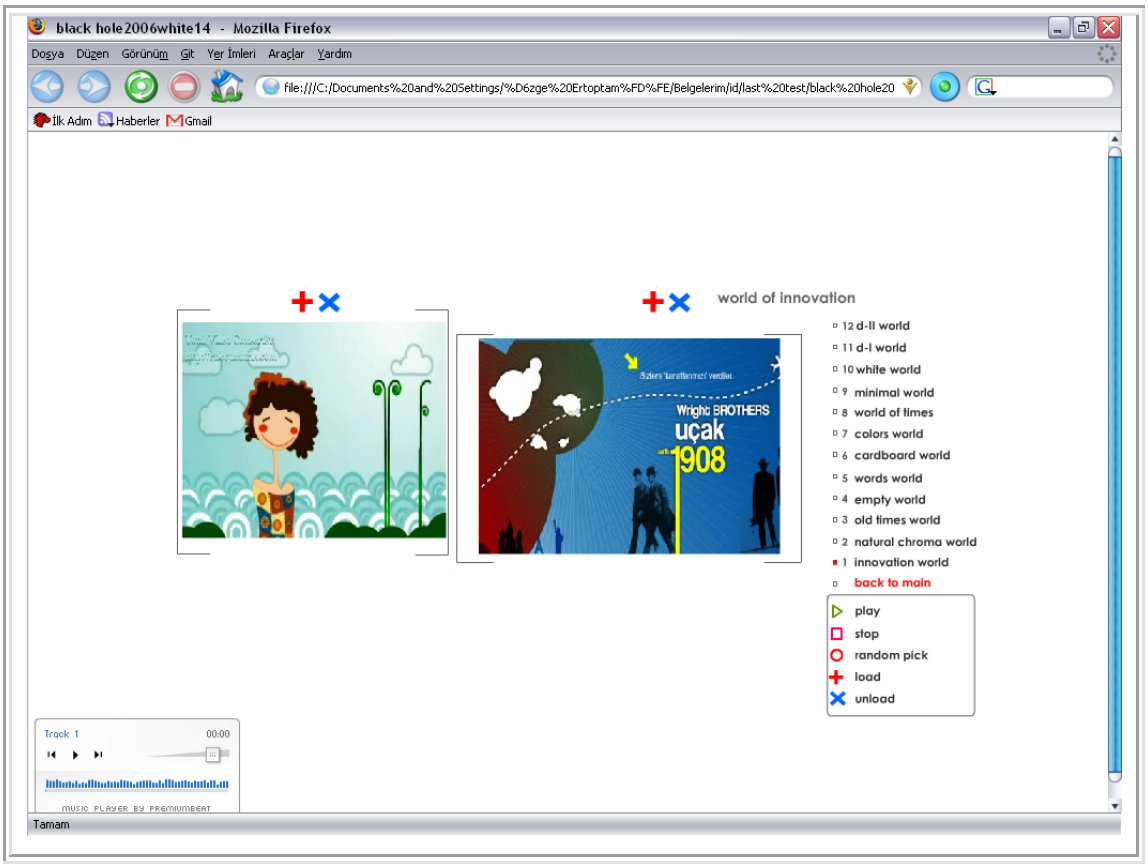


Figure 3.3 Screenshot from "World of Innovation"

Innovation World consists of two terminals into which the user selectively loads one of the two animations (Figure 3.3). The animations are meant to make the user recognize that he is moving down into an interesting and also innovative voyage.

The first movie stands as a showcase of the world's important innovations and their historical trip on a map to evoke the senses of novelty and its projection on the historical timeline of the world. Showing multiple and non-photorealistic depictions

at the same time and after one another, the second animated movie basically aims at teasing the designer's knowledge base through several levels at once.

3.4.3.2 World 2: Natural Chroma World

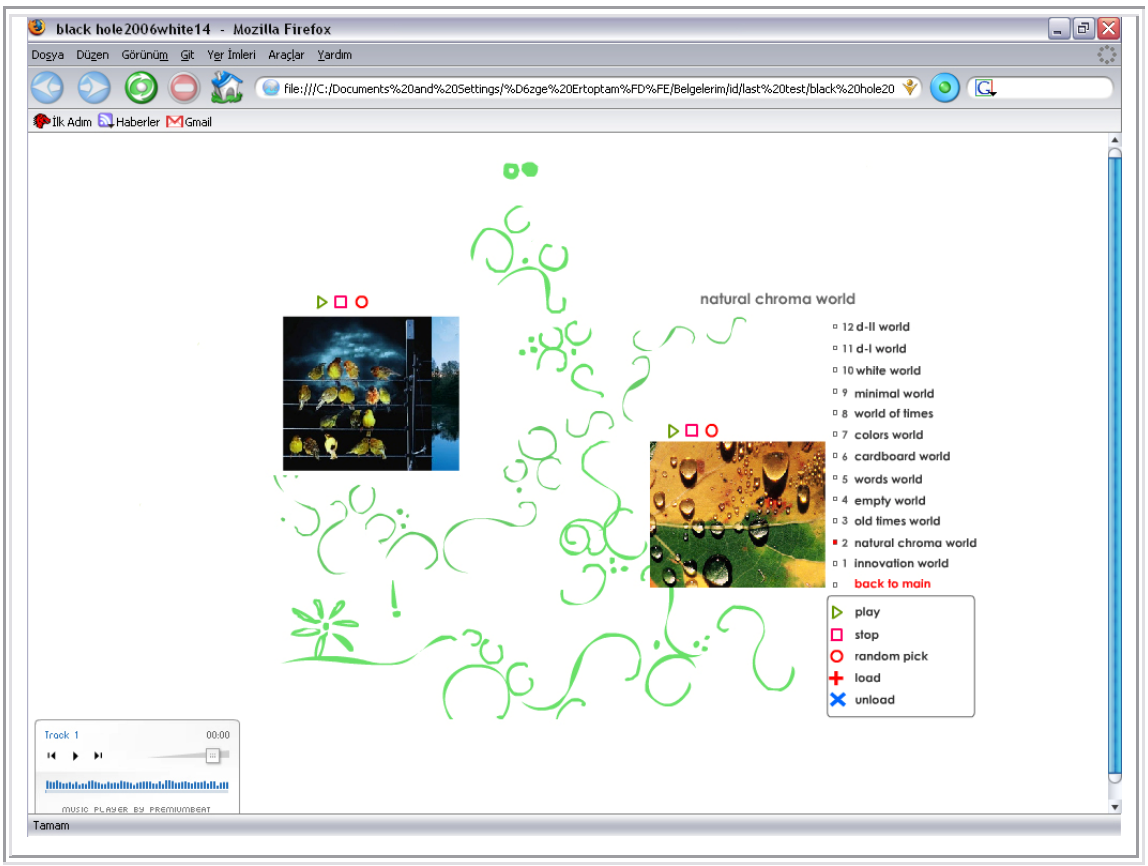


Figure 3.4 Screenshot from "Natural Chroma World"

As the name suggests, the second world is composed of images based on nature in two smooth slideshows (Figure 3.4). The images are expected to be influential in conceptual and in structural terms emphasizing nature as a source of code in designing. To sustain interesting output from random images that are related with nature, there has been a sequential approach in the arrangement of the images where a series of minimal depictions are followed by a series of fully loaded depictions.

Episodes of different poles of impressions and representations of nature are used to keep the designer's attention within the limits of the experience.

The images have been searched with the keywords of nature, tree and flower and within the collections of scenery and nature pictures found in picture and image sharing sites *www.fotokritik.com* and *www.deviantart.com*.

3.4.3.3 World 3: Old Times World

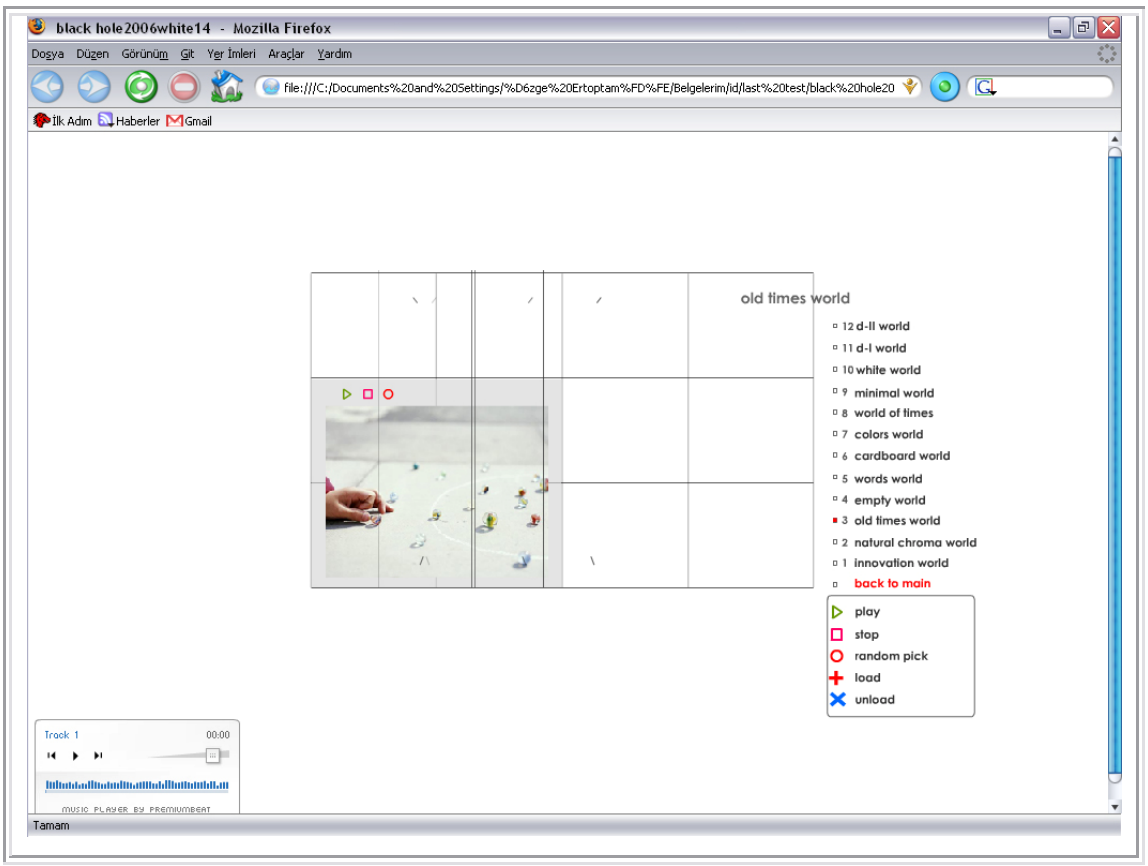


Figure 3.5 Screenshot from "Old Times World"

Old Times World addresses the concept of time not directly but through a composition of concepts that are related with time (Figure 3.5). The concepts that have been used to search within image collections are as such: memory,

remembering, childhood, the 60's, the 60's style, old times, old advertisements and the still imagery sections of the image sharing sites.

Two issues have been important in the selection of images. Firstly, the potential for arousing past-time experiences such as childhood memories related with timing/time or anything that is not remembered for a while; Secondly, the potential for using images of semantic ambiguity and indeterminacy so as to refer to the past but also stay a part of the day.

3.4.3.4 World 4: Empty World

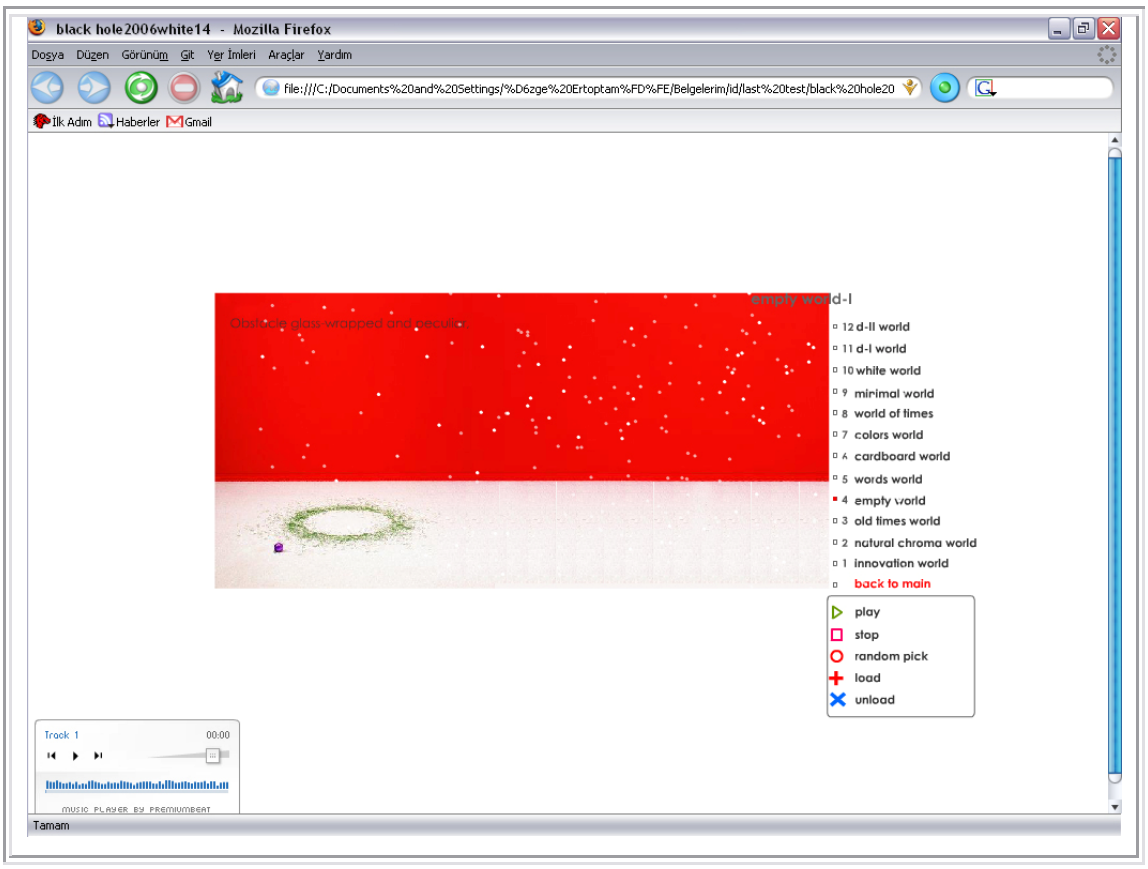


Figure 3.6 Screenshot from "Empty World"

Only Empty World has been defined as a by-pass world with a limited amount of image content but the integration of a poem by Sylvia Plath has provided a

conceptual basis for the scene (Figure 3.6). The poem selected is on the upcoming New Year and how newness is presented with the concept of New Year and how it is re-represented to a child in his mother's words.

The audio-visual manipulation of the scene is planned to awaken a sad feeling and the idea of time has been expressed through the implication of seasonal changes and the concept of the New Year. How a segment of time in a person's life ends and another segment begins with each New Year has been thought of as causing the user recall from past experiences.

3.4.3.5 World 5: Words World

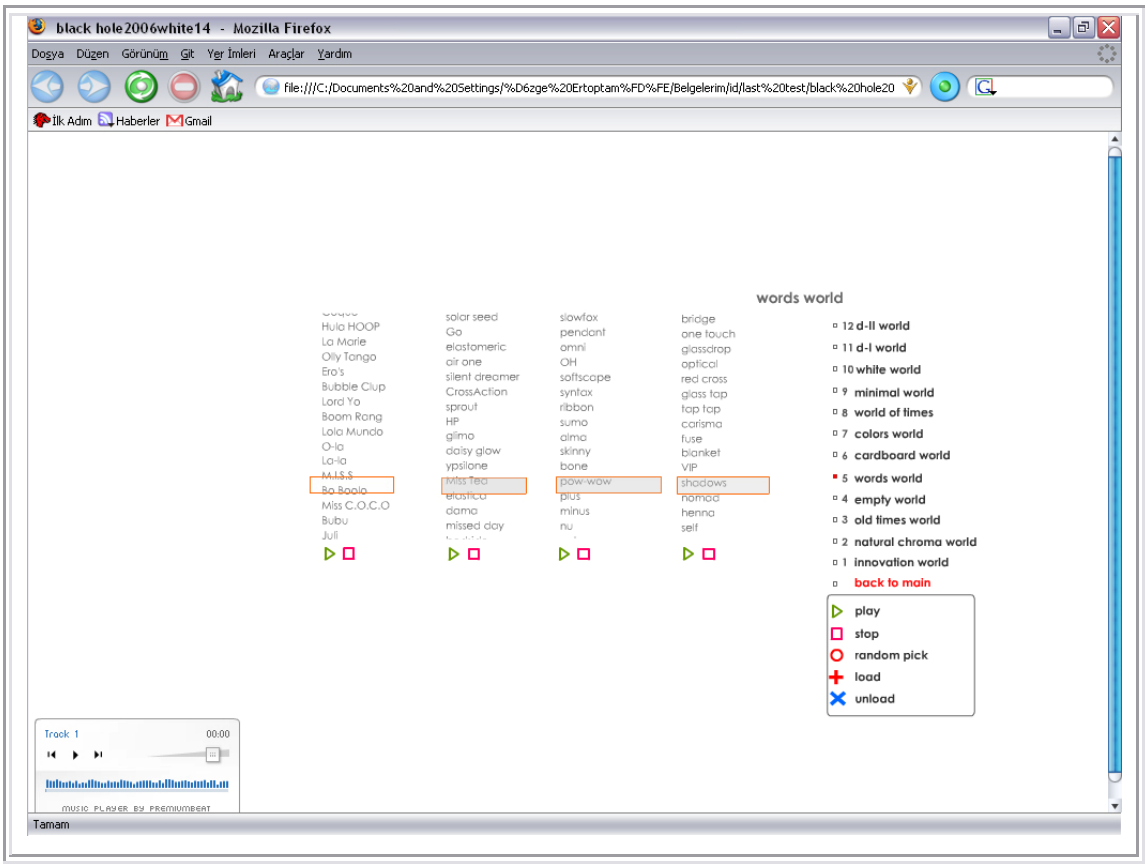


Figure 3.7 Screenshot from "Words World"

Words World has been entirely built up of words which have been placed into slots where the user, by stopping and playing the rewinding words, may try to formulate a

sequence that might mean something for them or just a random combination that might be the source of an unusual grouping which will lead to a creative idea (Figure3.7).

However, it is an inevitable fact that most of the designers are visual thinkers, that's why Words World is the only world where words are employed as the dominant single figure of the content without being assisted by visual media.

3.4.3.6 World 6: Cardboard World

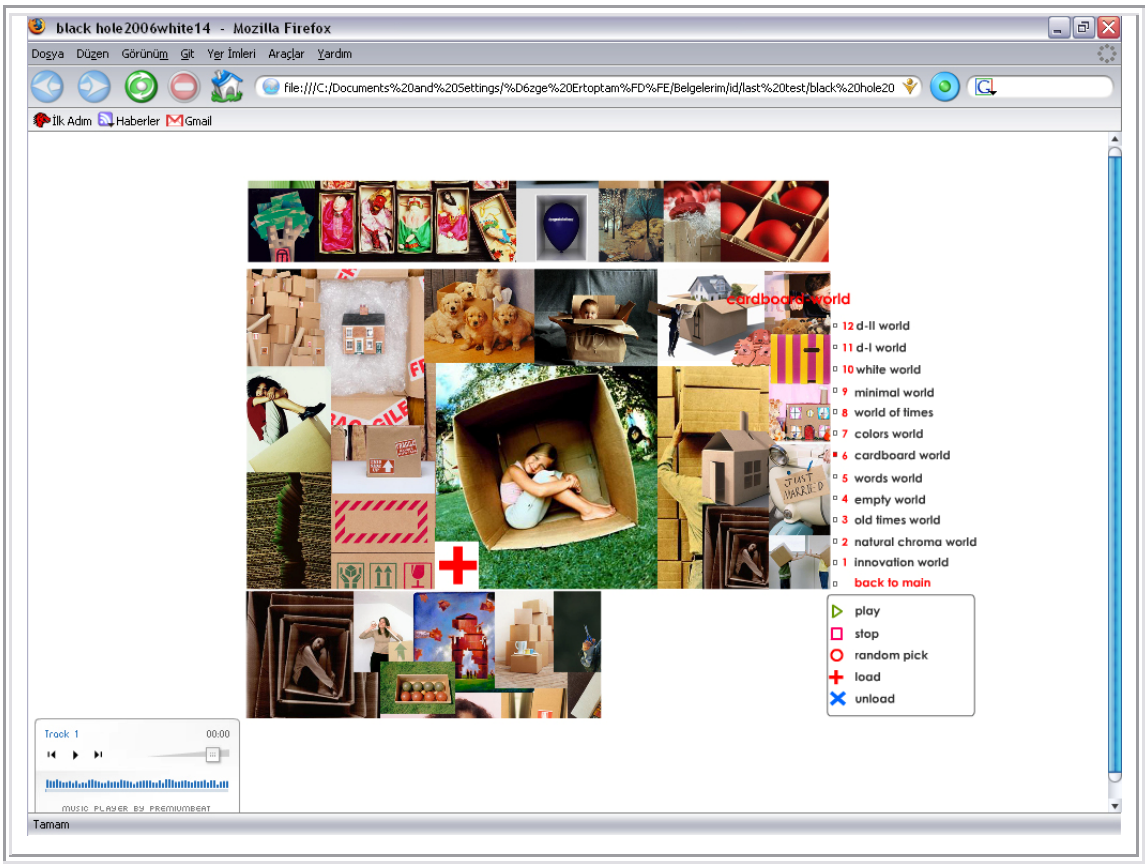


Figure 3.8 Screenshot from "Cardboard World"

Cardboard World aims to provide an experience based on irrelevancy (Figure 3.8). Representations included in this world are based on the keyword search of cardboard but formally they include many other concepts in addition to the common cardboard

theme they entail. Furthermore, cardboard as a word on its own may not imply anything related to time at first but the idea of capturing things within another thing has been favored as time keeps our lives in it and that's why cardboard has been selected as it has the ability to provide space to keep things in itself. Analogy between the concepts of time and cardboard has been used as high order arrangement in the scene.

In this world, the images are static but the masking plays important role in revealing different parts throughout the visit in the world. Additionally, an animation of a cardboard world is loaded within the scene.

3.4.3.7 World 7: Colors World

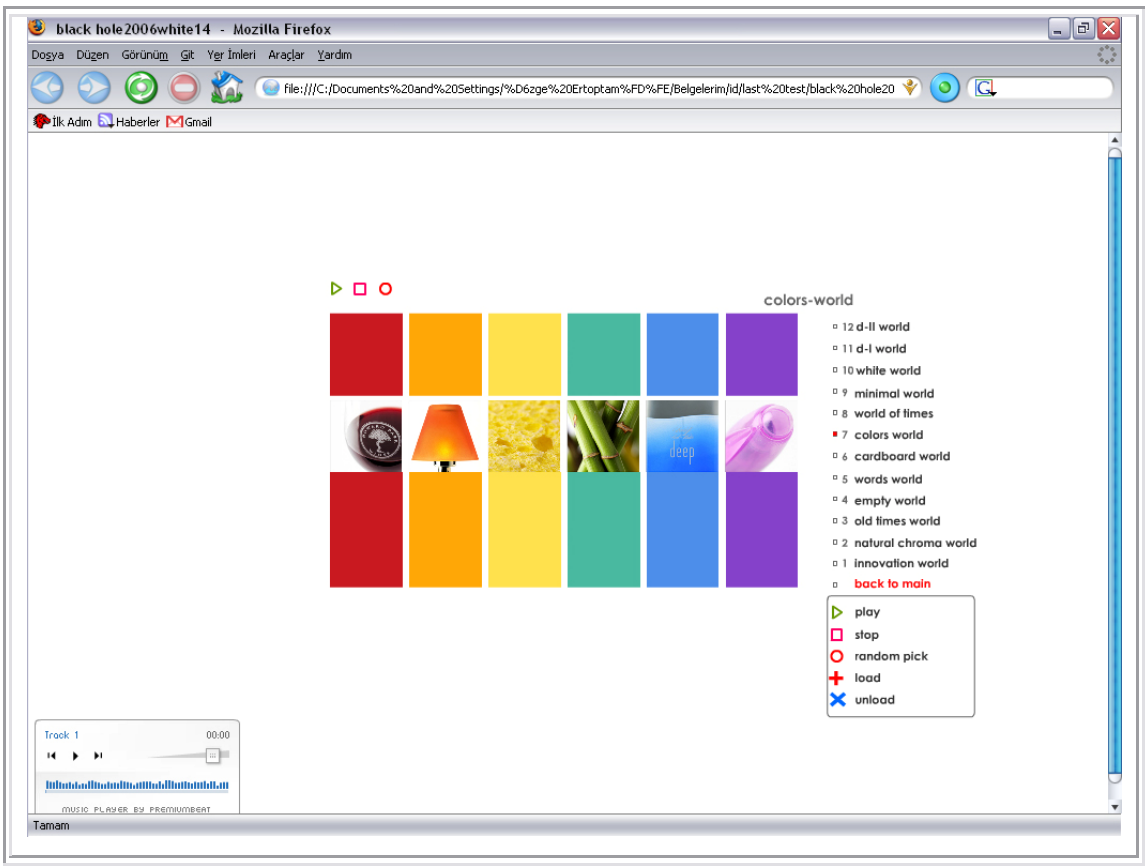


Figure 3.9 Screenshot from "Colors World"

The effect of color on design is indisputable. The visual vocabulary of Colors World has been developed through the detection and extraction of the everyday objects that

have different colors and categorization has been made with respect to the objects that share the same color (Figure 3.9). Each image is itself a collection of data, containing both patterns of color and a metaphorical connection to its everyday use aiming to stimulate connections between color and end-shape and intend of use.

The derivation of color from a scheme or a scheme from a color have been tried to be emphasized in the selection of the images.

3.4.3.8 World 8: World of Times

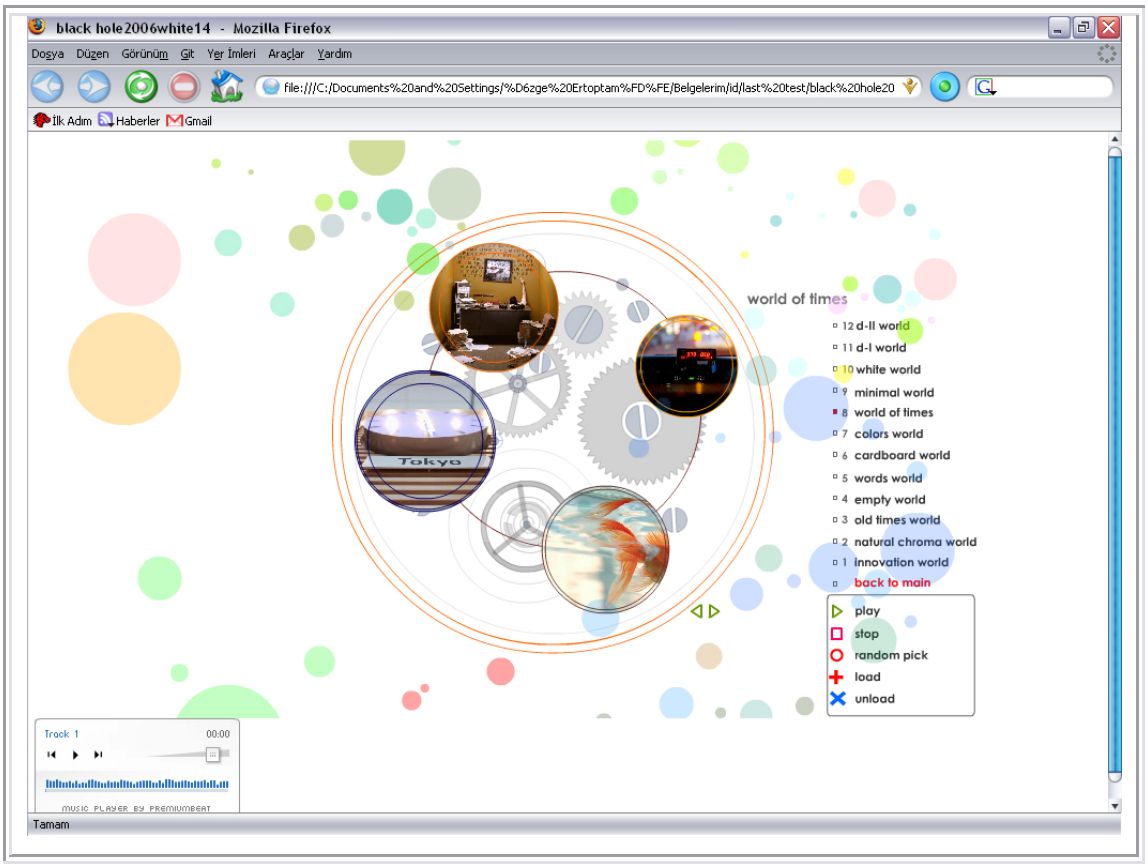


Figure 3.10 Screenshot from "World of Times"

Combining entities that are related with time and clocks, World of Times makes use of screens of varying circled geometry to show each time a different part of the same image when the play button is clicked (Figure 3.10).

World of Times is the world where there is a direct reference to clocks with the integration of different types of clocks in the image-range from hourglass to a public square clock. The emphasis has been shifted from differentiations of the form to the differentiations of the space of use of a clock.

3.4.3.9 World 9: Minimal World

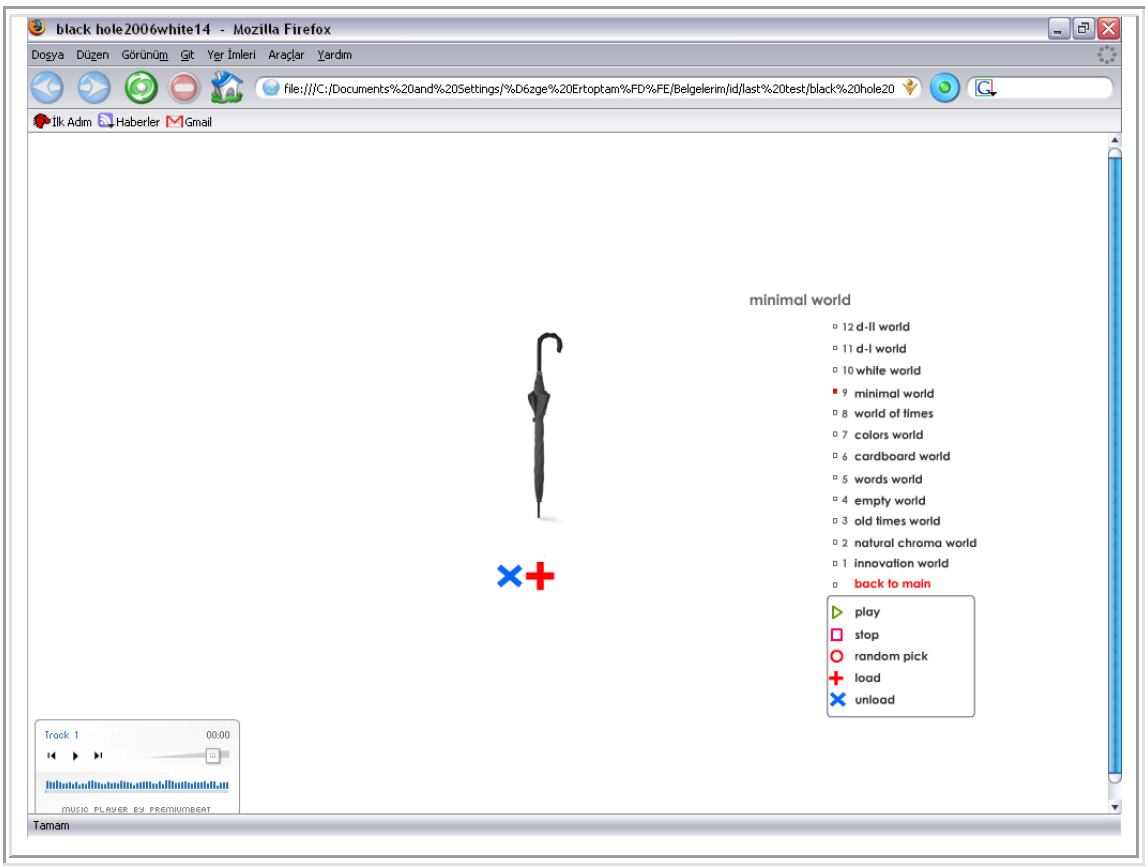


Figure 3.11 Screenshot from "Minimal World"

Minimal World consists of a single frame animation which entails minimal style industrially designed products by the design firm "±0" (Figure 3.11). The whole idea behind the scene was to show remarkably the effect of minimalism within an almost

monochromatic space that holds an animation content that is also composed of limited amount of design data.

Among the other worlds of Black Box, Minimal World is the one which also aims to rest the viewer's eyes in addition to widening his/her horizon reminding of the famous quotation "less is more".

3.4.3.10 World 10: White World

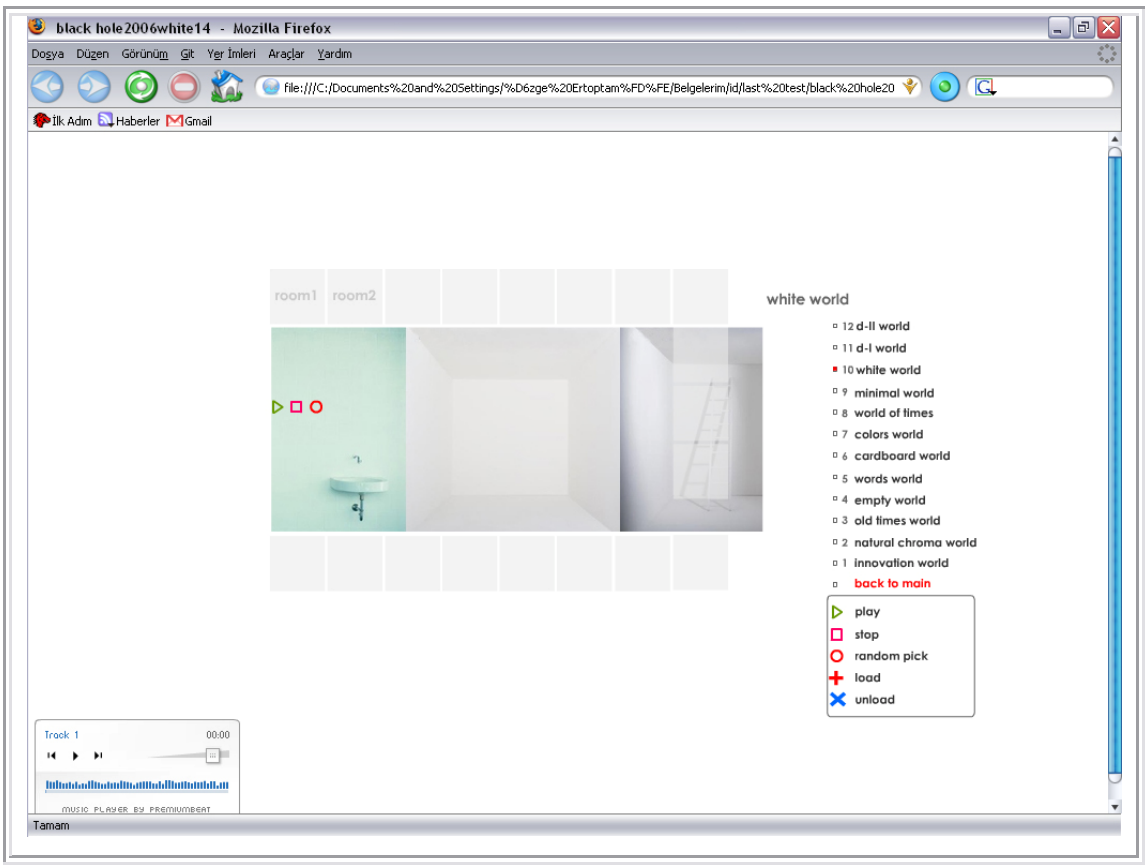


Figure 3.12 Screenshot from "White World Room1"

White World is actually composed of two different rooms with different categories of content. The first room is composed of images that have spatial meaning, describing mainly cubical spaces and minimal interiors to let the designer think of

time in spatial manner or of how the idea of space can be utilized by defining and measuring time itself (Figure3.12).

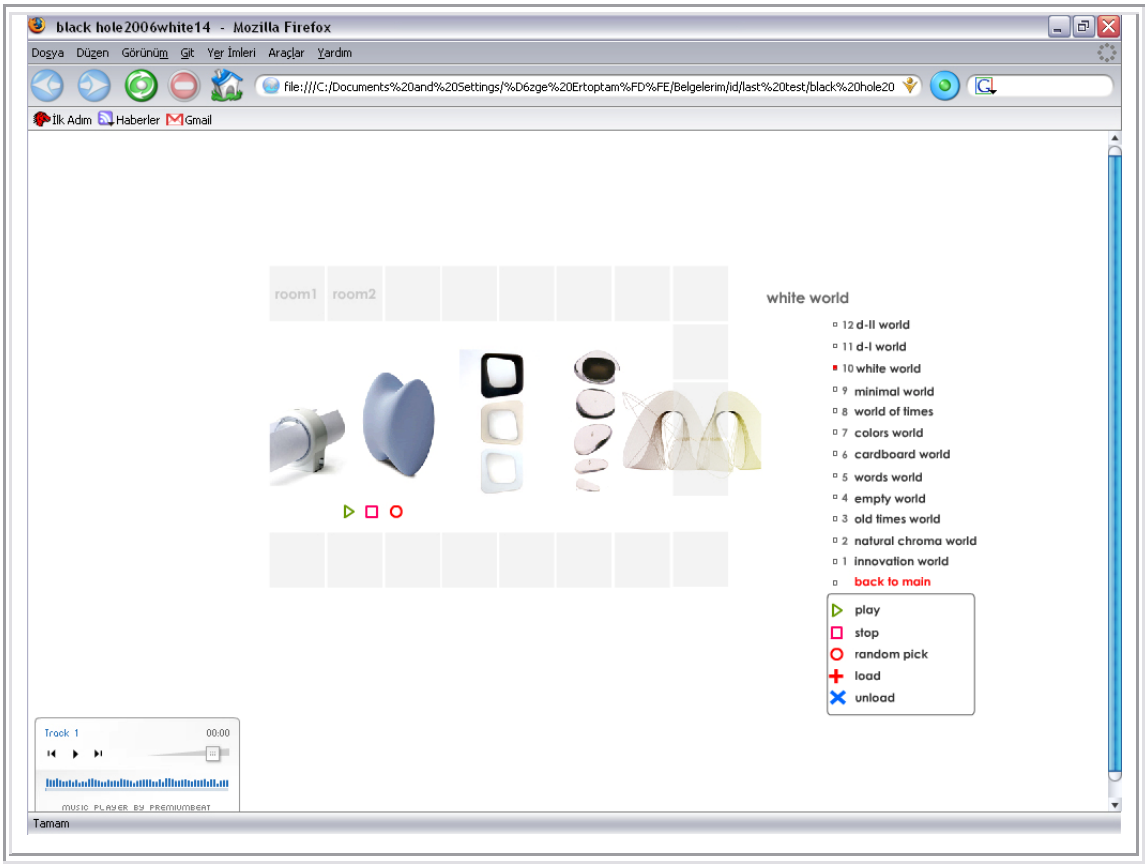


Figure 3.13 Screenshot from "White World Room2"

As seen in Figure 3.13, the second room of White World is made up of a collection of images that are varying under the scope of design. The second room also includes architectural images and high order computational models of design data.

Form appears as an important ingredient of the second room of White World with respect to "space" theme of the first room. As a result, the content selection has been made with respect to different formal characteristics of non-categorized product and object series.

3.4.3.11 World 11: d-I World

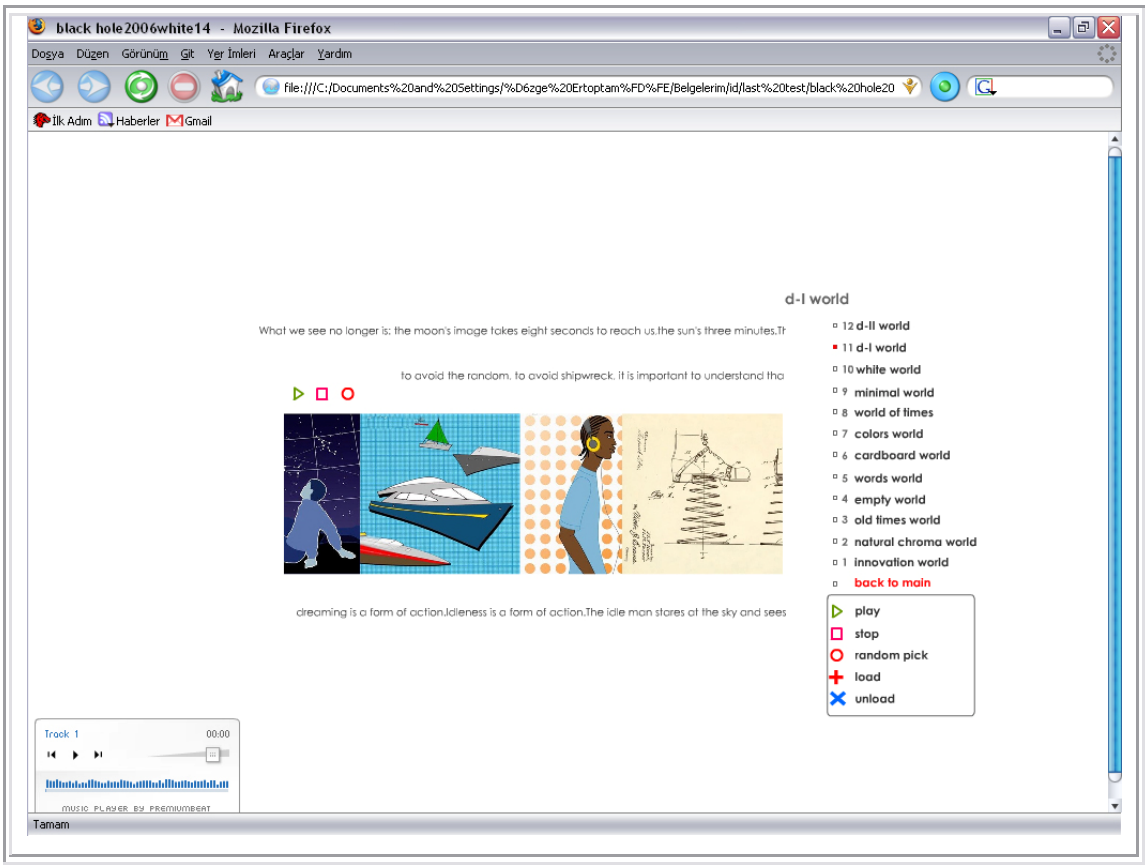


Figure 3.14 Screenshot from "d-I World"

The eleventh world of Black Box entails illustrations as pictorial content and moving verbal expressions on the concepts of time-space as textual content. The concept of time-space has been emphasized with respect to the way the beholder conceives these two different but inherently bounded phenomena in the actual and reconsideration and representation of their relationships virtually (Figure 3.14).

Verbal content of d-I World is based on how we conceive the world physically and how it actually is when referred to scientific explanations of the *seeing and perceiving* actions. The selection has been made in the stated direction in order to let

the designer realize how we change the world through the changes in our perceptual approach towards our surroundings.

3.4.3.12 World 12: d-II World

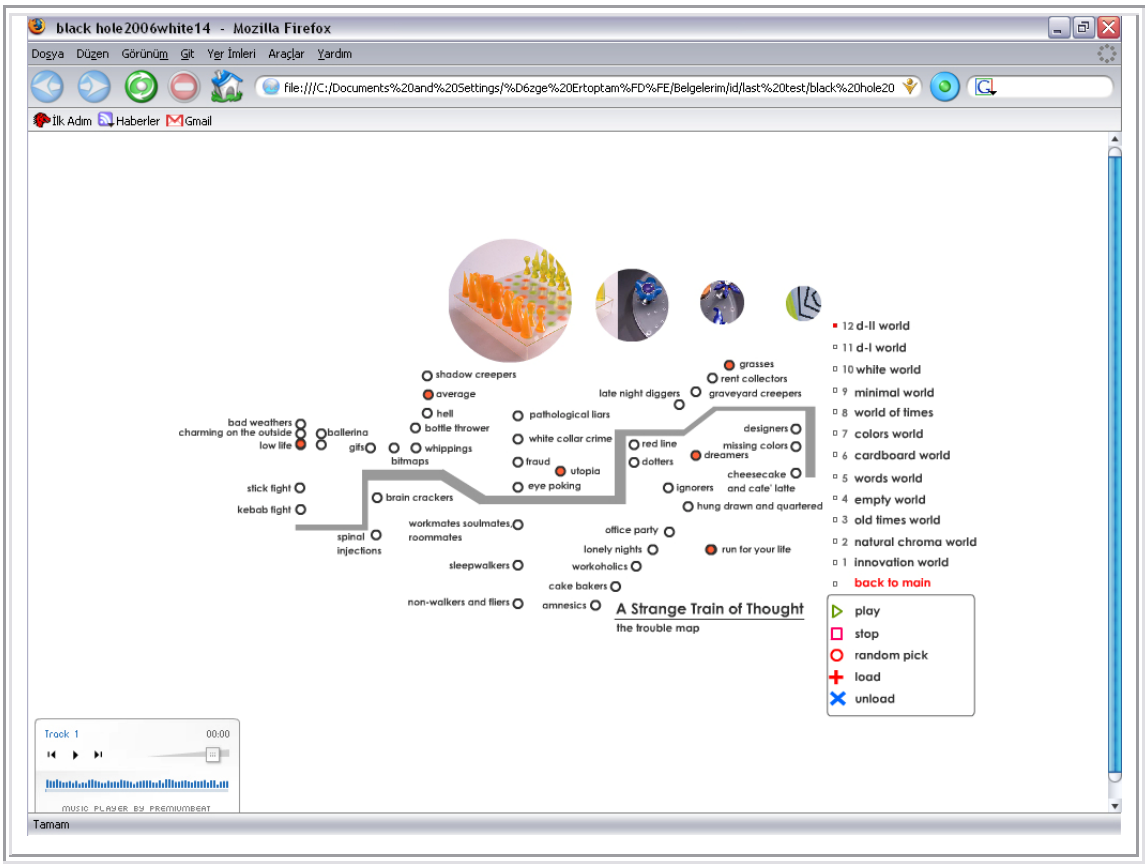


Figure 3.15 Screenshot from "d-II World"

The last world of Black Box is constructed on a peculiar train of thought. As the name 'a strange train of thought' suggests, the structure of the world is similar to the pictorial representations of a route for a train, subway, etc. with nodes and links (Figure 3.15).

The verbal content of d-II World, the nodes and their attributes have been defined mostly in a randomized but sequential manner. The train of thought is in its perception recognizable but not directly redeemable for constructing a logical road.

3.5 Pilot Study

The pilot study was performed within the course ID531 Methods and Models of Ergonomics at the Department of Industrial Design in METU in a format similar to that the main-study and presented as a virtual way-finding experience for the design students. It has been considered that design students were more likely to be free from professional thinking habits than experienced designers and that's why they might be more flexible in generating innovative ideas during concept generation. This was the basic reason behind the selection of students as subjects of the study.

One major aim of the pilot study was to re-introduce a known set of visual reasoning agents, *visual analogies*, so as to perceive the multifaceted and unpredictable potential in what we see and perceive in the normal within an experiential virtual space of visual and verbal abstractions to assist design thinking in concept generation phase within a sample of design. The design students were asked to solve a design problem using analogies and at the same time they were exposed to the use of the Black Box tool.

At this stage, Black Bow was not at its final stage. Black Box was composed of 13 Worlds, two of which were Words Worlds and one Sketch World allowing the user sketch on the computer. Classification of the worlds were more object and thematic text oriented.

The graphical layout of the scenes and pictorial and textual content were not finalized and multi-frame animations were not embedded. Moreover, the musical content was limited with the loop of the same song from the beginning to the end of Black Box experience with optional turning on or off.

The research was conducted by analyzing the relationship between creativity and the thinking process during concept generation phase and the resulting analogy-based concepts.

3.5.1 Sample Group of the Pilot Study

The sample was a total of six graduate and undergraduate students from the Department of Industrial Design in the Faculty of Architecture at METU. The major reason behind that selection was that the study was concerned about the investigation of the concept generation phase in the design process. The selection was made with an omission of the first year and second year industrial design students as participants because of the fact that they are at the beginning of their design education. As concept generation is not emphasized by the instructors of the first and second year studios as their utmost concern, the participants were assigned starting from the third year and up.

Aside from the academic situation of the students, a certain amount of computer literacy has been sought in the selection as the study is based on a virtual navigation experience on PC platform.

3.5.2 Design Brief of the Pilot Study

Please design the initial concept of a new clock presented to the market. The clock may be either wall-mounted, desktop or a watch, no limitations are set. The sketches are expected to convey the image of the idea in your mind.

3.5.3 Methodology of the Pilot Study

The methodology of the pilot study made use of a case study approach through a session of five parts that have been performed by the participants.

The general procedure of the protocol study involved:

1. Navigating without utterance (Generative Phase)

2. Designing without utterance (Exploratory Phase)
3. Reporting the designing section verbally
4. Encoding the design process using videotapes, sketches and protocols (executed by the author)

Expected participant actions were listed according to a categorization based on the action's that may occur on the sketching, navigational or cognitive level.

The navigation process for each participant was represented by using the tables that have been created according the categorized media. The protocol was encoded using a coding scheme (Table 3.1).

Table 3.1 List of Encoding Scheme of the Pilot Study

Action Category	**Abbreviation of the action**	**Action Definition**
Sketching (words, diagrams …)	D	Making depictions
	W (after nav.)	Writing, sketching
	Np (during nav.)	Pictorial Note taking
	Nv	Verbal Note taking
Navigational	S	Stopping at a point
	Bp	Going back to a Picture
	Bw	Going back to a Word
	L	Looking at lines of words
Cognitive (Behavioral)	M	Structural mapping
	I	Identification
	R	Retrieval from past experiences

The Black Box experience and the concept generation phase have been videotaped for each participant with the use of a video camera placed to have a view of the participant and the PC screen. The students were left on their own during both the Black Box experience and the concept generation phase and videotaped to allow the author to encode their actions retrospectively.

Before the session began, each participant was informed on the intention of the study and the reasons of realization and the expected results to be achieved.

3.5.3.1 Part One: Introduction Questionnaire (Attributed time: 5 minutes)

Each participant was asked to fill in a questionnaire, questions of which were based on the basic formation of the participant's academic status and the exploration of the participant's approach to design and his/her eagerness to use analogies in his/her designs (Appendix I).

The evaluation of the introduction questionnaire has pointed out what kind of an approach the participant takes in his/her designs and experiences. A simple and rough description of the participant profile is provided to help the evaluation of the next sessions and the resulting concept design.

3.5.3.2 Part Two: Generative Phase: Black Box Experience (Attributed time: 10-12 minutes)

Given the design brief, the participant was left on his/her own for the Black Box experience where s/he was videotaped during the whole navigation process.

3.5.3.3 Part Three: Exploratory Phase: Concept Generation and Sketching (Attributed time: 10-15 minutes)

The participant was informed at the end of the time dedicated to the Black Box experience and asked to move to the next part of the study where s/he was expected

to design a concept for a clock. During the sketching and concept generation phase, the participant was videotaped.

3.5.3.4 Part Four: Post-Questionnaire (Attributed time: 5-10 minutes)

The post-questionnaire of the pilot study aimed to collect data on the built analogy that had led to a concept for the participant (Appendix J). In order to retrieve information on the influencing data that shaped the concept and to relate it to participant actions during navigation which were to be retrospectively explored through the video recording, questions addressed the particular images, words and worlds that the participant found inspirational and initiator for the concept s/he generated.

3.5.3.5 Part Five: Retrospective Report on the Concept Generation (Attributed time: 5 minutes)

After the participant filled in the post-questionnaire, s/he was subjected to a retrospective interview where s/he was asked to describe and explain the concept s/he has arrived at as a result of the concept generation phase. The analogical mapping was tried to be explored through the route the participant described.

3.5.4 Analysis of the Pilot Study

Watching the videotaped sessions, for each participant, the actions table was filled to encode the navigational and sketching actions that occurred during Black Box navigation and concept generation (sketching).

Cognitive actions of the participant were encoded based on the participant's retrospective account of his/her concept.

3.5.4.1 Construction of Participant Profile

A brief designer profile was constructed with respect to whether s/he has made use of visual analogies or given names to his/her designs and based on his/her personal attitude towards the concept generation phase and the effects of visual media on his/her performance in this phase.

3.5.4.2 Construction of a Black Box Map and Analysis of the Sketching Activity

The navigation and the concept design processes were thus represented in terms of encoded actions of the participant in tables corresponding to the participant's Black Box Map and Concept Generation/Sketching Map. The produced tables involved the list of actions in order to retrieve cues from the participant's design process related to the resulting analogy that s/he produced.

3.5.4.3 Construction of Participant's Design Conversation Log

According to the list of data that was acquired through the protocol analysis and through the post questionnaire a conversation log was constructed to build a set of relations of participant actions.

Based on Schön's (1983) *see and move model* in design where the designer involves into a conversation with the design space, a conversation log has been constructed using the retrieved and observed participant actions and reports. Based on the collection of the references referring to the end concept, participant's actions have been split into two levels: references from the knowledge base (indicated on the upper right corner in Figure 3.16) and the references from the Black Box experience (indicated on bottom right in Figure 3.16). The transformation, combination of the recalled and retrieved references have been conveyed as the "output on the new media" within the conversation log of the participant and showed how idea sequences have appeared after one another.

The conversation log aimed to provide further insight into participant actions which resulted with the emergence of the analogies based on physical or structural relationships through the input of the knowledge and Black Box databases.

After the conversation log was constructed, designer's list of perceived data was assembled which involved the references of the associations and derivations that have been built during the concept generation in order to be used as cue in the analysis of the analogy.

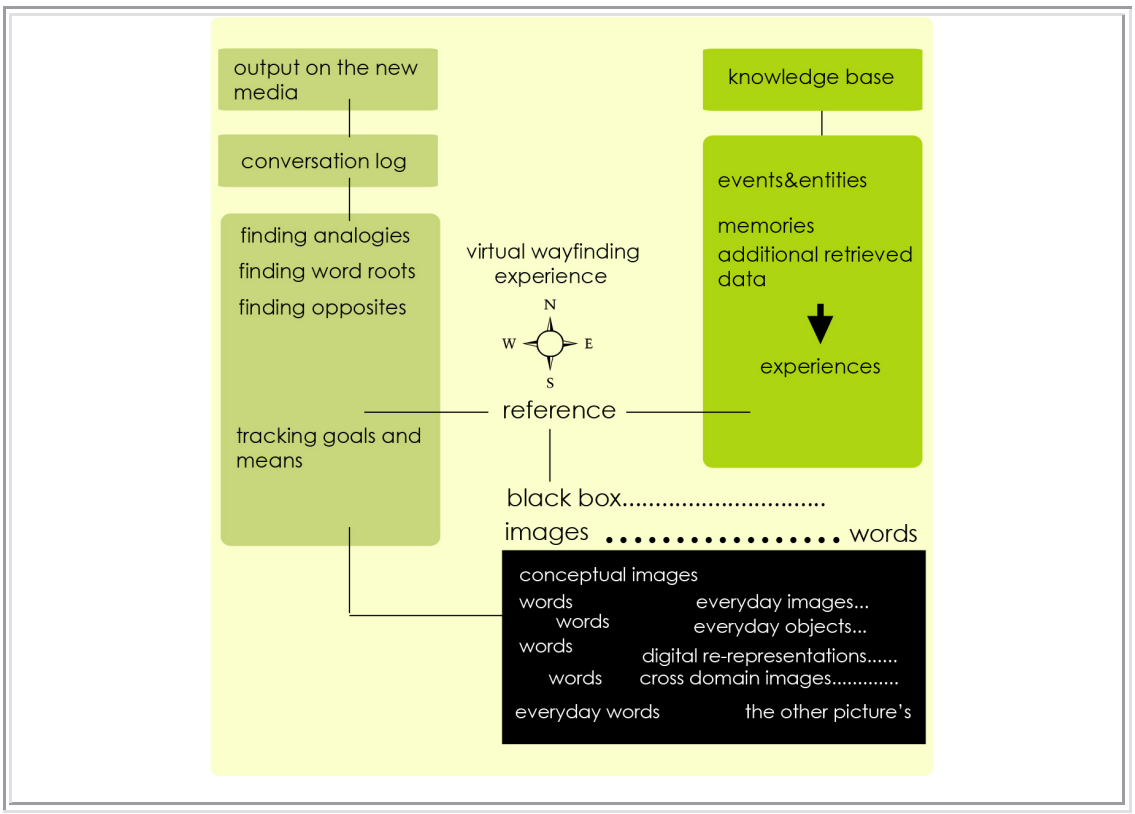


Figure 3.16 Design Conversation Log

3.5.4.4 Analysis of the Analogy

The analogy that the designer has come up with at the end of the generative and exploratory phases has been analyzed according to its functional type, cognitive type, according to the mental image or/and pre-inventive structure that supports the analogy, the verbal concepts that have been used.

- *Functional type* of the analogy has been defined according to its having been structured on whether structural relationships with one to one correspondence or surface relationships based on visual cues.
- *Cognitive type* of the analogy has been defined according to its having been based on verbal or visual associations or both.
- *Mental Image/Main pre-inventive structure* has been defined according to the dwell-in observation and the retrospective report of the designer on the concept to point out the main pre-inventive structure that has been developed into a concept in the exploratory phase.

Through the definition of the above described criteria, a configurative scheme of the analogy has been constructed. After the configurative scheme was produced, the mapping structure of the analogy has been analyzed.

3.5.5 Sample Evaluation of Participant 4 of the Pilot Study

The evaluation of one of the participants of the pilot study (Participant 4) is described thoroughly in this section in accordance with the analysis structure set beforehand.

3.5.5.1 Participant 4 Profile

Participant 4 stated that the concept generation phase was essential in a design process to provide a rich stimuli all through the route taken to complete a design task and as did most participants, he expressed that the externally provided media is supportive in assisting the designer's imagery and creative ability.

Participant 4 alleged that he does not like to name his designs and has not used analogy in his previous design experience.

3.5.5.2 Participant 4 Black Box Map

The actions that Participant 4 carried out during navigation in Black Box are given in Table 3.2. Participant 4 has finished the navigation process in 10:26 minutes and the maximum time he has spent in a world is 2:04 minutes (Table3.3).

Table 3.2 Participant 4 List of Actions during Navigation

Action time	Action category	Action type	Action definition	Action coordinates
1-5min.s	Navigational	S	Stops ,looks	World of wonders (image7)
	Sketching	Nw	Writes down a set of words	World of wonders (image7)
	Sketching	W	Writes word sequences	World of wonders (image 7)
	Navigational	S a	Stops and looks	d-world (image 18)
	Navigational	L	Reads the below lines	Free world
5-10min.s	Navigational	S	Stops the flow of words	M world (h-beam)
	Navigational	S	Stops the flow of words	M world (music tube)
	Navigational	L	Reads the below lines	words world
	Navigational	S	Stops the flow of words	words world II (a drop in the water)
	Navigational	S	Stops the flow of words	words world II (tap tap)

	Navigational	B	Goes back to a previously visited world	free world
	Sketching	W	Writes down notes	free world

Table 3.2 (continued)

Table 3.3 Participant 4 Black Box Time Intervals

Total time	Visited worlds (over 13)	Max time spent in a world	Words vs. images
10: 26	13	2:04	words

Participant 4 was among the other participants the one who spent the most time in the words worlds (Table 3.4). Especially in Words World II, he randomly stopped the flowing words many times and during the navigation process he wrote down word sequences, one word after the other until it began to mean something to him.

3.5.5.3 Participant 4 Concept Generation/Sketching Map

The actions that Participant 4 carried out during sketching activity are given in Table3.5.

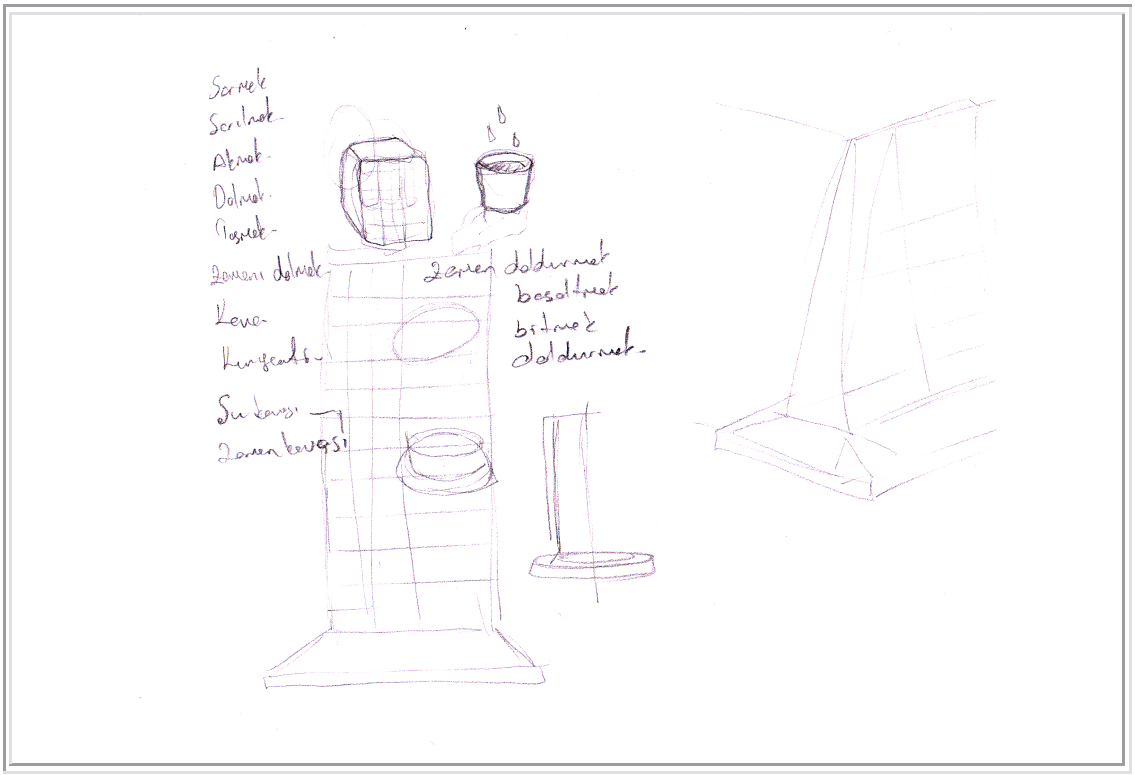
Table 3.4 Participant 4 List of Actions during Sketching

Action time	Action category	Action type	Action definition	Action coordinates
Concept	Navigational	B	Goes back to a	Free World

Generation Phase 17:20 minutes			previous visited world for the second time	
	Navigational	S	Stops the flow of words	Words World II
	Sketching	W	Writes words	Words World II
	Sketching	D	Makes depictions (cubes)	Words World II

3.5.5.4 Participant 4 Resulting Concept

The final concept resulting from the concept generation/sketching phase of Participant 4 is given in Figure 3.17. After the sketching phase, the participant was subjected to a retrospective interview to describe the designing section of the process.



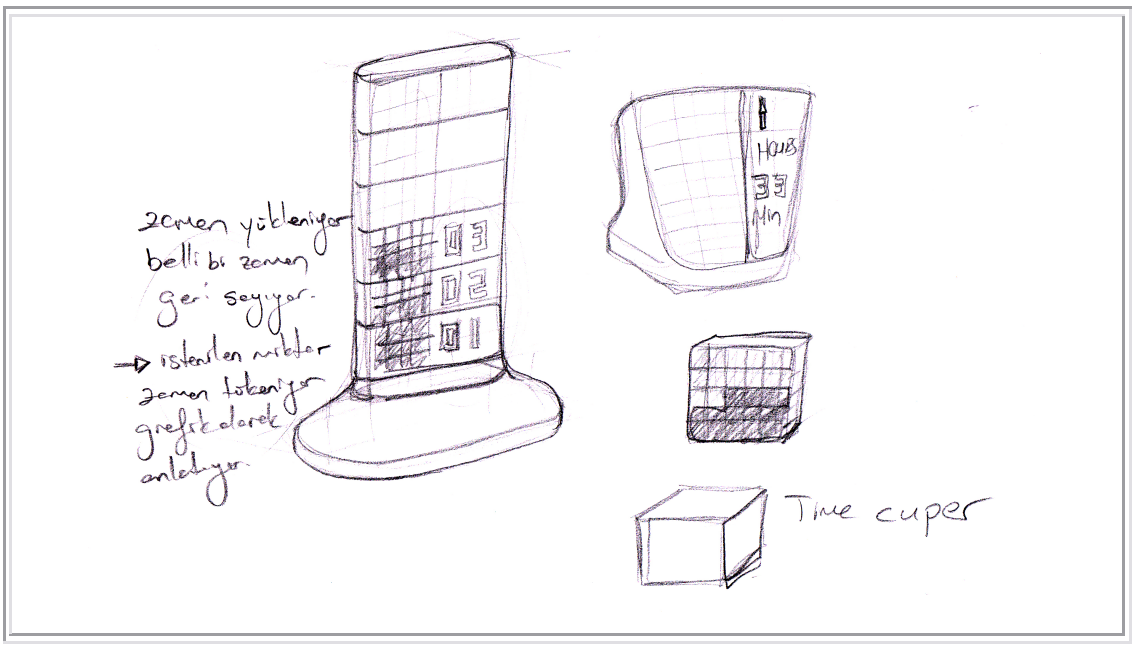


Figure 3.17 Participant 4 Sketch

3.5.5.5 Participant 4 Retrospective Report on the Concept Generation in the Exploratory Phase

The image of the aquariums placed on top of each other in Words World I was the key driver in Participant 4's concept generation for his clock. *Time cuper* was his basic idea; a clock that keeps time. It would be a clock where it seems as if the time is flowing from some place into the *time cuper*, in that the observer will see the proliferation of time in the display.

The aquarium and the act of filling it with water was the analogy that was built in order to design the *time cuper*. The participant asserted that he started with writing down the related words basin, dripping, filling, flowing, storing, holding etc. and after then he started to think of a clock which stores time and the act and process of storing it would be a driver in the clock's image. The word *cuper* came from the words *keeper* and *cube*. Keeping is the clock's basic mechanism and cubes are the idea that came across the participant's mind that in the display of the clock (which is apparently a clock to be used in public spaces, etc., quoting the designer's expression) could be cubes that are filled up with colors or alike. The visual properties of his clock stayed rather vague because of the fact that he preferred to

design just the concept of it and the exact form was in his sketches a series of cubes and rectangular prisms.

3.5.5.6 Participant 4 Design Conversation Log

The list of data extracted from the encoding of the navigation and sketching phases and the participant's report on the concept he has generated, has been put together in the conversation log of the participant. As it can be followed through the conversation log, Participant 4 had no direct or indirect recall from his knowledge base (hatch on upper right corner in Figure 3.18). Participant 4 based his concept rather on the words he read and on verbal associations derived from the images he saw during the Black Box navigation. The *time cuper* concept and related associations based on word roots he has collected has been shown in the conversation log as the input related to the experience in the Black Box (hatch on the upper left of in Figure 3.18).

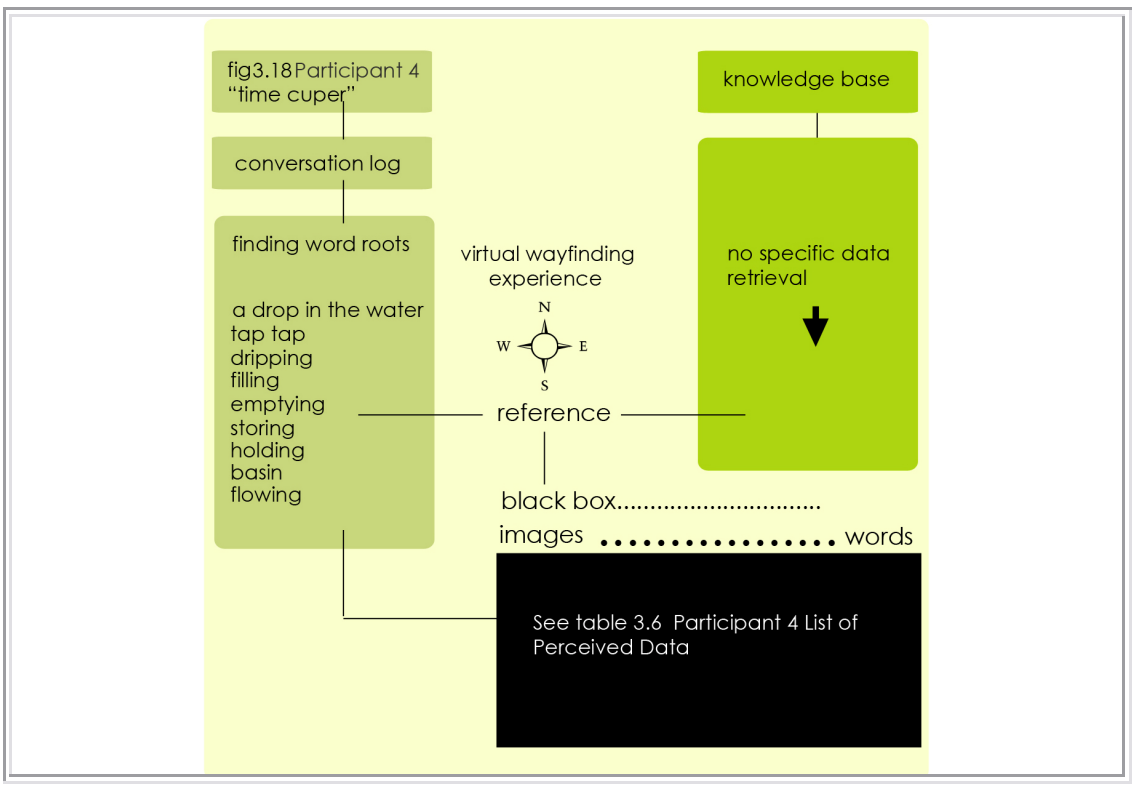


Figure 3.18 Participant 4 Design Conversation Log

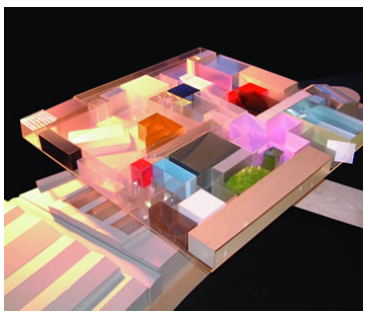
3.5.5.7 Participant 4 Post Questionnaire

Participant 4 has found Black Box interesting and creatively supporting the design process. Apart from a dichotomy that has been observed where he disagreed that the images and words in Black Box were helpful for him (although he had made use of them in creating his analogy) the post questionnaire seemed to provide correlated data for his Black Box experience-based concept.

3.5.5.8Participant 4 List of Perceived Data

Participant 4's expression of the images and words that inspired his initial design idea has been translated into representational data in Table 3.6.

Table 3.5 Participant 4 List of Perceived Data

Type of Perceived Data	**Perceived Data**		
Images			
Image coordinate	Free World	World of Wonders Image 7	d-World Image 18
Words	flow a drop in the water sponge, glass tap	tap tap blank aqua	
Word coordinate	World M	Words World I	

Participant 4 stated that, Words World II was his favorite world and he added that the proposed game in Words World II like the "slot machine" could work for any design activity by a random pick of words that will stop at each line of flowing word-lists. Participant 4 expressed that he could use analogies in his design and stated that the above cited words were the activators of the initial sketch lines for his design concept

3.5.5.8 Participant 4 Analysis of the Analogy

Table 3.6 Participant 4 Analysis of the Analogy of the Concept

Functional type	Structural
Cognitive type	Based on verbal associations
Mental image/main pre-inventive structure	Basin, hourglass
Verbal concepts	Time keeper, Time Cuper
Configurative scheme	The concept of "time keeping" as in the dripping action of water into a collector.

3.5.5.9 Participant 4 Analysis of the Mapping Structure

It has been observed that Participant 4 was successful in forming an analogy in his clock concept design. The activity of time keeping was at its base, strongly connected to the hourglass. This was the mental image in the participant's mind, and the key drivers of his scheme came after then when he encountered the image of the aquariums. The idea of filling an aquarium or just filling something that is empty ended up with his *time cuper*. The analogy seems clear but the form is unclear which has been explicitly stated by the participant that a search for formal characteristics has not been of prominence for him and the idea has been depicted with plain prisms.

It has to be pointed out that Participant 4 used another problem solving method by himself during his Black Box experience. He started to write down words that each time trigger the next word to be written down, cognitively connected to each other. The words he had seen caused him to play this mind mapping process and his concept actually owes its structure to the play of these words.

3.5.6 General Outcome of the Pilot Study

The virtual way finding experience in Black Box has been used in assisting the concept generation phases of the six students. All the participants came up with an idea out of Black Box that they have structured on an analogy with an image or images, a word or a sequence of words or through any impression that have caused a "sudden mental insight" (Akin, 1996).

The end ideas were all created within an average of 11 minutes and 20 seconds. Most of the participants were able to build structural analogies even if they were unfamiliar to the concept of reasoning with analogies. This has also shown that the virtual way finding experience does not need any pre-requisites and may be used by any designer regardless of his/her eagerness for and experience with analogical reasoning. This might be taken as a point to carry this playground with all of its players and rules to the educational area of design.

All the participants agreed that the interspatial voyage was interesting and that the Black Box was an innovative tool to assist creativity. The participants used the images and/or words of the Black Box, either by noting them during the navigation process or by going back to any referred image/word during the concept generation phase.

The analogies that have been built displayed scattered cognitive types where some of the participants relied much more on words to base their ideas and some participants did rely more on images and visual elements derived from Black Box. The analysis of their Black Box navigation showed a one to one equivalence with the resulting analogy-based concept. If the participant spent more time on words worlds s/he used

verbal associations to build an analogy; if s/he spent more time on images, s/he used visual associations to build an analogy.

3.5.7 The Pilot Study's Effect on Black Box Study

3.5.7.1 Regarding the Black Box Architecture

- The architecture of Black Box has by and large remained the same in means of computational coding. However the set-ups of the worlds have been reconsidered in a way where each of the worlds has been designed differently and accumulated on creative concepts to promote creativity also in a system-base level.

- The interface has been made to appear more minimal to relieve eye correspondence. Access to all worlds has been re-designed through a right justified set of links which appear in the set-up of every world. To ease the navigation process, the "swf" file has been embedded into an HTML file and the Black Box has also been made to appear like a website to awaken familiarity of use. In terms of graphical concerns, the interface has been developed with more advance use of scripting details.

- The integration of music has been improved with an embedded mp3 player that involves six songs in the playlist, seen enough for the attributed time of use of the Black Box tool. The Black Box of the pilot study had a single loop of music through the whole experience.

- The image selection has been extended and re-categorized under the concepts defined for the scenes. Animations and graphical content have been improved in terms of their pixel dimensions as well as in their quality regarding the conceptual meanings they stand for and in their arrangement within the scenes.

3.5.7.2 Regarding the Methodology

- The questions of the pre and post-questionnaires have been revised and expanded to get more inclusive and to the point responses from the designers and to gain

insight into their professional experience. In addition to the contextual differentiations in the questions, the pre-questionnaire has been changed into an interview as it is thought to be more efficient for collecting extensive data on the designer's approach to designing and concept generation.

- It was decided to base the Black Box study on real time observation instead of retrospective analysis of videotaped sessions.

- The action categories and expected actions have been modified in accordance with the results of the pilot study. As a consequence, charts and the evaluation methods have been reassessed and designed accordingly.

3.5.7.3 Regarding the Sample Group

- Instead of students, experienced Turkish design consultants were defined as participants of the Black Box study. The professional experience and skills that individual designers have is thought to be an important thriving force for the implementation of Black Box tool which will cause different responses and different outcomes with respect to design approaches and thinking.

3.6 Methodology of the Main Study

Black Box study uses a case study approach with the data derived from a real time observational protocol study and a retrospective protocol study. The process has been followed in the series of retrospective protocol of design sketches produced by experienced designers for the given design problem.

In this study, the two sets of raw data were obtained from a pre-interview with the designers aiming to define each designer's approach to concept design and from a post-assessment on Black Box and the designer's personal preferences in using it. Between the two sets of raw data, the designer has been let to experience the Black Box tool and generate a concept or concepts for the given design problem.

3.6.1 Sample Group

The sample group has been associated from eight Turkish design consultants with an industrial design degree. The selection was made within design consultants with experience rather than novices. It has been also taken into consideration that the participant design consultants have different work experience at different sectors to provide divergence in the approaches and methods of different professional sectors of industrial design (Table 3.8).

Table 3.7 Sample Group Classification

	Year of Experience	Sectors of Experience	Gender
Designer A	8 years	Furniture design, lighting design architecture	Female
Designer B	7 years	Small house equipment, furniture design, electronics	Male
Designer C	21 years	Furniture design, medical equipment, atm machines	Male
Designer D	20 years	Office furniture, toys, medical equipment, furniture design	Male
Designer E	8 years	Yacht design, graphic design, accessory design	Male
Designer F	25 years	Automotive, small house equipment, furniture and decoration	Male
Designer G	8 years (17)	Electronics, heating, software design	Male
Designer H	17 years	Furniture design, decoration, accessory design	Female

3.6.2 The Design Problem

The design problem has been defined as the design of a concept for a clock (See 3.4.2.1 Design Brief). The main reason behind the selection was that the idea of time is supposed to be a concept that most people have experience with.

3.6.3 The Process

As mentioned before, Black Box does not aim at reproducing the actual concept generation phase, but it suggests an alternative way of constructing it. The methodological process consists of five sequential parts that are indicated below. Before the sessions begin, the designer is briefly informed on the aim and objectives of the study and the author's intentions in developing it.
The general procedure of the study involves:

1. Observing and documenting the generative phase with/without utterance
2. Observing and documenting the exploratory phase with/without utterance
3. Documenting the retrospective reporting of the concept generation section verbally
4. Encoding the design process through real time observation and retrospective analysis

3.6.3.1 Part one: Pre interview (Attributed time: 15 minutes)

Session One is an interview with the designer through which the designer's approach to concept design is explored. The subject, visited at his/her choice of a surrounding, is interviewed through a set of fourteen questions, each of which addressed to the subject's personal style of designing. Especially, the subject's tendency to use analogies and visual aid in form of visual media in his designs is trying to be explored (Appendix K).

The pre interview also aims to retrieve data from designer's self design history based on to what extent he reasons his/her design on what s/he experiences or imagines.

The collected answers are used as guidelines in the retrospective analysis of the designer's experience during his/her navigation in Black Box.

3.6.3.2 Part Two: Generative Phase; Real-Time Observational Protocol Study (Attributed time: 15-20 minutes)

Session Two is the part where the designer is given the design problem. The designer is asked to design a novel concept for a clock. At the same time, the designer is informed that an "initial" concept is for concern and no details are needed. Just a simple but a novel concept is aimed to be arrived at after the use of Black Box for about 15 minutes, during which the author takes notes on an observation sheet that has been prepared beforehand with a checklist according to the actions the designer is expected to perform.

3.6.3.2.1 Use of Black Box Tool

As comprehensively described before, Black Box is a Flash based tool composed of a set of scenes and has been converted to a HTML page for ease of the user, having an appearance of a website to navigate within. It is an auditory and visual experience on the PC Platform and it is let to be used running on the author's personal notebook.

Following the set of the notebook and the start click on the Black Box icon, at the time interval, when the scenes of Black Box are loading, the designer is reminded of the fact that he is expected and encouraged to use visual/verbal analogies to create a concept. Furthermore, it is also indicated that the navigation process in Black Box aims at awakening different perceptions for the designer and that his/her concept might be based on a thing that s/he has experienced or s/he has recalled through experiencing a sensual shift through visual, verbal or auditory content.

Before navigational Black Box begins, the designer is instructed on the interface and the use of navigational buttons and any questions of the designer are to be answered for providing a smooth process for the navigation.

3.6.3.2.2 Real-Time Observational Protocol Study

As soon as the designer begins to navigate, the whole process is manually documented in terms of minutes by means of a chronometer. The designer actions and behaviors during the generative process are documented into the observation sheet designed to check expected actions of the designer. The entire process of documenting has been separated into small segments of time and the actions of the designer are collated in a series of 0-2 minutes' actions, 2-4 minutes' actions, 4-6 minutes' actions etc., in order to interpret the way in which concepts shifted in the designer's mind during navigation (Appendix M). Additionally, notes are taken during the observation, especially on designer's behaviors and any verbal explanations s/he produces, to be utilized as visual and behavioral cues for retrospection.

Designer behaviors during generative phase have been categorized into three action levels as seen in Table 3.9. Among the three levels of coding categorization, *expressional* and *perceptual* level actions have been coded during the generative and exploratory phases whereas the cognitive based behaviors at the *conceptual* level have been coded after the retrospective analysis.

Table 3.8 List of Encoding Scheme

Action Level	**Action Category**	**Abbreviation of the action**	**Action Definition**
Expressional	Drafting	S	Sketching
		NT	Note Taking
	Verbal	Vex	Verbal expression
Perceptual	Cognitive	T	Thinking
	Navigational	SdNav	Stopping during Navigation
		RP	Revisiting/returning to a Picture
		RW	Revisiting/returning to a Word

Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component
		MIS	Maps an idea with the inherent structure of a world component
		MFI	Maps a mental fixed idea as the design concept
		Assc	Maps an idea with an association derived from a world component

Table 3.9 (continued)

The main idea behind the coding scheme for the real-time observational protocol analysis has been first established by Suwa and Tversky (1997) and afterwards developed by Suwa, Gero and Purcell (1998). The coding scheme explores the concept design process by focusing on expressional designer actions like drafting, gestures and verbal expressions as well as the perceptual actions like navigating and thinking during generative and exploratory phases. Basically, it is a content-oriented coding scheme where *expressional*, *perceptual* and *conceptual* design behaviors of designers have been sorted into five categories: *drafting, verbal, cognitive, perceptual and mapping*.

Prominently, each component of the categories has interlinked relationships with other components in different levels. For instance, MPS action of mapping a sketch with the physical structure of a world component on the *conceptual level* is dependent on the S action of a previous drafting action on the *expressional level*. So, the design process is transferred into a composition of inter-linked levels and segments in a table showing the designer's Black Box Map.

3.6.3.3 Part Three: Exploratory Phase; Concept Generation and Sketching/Writing (Time left to the designer)

When the designer is finished with the navigational process in Black Box, s/he is left for designing with or without utterance. There are no limitations with time, so the

designer is let to end the session whenever s/he wants. Yet, the designer is formerly told that the expected result has to convey mainly the initial concept, therefore it is foreseen that the concept generation phase is to be over within 15 minutes.

While the designer sketches or writes or takes notes, s/he has been left free to go back to a specific or random point in Black Box. Throughout the concept generation session, the designer is observed to provide cues for the retrospective inspection of the process.

3.6.3.4 Part Four: Retrospective Report of the Exploratory Phase (Attributed time: 5-10 minutes)

Subsequent to concept generation in the exploratory phase, the designer is asked to retrospectively report the design process. S/He is asked to report every thought regarding each stroke in the sketches. The utterances during the retrospection are transcribed into text word by word. The entire protocol then is separated into small segments again, by interpreting the way in which concepts shifted in the designer's mind

The data produced by this method has been tried to be made more reliable through two ways. First, the method requires participants to report every stroke and related thought which they can recall. Second, participants can go back to a scene of the tool to remember what they were thinking at the time of experience. Consequently, the participants were able to report more information about physical and perceptual aspects.

Afterwards, the entire verbal protocol was divided into small units, *segments*, each accounting for a designer's single intention, and therefore consists of pieces of information that appear to have occurred simultaneously in the designer's mind.

3.6.3.5 Part Five: Post-assessment Questionnaire (Attributed time: 10 minutes)

The post assessment questionnaire is formed in order to get raw data on the navigational process of the designer and to provide a quick and simple evaluation of Black Box (Appendix L). The questionnaire is composed of two parts, first part being on the Black Box experience and the second on the Black Box tool. The first part aims at collecting data on the preferences of the designer during navigation and the inspiring content that has influenced his/her concept whether relying on the seen data or recalled events and entities. The second part aims at acquiring an evaluation of the tool based on its use and content.
Eventually, the methodology has been designed to take an hour.

3.6.4 Analysis of the Parts of Main Study

The five parts of the main study are analyzed with accordance to the behaviors' occurrence at the generative or exploratory phases.

3.6.4.1 Analysis of the Generative Phase

The generative phase that is carried out along and with the use of Black Box tool also includes the designer's profile in order to cast light upon the acts/behaviors of the designer in using the tool.

3.6.4.1.1 Construction of Designer Profile

According to the data inquired through the pre interview of Session One, a brief designer profile is constructed based on the designer's approach to the concept generation phase and the inspirational media or methods s/he makes use of during designing with her/his enthusiasm and experience with analogies in design.

3.6.4.1.2 Construction of a Black Box Map

According to the data inquired through the dwell-in observational protocol study of Session Two, a map of the designer's navigation within Black Box is constructed which is based on the action times on *expressional* and *perceptual levels*, to those levels relatively defined categories, definitions, coordinates and evoked pre-inventive structures with their type. It is aimed that through the investigation of the map, it can be inferred how associations are formed to cause pre-inventive structures to be generated and how ideas are transformed during the thinking and navigating process.

3.6.4.2 Analysis of the Exploratory Phase

The Exploratory phase is analyzed through the construction of the maps of the designer related with the concept design; during his/her behaviors at this phase and the maps refer to the emergence of the concepts.

3.6.4.2.1 Construction of a Concept Design Space Map

Conceptual level actions which are categorized under *mapping* actions are used in the construction of the 'Concept Design Space Map' to provide insight into how analogical mapping process is performed based on the retrospective report of the designer on the concept of Session Four and also on the observational protocol study of Session Two.

3.6.4.3 Construction of a Thinking Path of Concept Design

Based on the 'Black Box Map' and the 'Concept Design Space Map' and through the retrospective report of the designer, a thinking path of the designer is constructed in order to see how the concept or if available different concepts have evolved into the end concept or concepts through the generative and exploratory phases on a time-dependant axis in relation with the associated or derived media represented as nodes of the thinking path.

3.6.4.3 Analysis of the Analogy

The analogy that the designer has come up with at the end of the generative and exploratory phases is analyzed according to its functional type, cognitive type, according to the mental image and/or pre-inventive structure that supports the analogy and the verbal concepts that have been used (See Section 3.5.4.3).

Subsequent to the definition of the above mentioned criteria a configurative scheme of the concept based on the analogy is constructed.

CHAPTER 4

EMPIRICAL STUDIES

4.1 Study 1: Designer A

4.1.1 Designer A Profile

Designer A finds the concept generation phase essential to go further with the design process and considering the project input, she tries to engage a certain amount of time for concept generation, whether short or long. She sees design as a process that continues to be lived and experienced also throughout the times free from actual designing and sketching. That is why she is inspired, affected and channeled by everyday experiences during a design process. In the same line with this, she finds any kind of visual media and especially outer-domain concepts quite inspiring and useful during concept generation.

Watching movies to expand visual and cognitive horizon and spending time in the internet wandering around various unrelated themes of her interest is an important part of the design process and especially, of the concept generation phase.

Nature, among diverse types of visual media, is a favored source of inspiration for her while trying to find structural analogies. She has previously designed a furniture group with a theme of insect series with slim and slender legs carrying massive bodies as an example of the implementation of a visual and structural analogy for a design concept.

4.1.2 Designer A Generative Phase

The Black Box navigation process took a total of 32:02 minutes for Designer A where she visited 10 out of the 12 worlds (Table 4.1). Table 4.2 (Appendix A) shows the actions that have been indexed according to their occurrence in the expressional

or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.1 Time Segmentation for Designer A

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
32:02 minutes	17:47 mins	14:15 mins	10

4.1.3 Designer A Exploratory Phase

Designer A's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and her retrospective interview and shown in a concept space map in Table 4.3 (Appendix A). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer A have been then collected and transformed into a thinking path of concept generation in Figure 4.1.

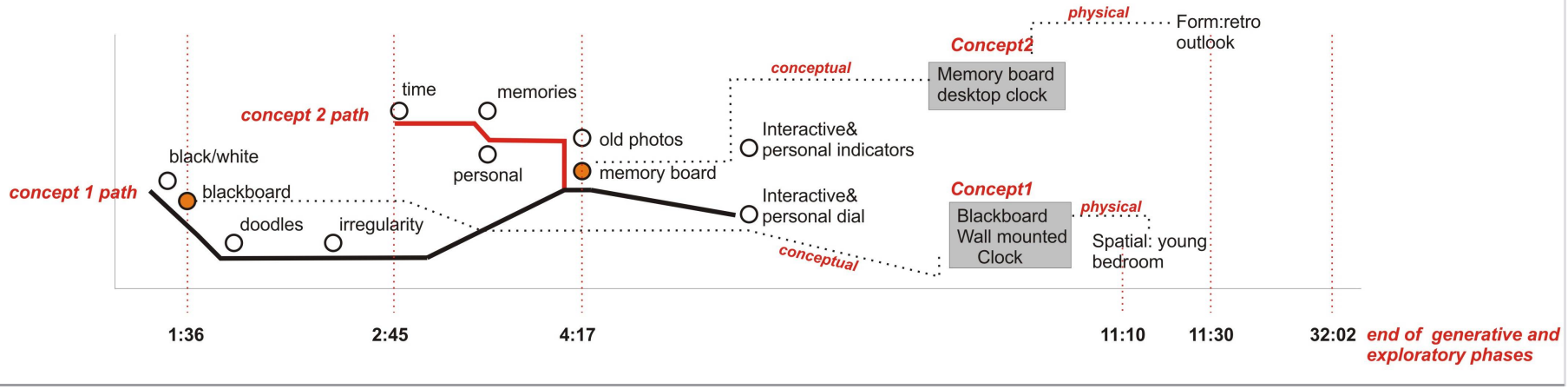


Figure 4.1 Designer A Thinking Path of Concept Design

4.1.4 Designer A Thinking Path of Concept Design in the Generative Phase

The first frames of the first animation immediately evokes a sudden image in Designer A's mind and she sketches as soon as the blackboard idea came through at 1:36. The following minute, she hangs on with the blackboard idea and tries to elaborate it with further derivations like irregular time indicators. Setting aside this first idea, she begins searching for another alternative. At 2:45, she begins thinking on the concept of time and on how it is divided into segments as lifetime is divided in the same way and at 4:17 the memory-board concept appears which she instantly sketches. Based on the two ideas, she then tries to associate form and/or space for her concepts. At 11:10 she puts the blackboard image into a cubical room and at 11:30 she finds a rounded rectangle form for the memory board idea and directly sketches. At 17:47 she returns to World 1, clicks on the first animation and starts the exploratory phase by sketching and writing.

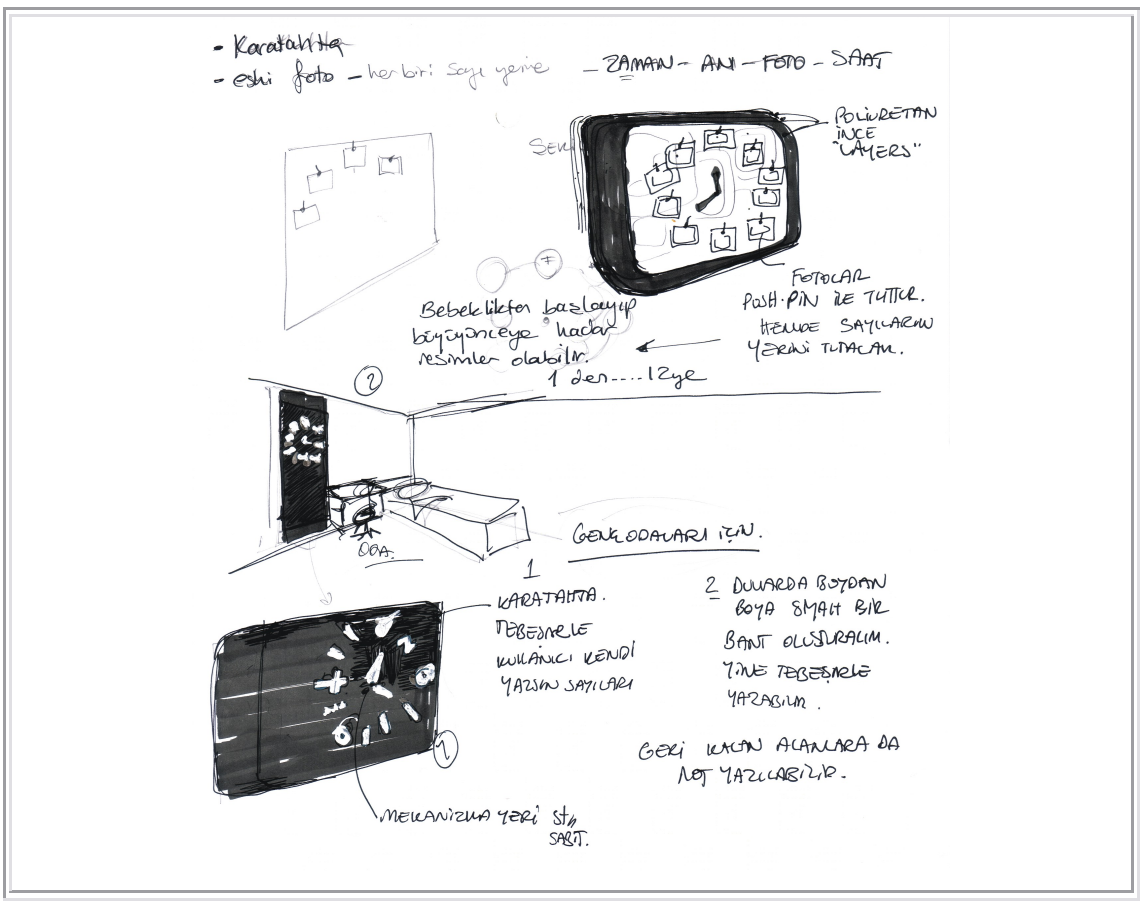


Figure 4.2 Designer A Sketch in Generative Phase

4.1.5 Designer A Retrospective Report on Concept Generation in the Exploratory Phase

The first few frames of the first animation in the Worlds of Innovation are the key-driver for Designer A. The first image in her mind is the *blackboard* image which transforms the idea of perceiving time with respect to the user's individual preferences talking of the simple time indicators. Numbers as the basic indicator of time have been transformed into a figure/word sequence of what the user wants to sketch on the blackboard. The blackboard idea of the clock forms itself on changeability and adjustability according to user preferences. The dial of the clock, in this case the blackboard, is going to be used also for taking daily notes for specific times and be easily erased and replaced each day. She indicates that the *blackboard clock* is meant for young persons bedrooms in a form and size of a real blackboard installed to one wall of the room, appearing like a panel with the hour-hand and minute-hand being stable and the surrounding dial area is emptied or filled every day.

The second idea of Designer A has come up with the concepts of old times, old photos, life cycle and different slices of life period. The concept of time is made use of as the concept of a clock. The instances of the user's life, the point of times, are used as the indicator of the specific point of time of a day. Photos that stand for points in time are located with the help of pushpins onto the soft dial-pane of the clock. Designer A states that the photos can even be arranged from childhood to adulthood being an analogy of the idea that time gets older towards the end of the day. The formal concerns of the designer have been relieved with retro-reminiscent filleted squares and rectangles and the polyurethane main pad is formed of a series of layers that have been pressed on top of each other allowing the user change between the different colors.

4.1.6 Designer A: Analysis of the Analogies

The analysis of the analogy for Designer A's first concept *blackboard clock* can be found in Table 4.4. The analysis of the analogy for the second concept *memory board clock* can be found in Table 4.5.

Table 4.4 Analysis of Analogy for Concept 1

Functional type	Structural
Cognitive type	Based on verbal and visual associations
Mental image/main pre-inventive structure	Blackboard
Verbal concepts	Blackboard, personal, interactivity
Configurative scheme	The concept of a memory board like clock in the appearance of a blackboard with time indicators that can be changed with a doodle made with chalk.

Table 4.5 Analysis of Analogy for Concept 2

Functional type	Structural
Cognitive type	Based on verbal and visual associations
Mental image/main pre-inventive structure	Life cycle, time
Verbal concepts	Memory, photos, personal, interactivity
Configurative scheme	The concept of using photos/figures and information which belongs to defined segments of a person's life as the indicator of time.

4.2 Study 2: Designer B

4.2.1 Designer B Profile

Designer B, though finding the concept generation as the key part of the design process can not help revealing the fact that most cases in professional design sector come with a ready-made concept defined by the client. Furthermore, he asserts that also functional requirements of the concept are by and far identified by the client and a *tabula rasa* approach is generally not likely to be taken. Inspiration for him, comes within the borders of the client's corporate identity and enclosed in a state of affairs where the client's previous product data and range of concepts become designating in searching for an idea for the concept of a product. As anticipated from his identification of concept with client identity, he prefers carrying out a search within the sectorial media and output. In his research process for a concept, he makes use of the internet and sectorial magazines and if possible, of an actual site-research where he goes and explores the items to be inspired based on the know-how for stimulating an initial idea that is concurrent with the day's trends and the project input.

Having an analytical approach in the design process, he finds analogies only appropriate when structural and mostly functional requirements are in question. When talking of associations, crustaceans and arthropods with their inherently functional and well-designed structures are his favorite source of detail analogies. Giving an example of one of his vacuum cleaner shell design inspired and constructed in detail with accordance to the lobsters shell, he once more indicates that analogies are tools for him to better understand and express structural relationships rather than formal concerns.

4.2.2 Designer B Generative Phase

The Black Box navigation process took a total of 25:53 minutes for Designer B where he visited 12 out of the 12 worlds (Table 4.6). Table 4.7 (Appendix B) shows the actions that have been indexed according to their occurrence in the expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.6 Time Segmentation for Designer B

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
25:53 minutes	18:38 mins	7:15 mins	12

4.2.3 Designer B Exploratory Phase

Designer B's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and his retrospective interview and shown in a concept space map in Table 4.8 (Appendix B). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer B have been then collected and transformed into a thinking path of concept generation in Figure 4.3.

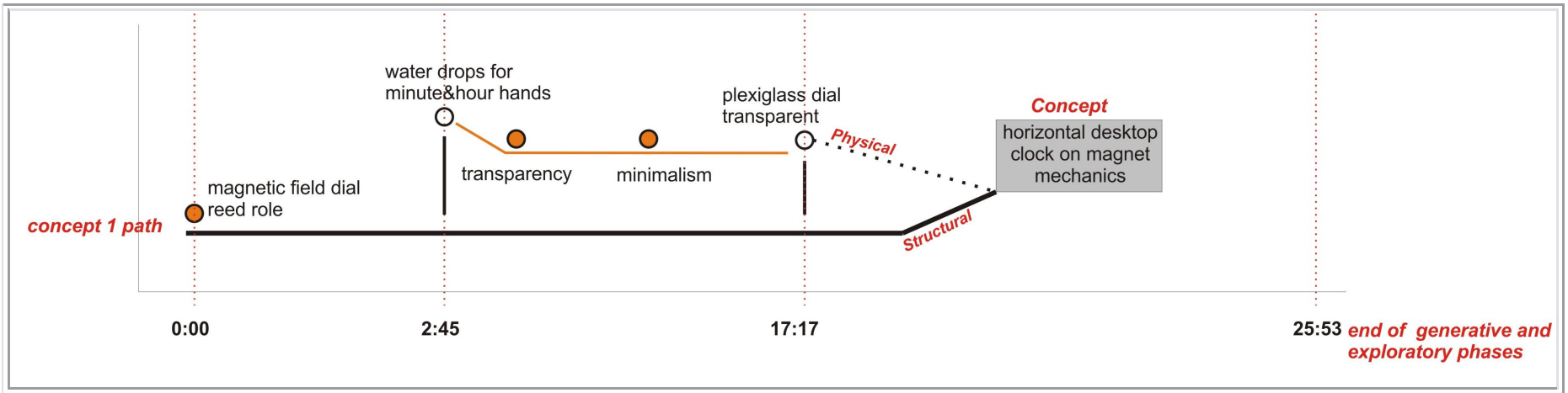


Figure 4.3Designer BThinking Path of Concept Design

4.2.4 Designer B Thinking Path of Concept Design in the Generative Phase

Designer B had a fixed concept at the beginning of the concept generation process based on a subject he has been interested in lately: the reed role. At the minute 0:00, he began with the idea of reed role mechanism for the hour and minute hands of the clock. At 2:45 he, upon seeing water drops on a green smooth surface, came up with the idea that the hour and minute hands could be in the form of drops. At 5:20, in the Words World he tried to make up a series from the words that would mean something to him. Having found nothing from the words, he kept on searching for formal analogies and stopped at 13:05 for a white horizontal CD-player and the formal search then continued producing the ideas of plexiglass as material and colorful candy-like cases at 17:17 and 18:38. It is figured out from the thinking path that the designer had an initial idea to begin with and he tried to visualize it through visual analogies.

4.2.5 Designer B Retrospective Report on Concept Generation in the Exploratory Phase

The idea of designing something working based on magnets has been keeping Designer B's mind busy for some time in his personal design work and as soon as he is encountered with the design brief of a clock for this case study, he tried to initialize a design based on this concept. He asserts that he started to think of how he can utilize the magnetic field mechanism and decided to apply it to operational mechanics of the minute-hand and the hour-hand. Visualization of the minute and hour hands are based on the water drops on a smooth surface. The minimal look of the drops are supported with a smooth dial of plexiglass, either transparent or translucent which veils on the horizontal plane rather than standing perpendicular to the sight axis. The colorful candy-like designs of mostly plexiglass in d-II World is also guiding for the idea of Designer B when he asserts that the clock may be produced in different colors and also may contain colored light sources within the case of the mechanism.

4.2.6 Designer B: Analysis of Analogies

The analysis of the analogies of Designer B for the concept *reed role clock* can be found in Table 4.9 and 4.10.

Table 4.9 Analysis of Analogy 1 for the Concept

Functional type	Structural
Cognitive type	Based on personal interest in the subject
Mental image/main pre-inventive structure	Magnets and magnetic field mechanics
Verbal concept/s	-
Configurative scheme	The concept of using the hour and minute hands floating on the dial of the clock

Table 4.10 Analysis of Analogy 2 for the Concept

Functional type	Surface
Cognitive type	Based on visual associations
Mental image/main pre-inventive structure	Water drops
Verbal concept/s	-
Configurative scheme	The minute hand and hour hand in the form of water drops on the clock's dial

4.3 Study 3: Designer C

4.3.1 Designer C Profile

Designer C thinks that the concept generation phase is a part of the design process that is to be experienced thoroughly if there is no predetermined concept imposed by the client. He finds it important to generate a concept for each of his design projects but within the limits of the client needs and requirements and the limits of probable production techniques.

Actually, concept generation phase according to him, is a more extensive and inclusive phase than just being a process at the beginning that somehow ends leading to the next phase. So, he usually takes an analytical approach where he constructs an overall scenario of the concept and tries to make it live up from the initial idea until the very last details. If he happens to live any type of block during the process he just isolates himself from the current work and gets involved with something else; either another design problem or something that is definitely unrelated with the process.

Emphasizing the fact that he is an analytical thinker, he does not make use of analogies whether visual or verbal. He asserts that, to be inspired anyhow, he makes keyword searches in the internet and looks at current magazines: He does not restrict his media with the design milieu but takes a look at whatever Google arranges in the search results, of course at the ones he interested in.

4.3.2 Designer C Generative Phase

The Black Box navigation process took a total of 20:52 minutes for Designer C where he visited 9 out of the 12 worlds (Table 4.11). Table 4.12 (Appendix C) shows the actions that have been indexed according to their occurrence in the expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.11 Time Segmentation for Designer C

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
20:52 minutes	17:42 mins	3:10 mins	9

4.3.3 Designer C Exploratory Phase

During the generative phase, no cognitive actions of Designer C have been observed with respect to any kind of mapping process with a reference or association from the Black Box experience. Instead, Designer C has tried to describe the fixed image in his mind (Table 4.13 in Appendix C).

The actions that have been observed during the generative and exploratory phases along with the fixed mental image for Designer C have been then collected and transformed into a thinking path of concept generation in Figure 4.4.

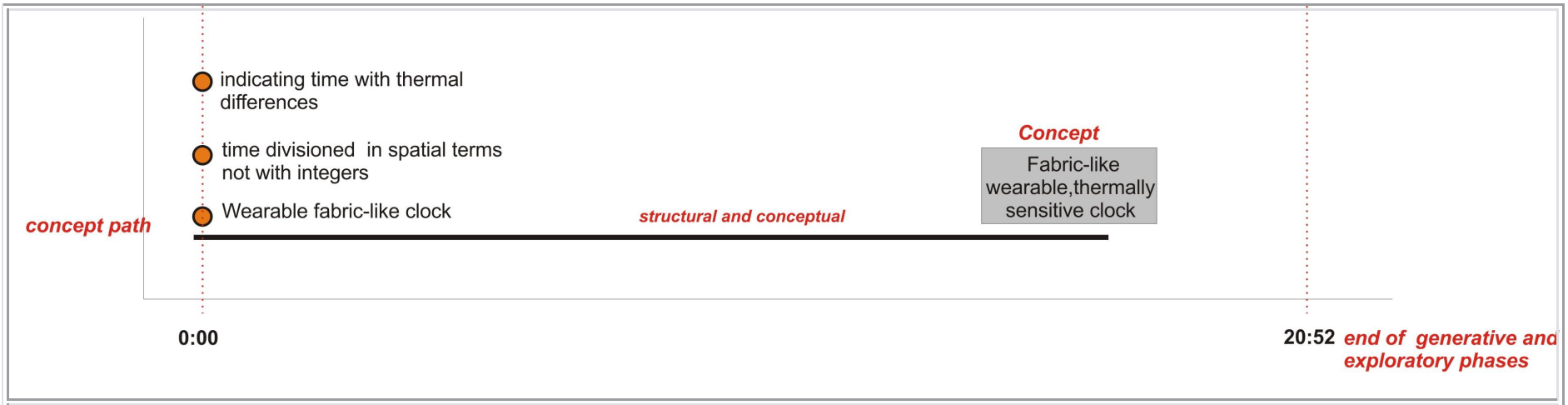


Figure 4.4 Designer C Thinking Path of Concept Design

4.3.4 Designer C Thinking Path of Concept Design in the Generative Phase

Designer C showed no specific perceptual or expressional actions that ended with any retrieval or recall throughout the Black Box experience. Thus, due to personal preferences, the outcome of the generative phase was in written verbal expression rather than sketches, where he defined how a clock must be according to him.

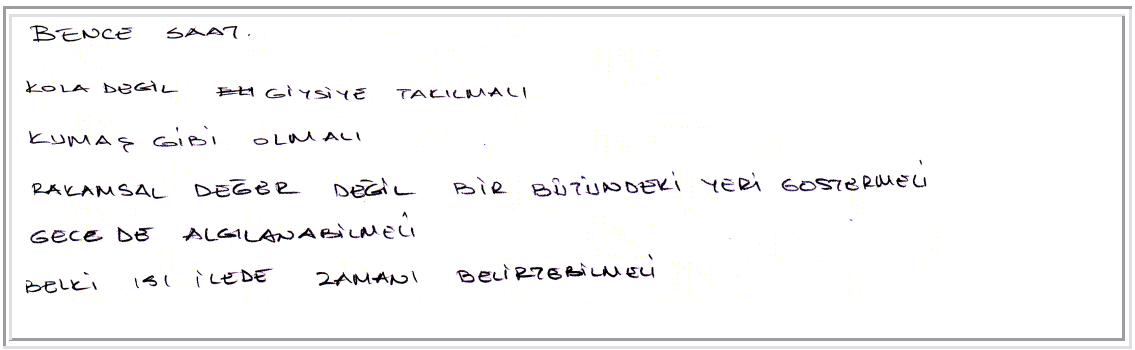


Figure 4.5 Designer C Writing in Generative Phase

4.3.5 Designer C Retrospective Report on Concept Generation in the Exploratory Phase

Designer C indicated that, as an experienced designer, he had a vision of how a clock should be and might be in his mind. Having the fixed mental image and definition of a clock he did not attempt to search for an alternative idea or concept that might replace the one in his mind or even provide him with a visual appearance of the idea in his mind. The ideal clock in his opinion has to be wearable like a fabric which can be attached to a part of the clothing terminating habits like taking off the clock when sleeping. He considers time as defined in spatial terms and wanted to use this concept as the basis for division of time on the dial of the clock. The dial is to be divided into segments but without any numeral indication so that time is conceived as spatial shift throughout the day. To emphasize the daily cycle of time, he asserted that the clock may also make use of thermal differentiations of the day, allowing the beholder to grasp time in a different way at different temperatures.

4.4 Study 4: Designer D

4.4.1 Designer D Profile

Designer D sees the concept generation essential in the way he also admits that however ubiquitous and overwhelming the concept generation might appear, it has to be kept within the deadlines. He asserts that it is for sure that there is no perfect solution no matter how far and how long the designer spends time on concept generation that's why it has to be concluded within reasonable time to be able to continue with the design process.

Continuous, divergent and plural sketching is his main approach in searching for a concept. In the same line with the continuous process of the sketching phase, the designing process is also continuous for him where he is affected by the changes in his state of mind caused by any kind of external intrusions throughout the daily life. Visual media is a source of inspiration; it is frequently searched in a diverging manner in the internet and magazines. In addition to being inspirational, visual media becomes a source of confirmation when he is finished with his design where he checks his design with the available designs on the sector. Apart from visual media, he usually searches for confirmation of his designs through children's responses, especially through his own child's. He claims that he uses visual analogies in his designs if he comes up with something but does not exerts extra effort to find one. An example of his use of visual analogy was the "maki" series of office furniture which were chunky in appearance and made use of Mediterranean colors. A recent project of him has also come up with the realization of a verbal expression: "the table is able to hide the cable" which points out a table that hides the cables within its design.

4.4.2 Designer D Generative Phase

The Black Box navigation process took a total of 34:19 minutes for Designer D where he visited 12 out of the 12 worlds (Table 4.14). Table 4.15 (Appendix D) shows the actions that have been indexed according to their occurrence in the

expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box

Table 4.14 Time Segmentation for Designer D

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
34:19 minutes	29:19 mins	5:00 mins	12

4.4.3 Designer D Exploratory Phase

Designer D's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and his retrospective interview and shown in a concept space map in Table 4.16 (Appendix D). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer D have been then collected and transformed into a thinking path of concept generation in Figure 4.6.

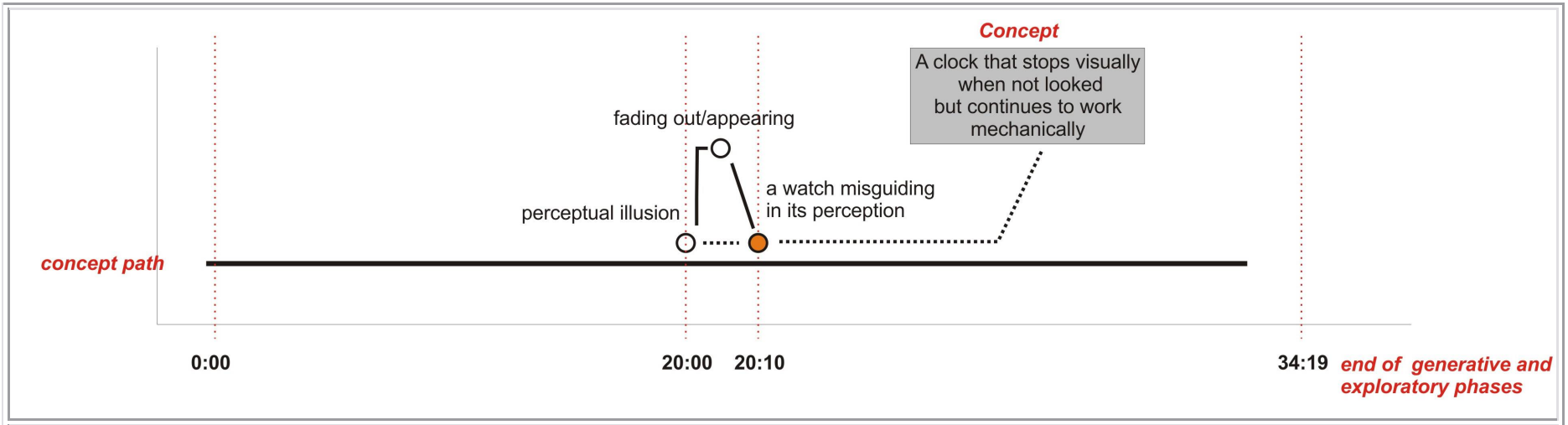


Figure 4.6 Designer D Thinking Path of Concept Design

4.4.4 Designer D Thinking Path of Concept Design in the Generative Phase

Designer D navigated within the Black Box with attention and tried to perceive as much data as possible and expressed this intent at 3:32 which lead to a smooth navigation process uninterrupted by his own actions until the 10th world. Having been through most of the worlds, at 20:00 he took a note of "perceptual illusion". The design idea struck him with the internal movie clip of White World which was composed of a set of translucent squares that fade from translucency to transparency. At 20:10 he mentioned of a clock that is misguiding in the way it is perceived and he after all reached a concept which did not however prevent him from navigating in the last two worlds but no other idea erected.

4.4.5 Designer D Retrospective Report on Concept Generation in the Exploratory Phase

Designer D indicated that it was a watch for personal uses that came across his mind. The main wit behind the design of the watch is that its hour and minute hands stop when not looked. The mechanism of the watch will continue to work but the indicators will stop moving around the dial. Considering the fact that time is not conceived in spatial terms when we usually look at the watch as the minute movements are not grasped as a whole, the watch will hatch the elapsed time each time it is reactivated after having stopped in appearance.

4.4.6 Designer D: Analysis of the Analogy

The analysis of the analogy of Designer D for the concept *misguiding clock* can be found in Table 4.17.

Table 4.17 Analysis of the Analogy for the Concept

Functional type	Structural
Cognitive type	Based on verbal associations

Mental image/main pre-inventive structure	Fading out, passing
Verbal concepts	Perceptual illusion, misguiding
Configurative scheme	A watch that enables the beholder to notice how much time has faded through an activation and re-activation of the hour and minute hands by the beholder.

Table 4.17 (continued)

4.5 Study 5: Designer E

4.5.1 Designer E Profile

Designer E thinks that the concept is the key part that holds the whole design project together, that is why he finds concept generation phase essential for structuring a design process above all. He refers to the concept as a constraint which is used as a guideline throughout the other stages of the design process. As a matter of fact, the existence of a concept makes it easier to define the successive processes in his opinion.

Methods like mind mapping and constructing diagrams are among the techniques he makes use of during concept generation. However, methods are not the only help source when trying to configure his design concepts; he looks at the adjacent sectors of his area to derive a concept. For instance, in yacht design he makes use of automobile designs looking at a new model of Lamborghini.

As for inspiration he makes Google Image search and looks at the styling or surface compositions of different products, objects and of anything with surface qualities. Most of the time happening serendipitous, he sees a part of a product and re-arranges it for a surface or style detail of a yacht. Recently, a book called, Visual Dictionary for Designers has drawn his attention which involves concepts and the sub-concepts and sketches related with those concepts within it.

4.5.2 Designer E Generative Phase

The Black Box navigation process took a total of 49:20 minutes for Designer B where he visited 12 out of the 12 worlds (Table 4.18).

Table 4.19 (Appendix E) shows the actions that have been indexed according to their occurrence in the expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box

Table 4.18 Time Segmentation for Designer E

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
49:20 minutes	45:15 mins	4:05 mins	12

4.5.3 Designer E Exploratory Phase

Designer E's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and his retrospective interview and shown in a concept space map in Table 4.20 (Appendix E). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer E have been then collected and transformed into a thinking path of concept generation in Figure 4.7.

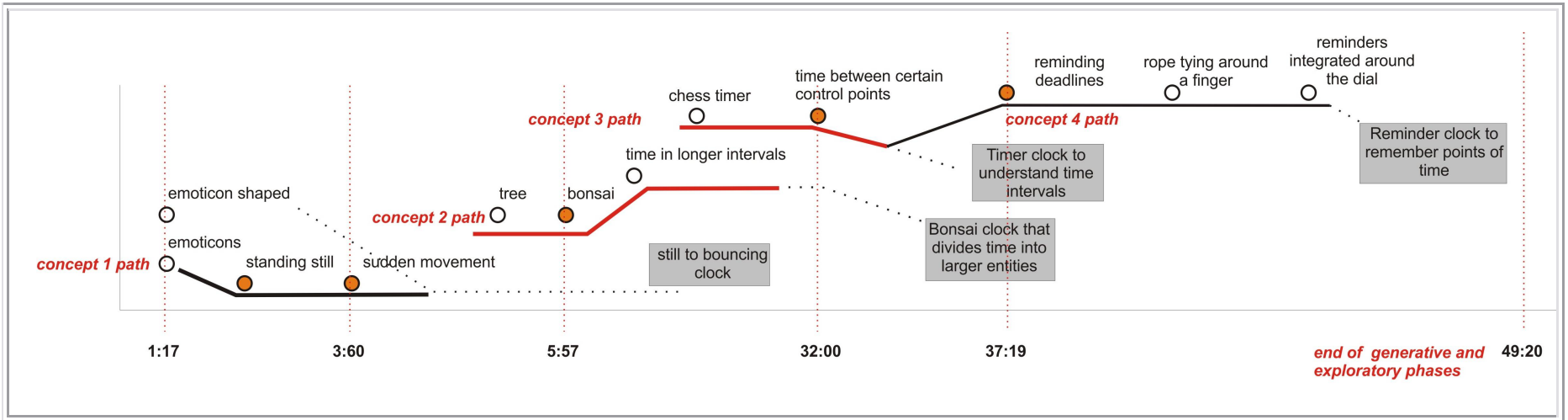


Figure 4.7Designer EThinking Path of Concept Design

4.5.4 Designer E Thinking Path of Concept Design in the Generative Phase

At the very beginning of the navigation, Designer E was affected at 1:17 minute by the bouncing emoticon-like shapes in the first animation of the World of Innovation which he expressed at the very moment and sketched on paper to emphasize the replicated shape as the clock's appearance. Going further with the emoticon concept, at 3:60 he expresses that just as the emoticons were bouncing one after another in the animation, the clock he was going to design would at the beginning stand still and would be activated when touched or approached displaying a reaction like a bounce-movement. While moving to the next world he set this first concept aside and started to search for another concept which at 5:57 made him recall the bonsai concept. At 6:15 he sketched a rough shape for bonsai concept and upon changing the world in the navigation he left the bonsai concept also aside. Designer F tried to produce another concept for each world he visited. At 16:12, the ladybugs in the empty world made him think of designing a clock only with formal concerns and associations based on the ladybug concept which made him recall one of his previous design experiences where he just searched for a form for a lighter and ended up with the deer head as a visual reference. At 18:38 in the words world, he tried to catch or improvise a creative sequence that would cause a design concept to arise but after insisting on the "dovetail" word, he all the same came up with nothing and moved to the next world. Then, he saw a portable chess board and at 32:00 he indicated that he has always been in a want of measuring how much time between certain events have passed. He expressed that he would like to know how much time he spends on a certain job and a clock that can be used as a chronometer between events after which he makes a doodle of a chess timer at 37:08. In the very succeeding moment at 37:19 he expressed that a clock that would mark preferred points of time along or around its dial could be developed which was in the same line of his previous idea based on its approach to define the area that time hatches but this time he indicated that the clock would act like the string tied on a finger making us remember that we are up to something at a designated moment of the day. At 37:40 he sketches the clock idea with markers around the dial and then continued to his navigation with no further idea generated but he still kept on searching for another reference by visiting previously visited worlds again.

4.5.5 Designer E Retrospective Report on Concept Generation in the Exploratory Phase

Designer E has come up with a number of concepts during the Black Box experience. The first concept that came across his mind was evoked by the first animation in World of Innovation. The one after the other bouncing emoticon-like figures made him think of a clock that stands still but responds when approached in a sudden manner and may even involve a physical action. The form of the clock was a corresponding one to the image of the emoticon, colorful and cheerful in appearance.

The second concept of "bonsai" in Designer E's mind was reminded by the image of a tree trunk leaning to one side. He had been interested in bonsai culture and planting for a while in the recent years. The fact that bonsais require quite a long time to grow and into a form that is unknown in advance has been a key driver in the emergence of a clock concept that only shows greater time changes throughout the day. He asserted that the clock might be lacking the minute hand showing only the hour changes or even the hour hand might be converted into a "day hand" or "month hand" or showing time in a way that only makes sense when seasonal changes appear. The formal concerns for the bonsai concept developed with the cross-sectional appearance of a tree, a clock that lies in the horizontal and shaped in imperfect curves of a tree section.

The third concept was based on the idea of a "timer" inspired by a chess-game set which recalled the image of a chess-timer for Designer E. He asserted that he always wanted to know how much time he spends for a certain job or for anything he is occupied with. The timer clock would point to the amount of time that passed between two events, the specific interval of time. The fourth concept was actually triggered by this third concept which made Designer E think of marking some focal points of time in order to measure the time that has passed until the minute hand or hour hand catches the next mark. The marks as adapted and externally attached to the clocks outer dial are going to make the user remember an up-coming event or point of time that he has been waiting or for which he has been assigned to do something,

to finish a job, to catch up with a friend, etc. Additionally, the marks are going to act like the string tied around a finger to remember a certain thing on the to-do list.

4.5.6 Designer E: Analysis of Analogies

The analysis of the analogy of Designer E for the concept of *emoticon clock* can be found in Table 4.21. The analysis of the analogy for the second concept of bonsai *clock* is in Table 4.22. The analysis of the analogy for the third concept of *timer clock* and the analysis of the analogy for the fourth concept of *reminder clock* can be found in Table 4.23 and in Table 4.24.

Table 4.21 Analysis of Analogy for Concept 1

Functional type	Structural and Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	Bouncing emoticon
Verbal concepts	Suddenness, responding clock
Configurative scheme	A clock that stands still until it is approached and activated with and shaped like an emoticon

Table 4.22 Analysis of Analogy for Concept 2

Functional type	Structural and Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	Bonsai
Verbal concepts	Gradual growth, slowness, preciousness
Configurative scheme	A clock that does not show the minutes or even hours but only major changes in time.

Table 4.23 Analysis of Analogy for Concept 3

Functional type	Structural and Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	Chess timer
Verbal concepts	Timer, passed time, chronometer
Configurative scheme	A clock that makes it easier to understand the time intervals between events or along a job.

Table 4.24 Analysis of Analogy for Concept 4

Functional type	Structural and Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	String tied on a finger
Verbal concepts	Reminder, attached marks
Configurative scheme	A clock that reminds marked points of times of the day corresponding to the planned activities.

4.6 Study 6: Designer F

4.6.1 Designer F Profile

Designer F usually finds it exclusively important to allocate a certain amount of time for concept generation in most of the design projects. However, the projects for which he actually tries to formulate a concept generation phase is around 70% of the total. He additionally states that in cases where the projects are defined beforehand and where only stylistic interventions are expected he does not need generating a concept. He alleges that methods he and his colleagues use differ according to the project and according to the process they have anticipated. In some cases, they think with sketching and in some cases they observe user responses and preferences. Yet, mostly they create inspiration folders for the concept generation of the design projects. Through a search in the internet based on the keywords in terms of which they want to define the product, they come up with a series of images for each concept. For example they search images that convey the notions of "quality" or of "emotional", "attractive" and then make collages of these images so as to construct mood-boards. There have been projects where they also have prepared questionnaires for users to investigate what certain product ranges in certain concepts awaken in user's mind.

He prefers verbal analogies over visual analogies. A kitchen-robot designed in its proportional and associational references referring to the panda has been an example of a visual analogy they have recently used. Verbal concepts like high-tech, of good quality, emotional, attractive are some examples of their search for a concept for a design project.

4.6.2 Designer F Generative Phase

The Black Box navigation process took a total of 31:47 minutes for Designer F where he visited 12 out of the 12 worlds (Table 4.25). Table 4.26 (Appendix F) shows the actions that have been indexed according to their occurrence in the expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.25 Time Segmentation for Designer F

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
31:47 minutes	22:15mins	9:32 mins	12

4.6.3 Designer F Exploratory Phase

Designer F's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and his retrospective interview and shown in a concept space map in Table 4.27 (Appendix F). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer F have been then collected and transformed into a thinking path of concept generation in Figure 4.8.

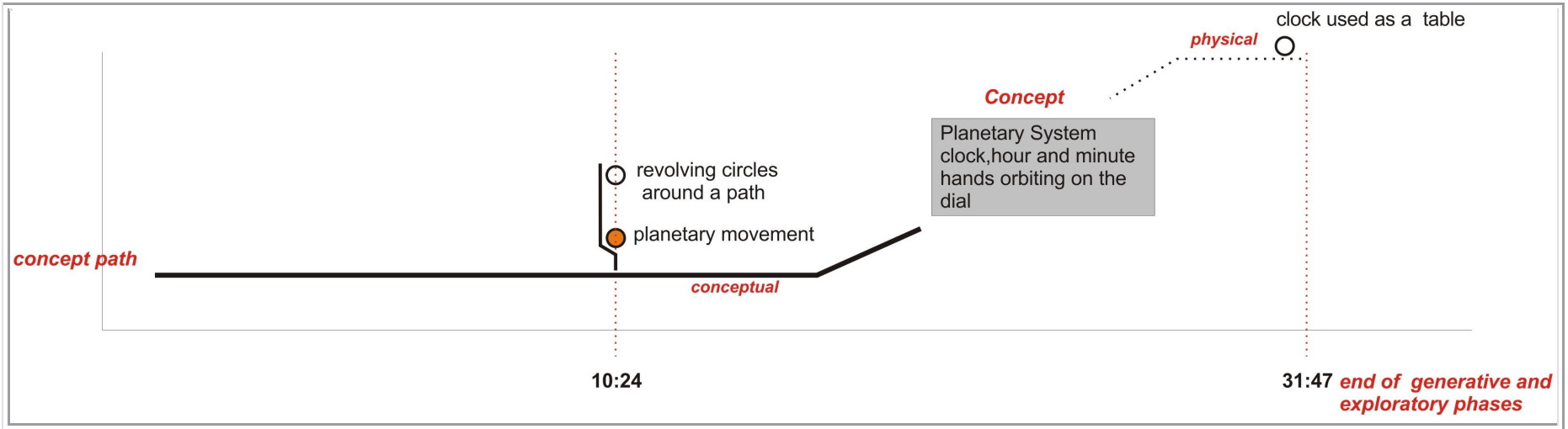


Figure 4.8 Designer F Thinking Path of Concept Design

4.6.4 Designer F Thinking Path of Concept Design in the Generative Phase

Designer F consistently moved up from one world to the next up something came into his mind and at 10:24 he expressed that planetary movement reminds him of the concept of time. After this expression, he carried on navigating and left Black Box at 22:15 with no further expression.

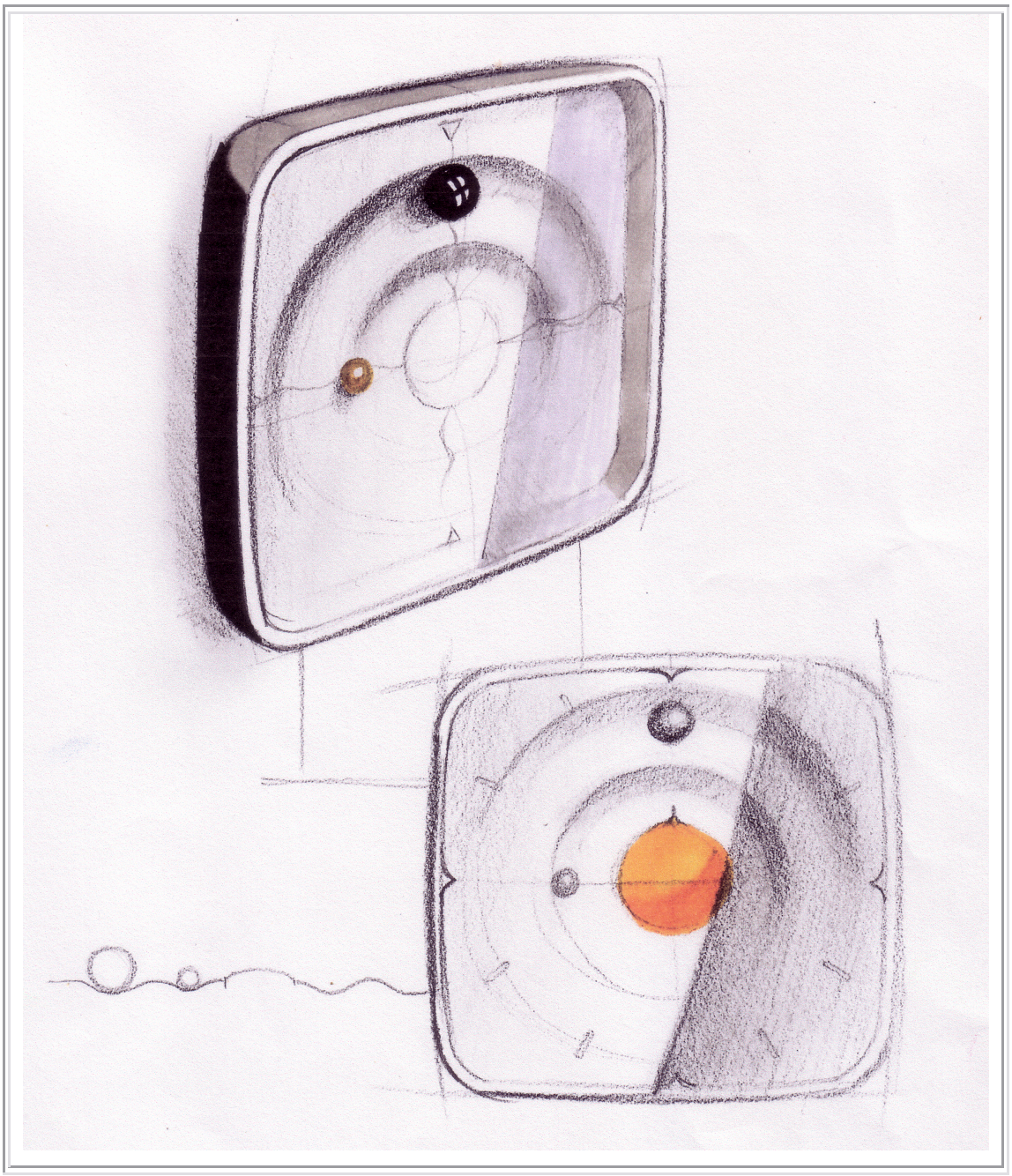


Figure 4.9 Designer F Sketch in Exploratory Phase

4.6.5 Designer F Retrospective Report on Concept Generation in the Exploratory Phase

Designer F has stated that he started the concept generation process with pointless doodling, drawing scratches of lines and curves. As he stated before, he is used to thinking during and through sketching and the thinking process during doodling made him think of a clock that somehow becomes an object of use not just an object to place or hang or wear on something. In accordance with that idea, he thought of a wall's or a coffee table's transformation into a clock. The planetary movement idea being the driving force of the visual appearance for the clock he has designed, he asserted that planetary movement reminds him of time and how it is formed by the movement around. So he tried to convey the idea of passing time through a set of planets moving within the dial of the clock either on the orbit of the hour or on the orbit of the minute. He designed the dial of the clock to have splits embedded within the body and the ball-like hour and minute planets will be moving within the course of those splits.

4.6.6 Designer F: Analysis of Analogy

The analysis of the analogy of Designer F fort he concept of planetary system clock can be found in Table 4.28.

Table 4.28 Analysis of Analogy for the Concept

Functional type	Structural and Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	Planetary system
Verbal concepts	Planets, wall, table
Configurative scheme	A clock that indicates the movement of time through planetary movement where its hour and minute hands act as the planets revolving around the orbits of daytime.

4.7 Study 7: Designer G

4.7.1 Designer G Profile

Designer G thinks that concept generation is not just at the beginning of a newly assigned design of a product but he insists on the fact that concepts can be designed even for details of products which are being re-structured in order to form new derivations from an existing design. He tries to gather experience and knowledge of any kind and emphasizes the importance of the ability to recall certain knowledge at a certain point of time. The scatteredness of his attention to collect as much data as possible from his surroundings shows a parallel echo in his approach to applying methods which is just talking of unrelated subjects or taking a walk until he is stimulated by something.

As for inspiration he never uses Google or any such search engines alike. Whatever he has collected so far during the casual experiences of the day and as a summation of his areas of interest becomes what he believes he will use at some point in the future to solve a design problem. From time to time, he makes use of visual analogies in his design projects. Inspired by the Spaceship1, he has designed a drill which is easy to be used by any user as Spaceship1 was also designed to be operated with basic knowledge of an average astronaut. A visual correspondence has also been constructed by the designer to support the reference of design. In addition to visual analogies, he asserts that he makes use of verbal analogies too. A recent project of his was evoked by the word “wire-monkey” which was a three-armed robot for use in high-current voltage measurement in electrical towers. The wire-monkey progressed on the wires like a monkey and for measuring the voltage level each time two hands touch the wire simultaneously for the very shortest time.

4.7.2 Designer G Generative Phase

The Black Box navigation process took a total of 21:56 minutes for Designer G where he visited 12 out of the 12 worlds (Table 4.29). Table 4.30 (Appendix G) shows the actions that have been indexed according to their occurrence in the

expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.29 Time Segmentation for Designer G

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
21:56 minutes	11:50 mins	10:06 mins	12

4.7.3 Designer G Exploratory Phase

During the generative phase, no cognitive actions have been observed with respect to any kind of mapping process with a reference or association from the Black Box experience but rather the fixed mental image of the designer has been mapped by him into a design idea (Table 4.31 in Appendix G).

The actions that have been observed during the generative and exploratory phases along with the fixed mental image for Designer G have been then collected and transformed into a thinking path of concept generation in Figure 4.10.

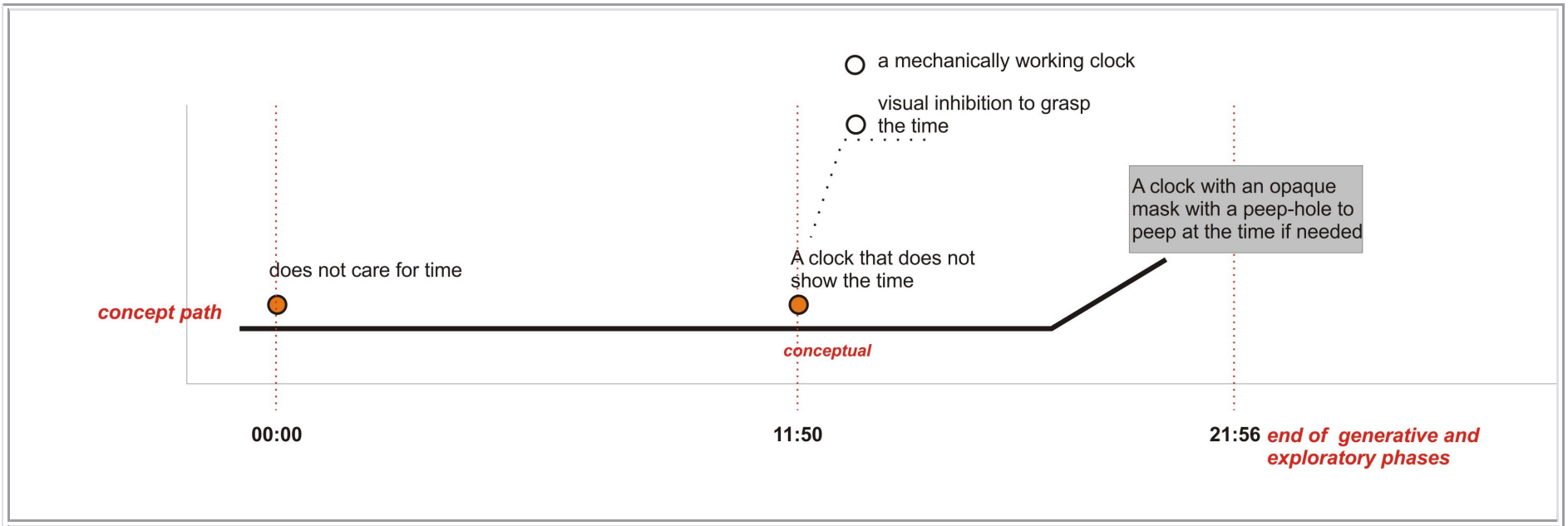


Figure 4.10 Designer G Thinking Path of Concept Design

4.7.4 Designer G Thinking Path of Concept Design in the Generative Phase

Designer G showed no specific perceptual or expressional actions that ended with any retrieval or recall throughout the Black Box experience. The navigation in generative phase for Designer G was rather randomly processed. He kept moving from one world to the other without paying attention to the world components, rather he just jumped in between the worlds several times and without spending much time in any of them. Thus, the product as a result of the generative phase was neither sketched nor written but dictated to the author.

4.7.5 Designer G Retrospective Report on Concept Generation in the Exploratory Phase

Designer G alleged that he did not care for time at all and the concept he had in mind was based on the concept of time in his mind. The first thing that came across his mind was a watch with visual qualities to determine it as such: plain, light, comfortable, neutralized colors like white or chrome. To continue with formal properties he asserted that the dial was plain white with nothing on it regarding to time indicators like digits etc., with only the hour hand on it which however can not be seen without extra effort. The dial would be covered with an opaque second dial having just a small circle of transparency to let the time be read only when needed. He expressed that life with its everyday cycle makes time push harder on people and that's why he did not want to exert more pressure with an ordinary clock to a person's personal life-time.

4.7.6 Designer G: Analysis of Analogy

The resulting concept of Designer G was *time-hostile* clock. There have been no analogies observed neither were any indicated by the designer during the generative or explorative phases.

4.8 Study 8: Designer H

4.8.1 Designer H Profile

Designer H finds concept generation phase highly significant to be able to carry on with the design process but she complains about the restraints of the client's time limits and the sectorial constraints which in many cases end up with either skipping the concept generation phase in a hurry or even not being able to conduct one.

The design process for her is mainly incorporated with the problem definition. She tries to realize what the end product has to answer, having a solution oriented perspective throughout the designing process, that's why the problem definition and the construction of the baseline objectives for the design of a product becomes her utmost concern.

Huge towers made of magazines forms her space of reference when looking for inspiration during a design project. She gradually inspects what the day offers and tries to formulate a proper answer to the question she has been asked. Magazines playing an important role in canalizing her thought in concept generation, she also makes use of the vast pool provided by internet through keyword searches whether related or unrelated to the theme of inquiry.

She asserts that sometimes she happens to use visual analogies pointing out to a recent project of a drawer, the finger pulling part of which is made like a smiley figure.

4.8.2 Designer H Generative Phase

The Black Box navigation process took a total of 25:00 minutes for Designer H where he visited 12 out of the 12 worlds (Table 4.32). Table 4.33 (Appendix H) shows the actions that have been indexed according to their occurrence in the expressional or perceptual levels and located with respect to their time of occurrence and coordinate of occurrence in the Black Box.

Table 4.32 Time Segmentation for Designer H

Total time	Time of navigation	Time of sketching/writing	Visited worlds over 12
25:00 minutes	18:45 mins	6:15 mins	12

4.8.3 Designer H Exploratory Phase

Designer H's mapping actions in conceptual level have been indexed with respect to designer's Black Box map and his retrospective interview and shown in a concept space map in Table 4.34 (Appendix H). Referencing to a point in time during Black Box navigation the type of mapping and the definition of the idea has been indicated.

The actions that have been observed during the generative and exploratory phases along with referenced pre-inventive structures and the inspirational material for Designer H have been then collected and transformed into a thinking path of concept generation in Figure 4.11.

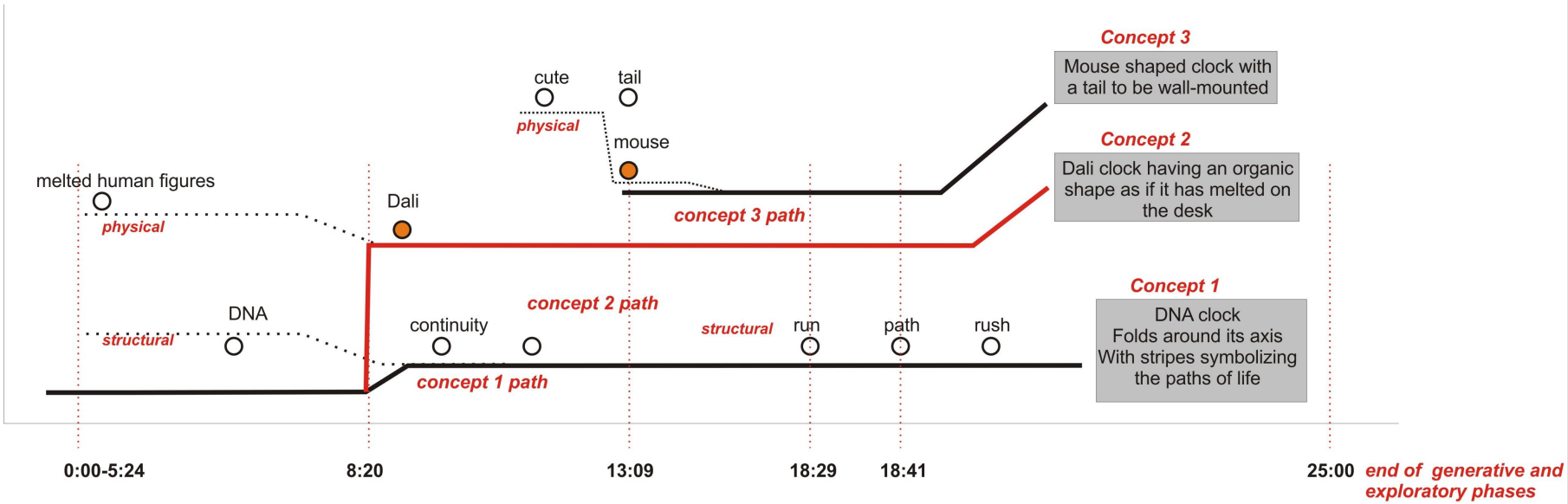


Figure 4.11 Designer H Thinking Path of Concept Design

4.8.4 Designer H Thinking Path of Concept Design in the Generative Phase

Designer H did not show any expressional actions until 8:10 minute but she smoothly navigated in the first four worlds with attention. At 8:10, in Words World, upon seeing the word DNA, she expressed that words can recall many different things to one's mind followed by her expressions on the two concepts that were triggered in World of Innovation at the very beginning of her navigation. At 8:20 she took notes of the verbal concepts that came across: *DNA* and *Dali*. Keeping on with navigation, at 13:09 in Minimal World, she took another note *mouse* but with no further explanation of what she was thinking of or what was crossing her mind about the mouse idea. Then at 18:29 in d-II World she saw the word *run* and instantly noted which was followed by another note-taking action of the word *path* at 18:41 and she ended her navigation with these last two actions.

4.8.5 Designer H Retrospective Report on Concept Generation in the Exploratory Phase

Designer H asserted that, the idea of Dali was evoked by the human figures and faces in the second animation of World of Innovation. The *meltedness* feature in the successive human sketches has made her recall the drawings of Dali, so she thought of a clock with a melted shape and then reconsidered her idea from the viewpoint of whether such a shape could be appropriate for a clock. The next concept that came into her mind was reminded through a series of points in a series of different worlds. The concept prompted by the DNA image in the same animation of World of Innovation was afterwards strengthened by seeing it written in Words World and supported by sub-concepts of running and path which she has successively seen in d-II World's strange train of thought. As a summation of those mainly verbally constructed concepts, she developed the idea of a clock that revolves around the y-axis like the molecular structure of DNA and folds around itself to be placed on a desk horizontally or vertically. The body of the DNA clock was to be striped as lines reminded her of the rush of every day life and the paths one follows always being in a hurry towards something. Then in Minimal World upon seeing the speaker with a tail-like cable, she thought of the image of a mouse which could be assigned

emotional values like sweetness and fun. She visualized the clock image as a mouse with a spherical body and a tail to be wall mounted adding that it would be a cute decorative icon.

4.8.6 Designer H: Analysis of Analogy/Analogies

The analysis of the analogy of Designer H for the concept of *DNA clock* can be found in Table 4.35. The analysis of Designer H's analogy for her second concept of *mouse clock* is in Table 4.36 which is followed by the analysis of the third concept of *Dali clock* in Table 4.37.

Table 4.35 Designer H Analysis of Analogy for Concept 1

Functional type	Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-inventive structure	Molecular structure of DNA
Verbal concepts	DNA, Spiral, continuity, path, run
Configurative scheme	A clock that folds around itself like the DNA and one that has lines around its body assigned the meaning of every day's rush.

Table 4.36 Designer H Analysis of Analogy for Concept 2

Functional type	Surface
Cognitive type	Based on verbal and visual
Mental image/main pre-	Dali paintings

inventive structure	
Verbal concepts	Melted figures,
Configurative scheme	A clock that reminds marked points of times of the day corresponding to the planned activities.

Table 4.36 (continued)

Table 4.37 Analysis of Analogy for Concept 3

Functional type	Surface
Cognitive type	Based on visual
Mental image/main pre-inventive structure	Mouse
Verbal concepts	Mouse, sweet, tail
Configurative scheme	A clock that has a tail like a mouse and shaped like an abstracted figure of a mouse having a funny appearance.

4.9 General Evaluation of the Black Box Study

It is inevitable to admit that designers with different approaches to the design process, considering the disparity between the design projects they are involved in, in their professional life, have shown different styles during the generative and exploratory phases of the study. From the analysis, it appears however, despite differences of the designers, there have been similar aspects in the study.

As a consequence, four distinctive aspects came forth during the evaluation of the user performances during concept generation with the use of Black Box tool.

Regarding the project aims, these aspects appear to be key in determining whether the study met its objectives in the outcomes.

4.9.1 Whether the final concept realized an analogical transfer

From the analysis of the generative and exploratory phases, it has been observed that designers with a fixed mental image of an idea, Designer C and Designer G, have not been able to build an analogy regarding neither formal characteristics of the fixated image nor structural acquaintances with any reference from Black Box or from the knowledge base. Actually, Designer C and Designer G have not even attempted to build an analogy and their generative phases mostly relied on *perceptual level* actions of *navigational* and *cognitive* categories which do not show any cue for what has been going on in the designers' minds. On the other hand, Designer B, also having a fixed mental concept to start the generative phase, has tried to search for formal references for his idea attempting to build visual analogies based on surface relations. Designers with no fixed mental image have been able to realize analogical transfers and mostly individual analogical mappings, regarding visual and structural formation of the concept. Designer A and partly Designer F have used the analogical transfer in finding physical references, spatial references and also conceptual references, whereas Designer B, Designer D, Designer E and Designer H have mostly relied on physical and conceptual references in the analogies they have built.

4.9.2 Whether the concept design was novel or not

As stated in 4.9.1, Designer C and Designer G have fixated concepts throughout the study, that's why the novelty of their concepts has been kept out of the limitations of the evaluation. Designer B had also a fixed mental image which was supported with the help of visual analogies but as it comes to novelty it can be considered to have a novel working mechanism. However, Designers A, D, E, F and H have been able to generate novel concepts for the design of a clock regarding their retrospective reports on the concept's formation and the interestingness of the concepts that have arisen as a result of the exploratory phases. Designer A's Blackboard Clock, Designer D's Misguiding Clock, Designer E's Bonsai Clock, Designer F's Planetary System Clock

and Designer H's DNA clock can be considered within the notion of novelty in terms of their conceptual application of a reference into the design of a clock and also visual novelties in the appearance of a clock.

4.9.3 Whether the concept was evoked by the Black Box experience or not

The fact that the design concept was evoked through the experience of Black Box is important as it is a major point of assessment in the use of the tool. The key concern is that the references that have been used in analogical transfer are evoked through the navigation process in Black Box regardless of its being based on a concept, image, word within the content or not. From this point forward, it can be said that Designer C and Designer G are in no way influenced by the navigational experience, instead they are stuck with what they have visualized in their minds until the end of the exploratory phase. Designer B's first idea was also formed beforehand but the visual appearance has been evoked through a formal search within the contents of Black Box. Alternatively, Designer A and Designer H have based their concepts on associations derived from the world components; Designer A developed from black and white cartoons the Blackboard idea, Designer H from the irregular human forms the Dali idea of the clock design. Having a different cognitive approach, Designers D and F have been influenced by the structural and graphical organization of the tool itself; Designer D developed the fading images into a resolving dial that disappears and re-appears, Designer F developed the connected circles on the scene graphics into the planetary system idea. Designer E, instead, has produced ideas that in a way give reference to his personal experience with time and other things he has been occupied for some time at a certain point; through the former approach developing the idea of a reminder clock and from the latter approach developing the bonsai idea referencing to a leisure pursuit he had for some time.

4.9.4 Whether concept generation involved divergent thinking or not

As stated in the theoretical framework of the study, divergent thinking is counted as a designative attribute of creative thinking. An analysis of the divergent thinking involved, has been conducted according to the number of pre-inventive structures

that have been constructed during the generative phase regardless of whether further explored during concept generation in the exploratory phase. Accordingly, Designer E with the attempt of building analogies of different references in each different world of Black Box has shown a divergent approach in his Black Box experience. Designer A has also tried to generate alternative paths for another design concept. In terms of her effort in building the concept on divergent levels considering the spatial, visual and conceptual implications she can be said to involve a divergent process of thinking throughout the study. On the other hand, Designers C and G have not attempted to look for alternatives other than their fixated images. Designers B, D and F have kept with the first idea that appeared in their minds with no further search for an alternative.

It has been also observed that designers participating in the study, most of the time, verbally expressed the ideas that first came across their minds and tried to develop them through verbal explanation of what they have recalled, triggering a series of other recalls.

4.10 General Outcomes of the Study

4.10.1 Regarding Black Box Tool

The general idea is to capture the construction of the totality of ideas and relations of the designer while he uses the tool. These ideas and relations are formed in the mind of the designer, but also partially made explicit in multiple representations. To a certain extent, the designer will have to use the tool in a way to create nodes and links, according to which his/her ideas and relations are going to be interpreted.

The aim of the envisioned tool has been that the designer will be able to create conceptual mappings for a design concept. These will be then captured by the observer and attached higher-level cognitive information to it with the help of the observational protocol study and a retrospective report on the concept generation from the designer. The ideas and relations are represented internally as nodes and links placed into the path the designers have taken during the use of Black Box. In other words, the designer creates and edits both his/her own physical ideas and

relations, and the representing structure of the system, a frame of reference or idea-space, consisting of nodes and links. The higher-level cognitive information consists of nodes and links, with properties assigned to both. Nodes play the role of pre-inventive structures whereas links show the type of the pre-inventive structure: *physical, structural or conceptual*.

These nodes and links and their properties have made it possible to represent the development of concepts in time, how different ideas shifted during the generative or exploratory phases. The tool and the sessions have thus been able to give an overview of the concepts.

The ability to show the differing states in various ways to the designer, s/he can be made to get a different viewpoint on the nodes of his/her pre-inventive structures which will make it possible for generation and exploration of new concepts.

As stated before in the literature review, it is not easy to see into the conceptual world of the designer and it is also not easy to capture the *conceptual* ideas with the expressional actions made by the designer. In order to do so, it is necessary to handle ambiguous information, represented by sketch, writings and images. To a considerable extent the designer needs to determine what the nodes and links are, since the tool is not able to do so. That is why a retrospective report on the concept generation happened to be appropriate for the aims of the study.

The tool could have been developed in a way to capture what kinds of ideas and relations are made and how many times in the design space throughout the generative phase. In the construction of a design space, it is important to consider how the designer will retrieve the information that's why a general map of the thinking process may be of use in constructing the related scripts to embed within a more advanced computational model of the tool.

4.10.2 Assessment of Black Box

The answers given to the post-questionnaire's second part which was constructed with an aim of assessing tool properties shed light to following points for further development of the tool.

- The interface of the tool is to be more explanatory with a minimal use of metaphorical icons
- The tool can be developed into a wizard for concept generation based on an idea of it's being a general starting kit to design
- The set-up of the scenes can be minimalized to a degree in order to provide ease of navigation within the given time
- The content of the scenes can be developed into a more context-oriented (design-problem oriented) content
- The content of the scenes can be developed into entailing a wider scope of concepts supporting more then one concept
- The tool can be enhanced by integrating user interactivity where the users can add or replace content of the tool transferring it into a kind of visual and conceptual dictionary or library for individual design projects.

In addition to the recommendations for further development of the tool the assessment according to the set items (Appendix L) regarding the content and architecture of the tool is given in Table 4.38 and 4.39. The scores have been calculated as mean values over a 0-4 scale.

Table 4.38 Assessment of Black Box Regarding the Content

Rate of success over 4	Inspirational quality of Black box Worlds	Sufficiency of the content for the given time and problem	Attractiveness of image variation	Distractiveness of image variation
	3.25	3.75	3.75	1.25

Table 4.39 Assessment of Black Box Regarding the Architecture

Rate of success over 4	Ease of navigation	Set-up of the scenes	Use and application of graphics and animations	Use of music
	2.63	3.63	3.75	3.75

4.10.3 A General Thinking Map of the Creative Design Process in Black Box

Through the observation of differing designer styles in the generative and exploratory phases of Black Box, it is seen that there are similar aspects to the process adopted by the designers.

Analyzing further the designers' thinking paths during concept generation in explorative phases, it has been recognized that a common path of the creative design process in the Black Box can be modeled and visualized as in Figure 4.12, which will be useful in terms of the insight it provides into the common aspects of different thinking styles in concept generation and into the formation of scripts to support the Black Box tool with the help of the knowledge organization model it proposes.

As seen in Figure 4.12, in the light of the analysis of the generative and exploratory phases of the designers, two different design paths have been observed. The first path is directed through the subjective stimuli based on the designer's knowledge composed of events and entities referring to any experience of the designer. The second path is directed through the predicative content of Black Box composed of the diverse themes of its worlds. The paths involve nodes on them which point to the pre-inventive structures that arise during the process of concept generation. These nodes are then transformed into concepts through the path with adding or replacing them until a concept reaches its final. Designers taking the *design path of the subjective input* make associations and form analogies based on his/her experience and recalled events whereas designers taking the design path of predicative input

make associations directly with the things they have seen at that moment of time within any scene of Black Box. It is for sure; that the two mentioned paths are not followed in a strictly separated manner rather cross references and connections between the nodes from different databases can be seen which also cites for further development of a concept. The two paths either progressing on the timeline in parallel or in a way of having intersections end with the expression of the concept in an image or in utterance. The concept may be arrived at through a solo of the subjective path, through a solo of the predicative path or through a combination of the subjective and predicative input based design paths.

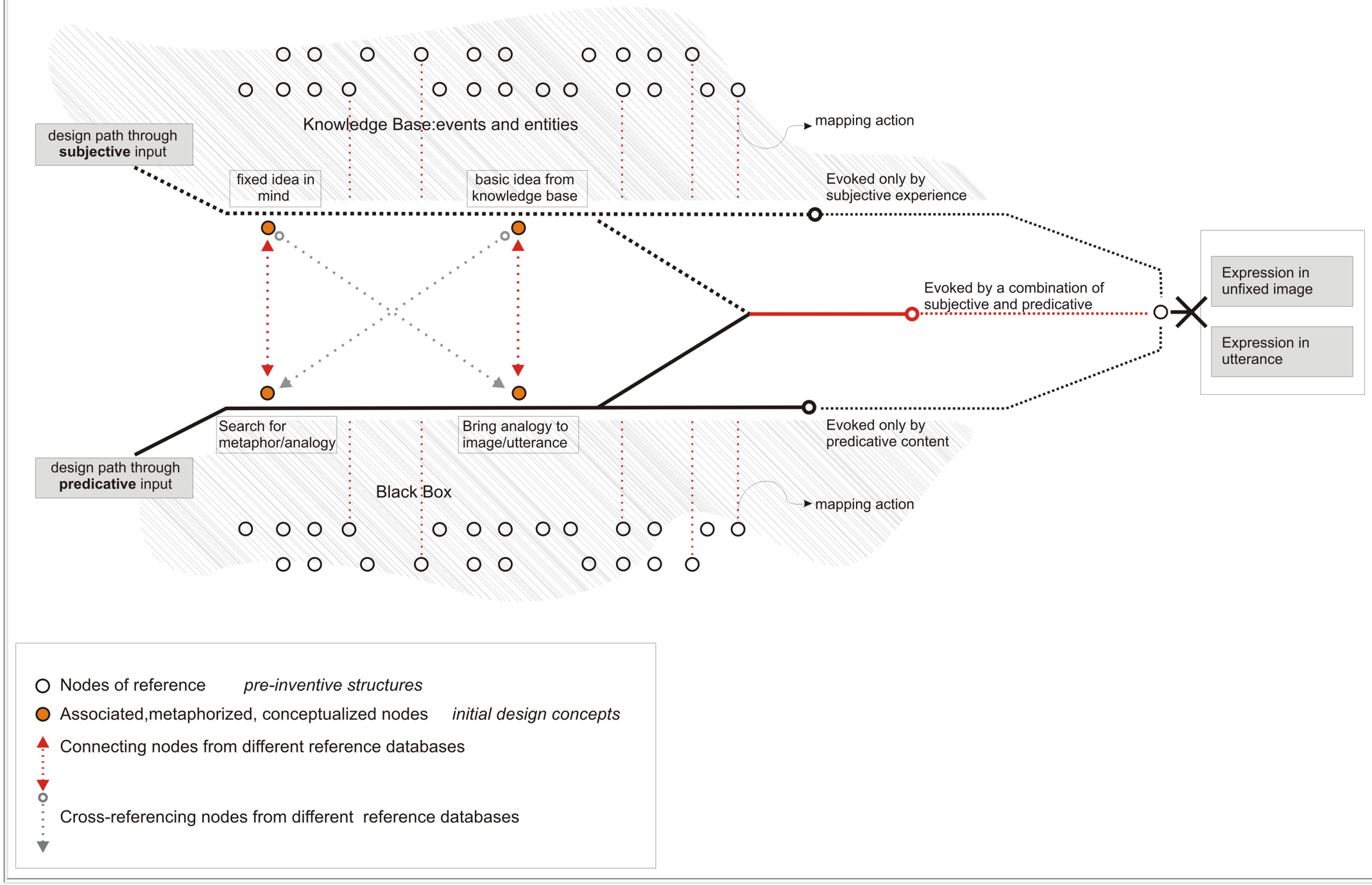


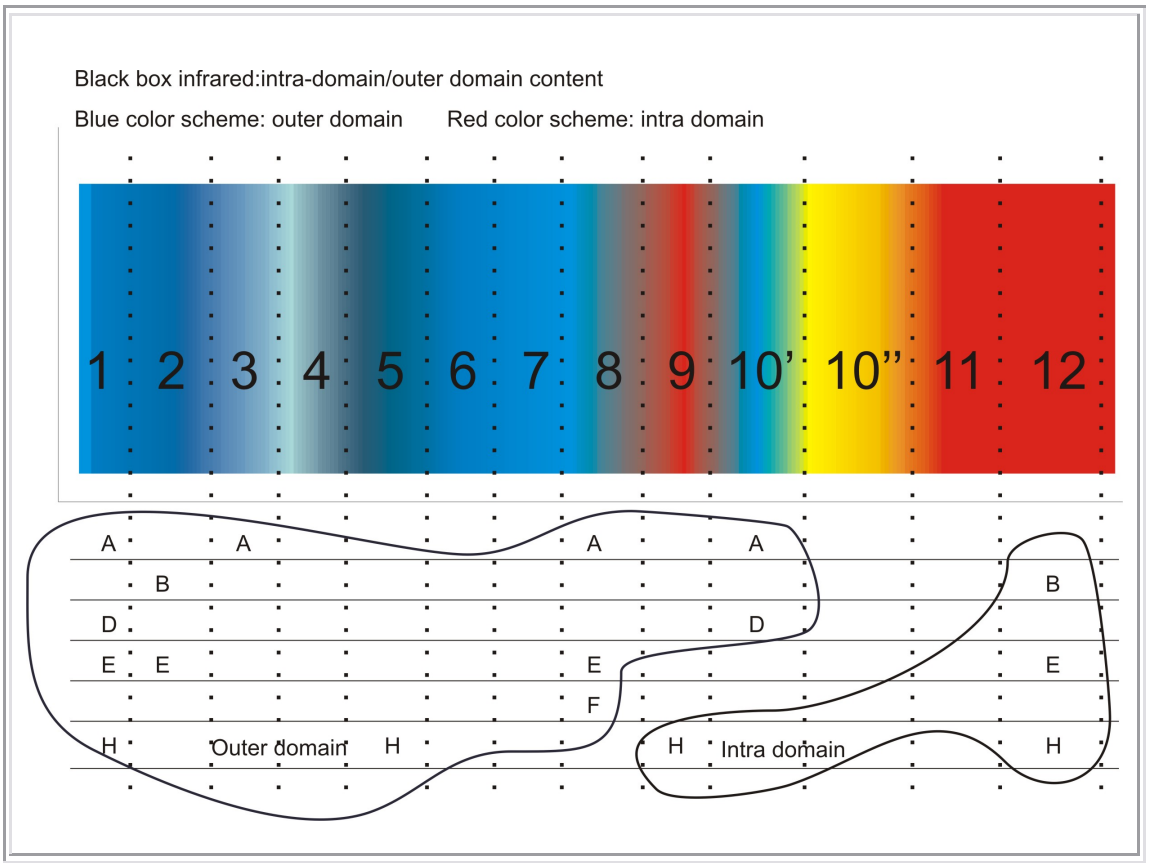
Figure 4.12 General Think Map of the Creative Design Process in Black Box

Table 4.40 Comparison of Designers Black Box Navigation with Concept Generation Paths

	Nav. Time	Total Time	Year of exp.	Experience Area	No. of Concepts	Design path
Des E	45:15	49:20	8	Yacht design Graphic des. Accessory des.	**4**	**Predicative**
Des D	29:19	34:19	20	Furniture Medical eq. Toys	1	Predicative
Des A	17:47	32:02	8	Furniture Lighting architecture	**2**	**Predicative**
Des F	22:15	31:47	25	Automotive House eq. furniture	1	Predicative
Des B	18:38	25:53	7	House eq. Furniture Electronics	1	Subjective
Des H	18:45	25:00	17	Furniture Decoration Accessory	**3**	**Predicative**
Des G	11:50	21:56	8	Electronics Heating Software	1	Subjective
Des C	17:42	20:52	21	Furniture Medical	1	Subjective

Table 4.40 shows that designers with a relatively divergent approach (Designers A, E and H) have reached concepts along the path of predicative input signifying that Black Box with its content has been able to cause formation of various alternatives as concepts. Sectorial backgrounds of Designers A, E and H point to the fact that designers having experiences with parallel areas to product design have shown a more enthusiastic approach to produce different concepts. Furthermore, designers taking a subjective path have been able to create only a single concept mainly

because of a fixated image of them. Year of experience has also been a designative factor in the emergence of the concepts. The three most experienced Designers F, C and D have stuck with one concept and tried to elaborate it rather than trying to look for alternatives. They have also shown a similar approach in their navigation process where they have created their concepts after a long navigation without showing or naming any clue of a concept idea.



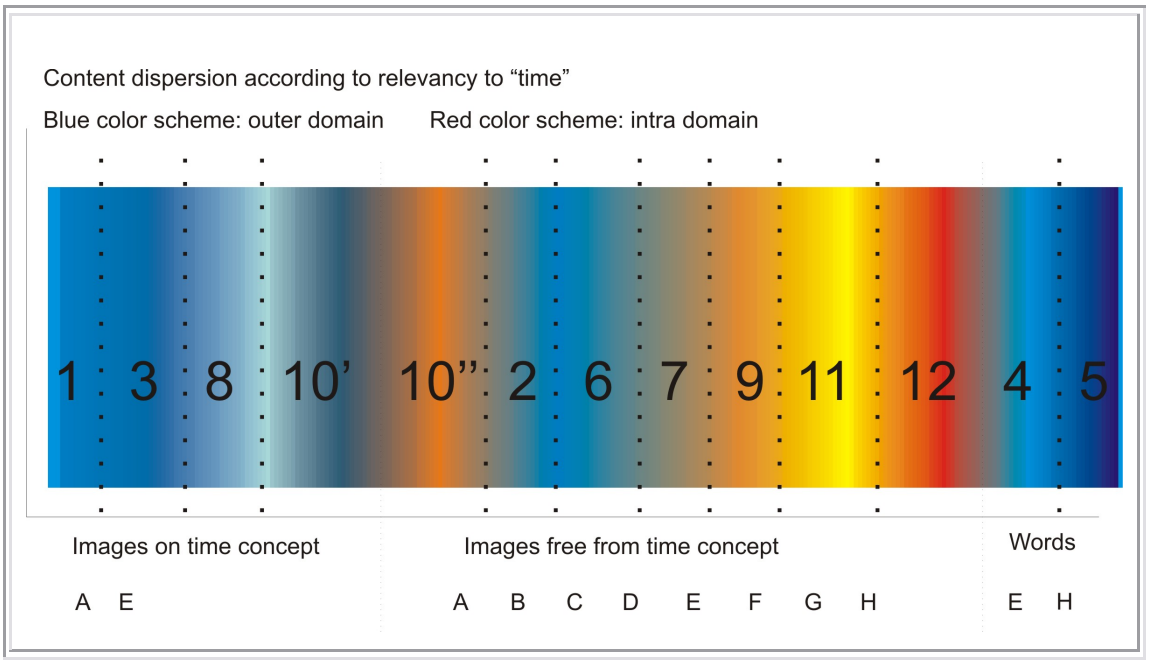
* Numbers 1-12 correspond to the Worlds of Black Box

* Letters A-H correspond to the Designers A-H

Figure 4.13 Dispersion of Designers' Use of Outer-Domain or Intra Domain Content of Black Box

Figure 4.13 indicates that most of the concepts produced by designers with no regards of being formed into a final concept have been triggered through the outer domain content of the Black Box. Designer A for example has come up with

concepts through the influential media in World 1, 3, 8 and 10' and Designer B has based his concept with the help of the Black Box content in World 2 and World 12. (The other designers' inspirational content according to the domain related stimulus have shown in Figure 4.13) Furthermore, it can also be inferred that World 1: Innovation World with the most scattered content among the others has been effective in stimulating Designers' actions at manipulating concepts which shows that image dispersion at the level of irrelevancy is an important stimulator in concept generation.



* Numbers 1-12 correspond to the Worlds of Black Box

* Letters A-H correspond to the Designers A-H

Figure 4.14 Dispersion of Designers' Use of Time Related/Word Related Content of Black Box

As Figure 4.14 indicates that images and animation content independent of the concept of "time" has been more stimulating in the emergence of concepts. Most of the designers have made use of free images to generate concepts. Words, on the other

hand have not been as preferred as the image and animation content of Black Box, however they have been quite useful in building structural analogies. Additionally, it can be said that, the most influential stimulus

CHAPTER 5

CONCLUSIONS

5.0 Overview

This thesis presented the overall architecture and theoretical background behind a study on enhancing creativity in concept generation phase through the implementation and use of a tool, Black Box, for analogical reasoning. The highlighted aspects of the study with respect to the literature review and the empirical study are italicized in this final chapter.

5.1 General Discussions

Assisting creative processes of design is a great area of inquiry of today's design world and one of the ways of this was assisting creativity through the expansion of design space which was the first assumption of this thesis. If we are to turn back to the introduction of this thesis, to special relativity and spatial relativity, it is once more to be stated that common experience highlights certain ways in which observations by individuals differ. As for *spatial relativity*, it might be said that, certain features of the space that is inhabited are conceived of in different manners by different individuals. Phrased in this manner, space appears to be a rather mundane concept. However, when it comes to a time related inspection of space as the study of this thesis focused, an explication of the *experimental dimension of the design space* is set into light. Considering the fact that space is related with our notions of motion which in designing is based on our behavioral actions, it becomes inevitable that the definition of a *design space should plausibly fit the designer behaviors* which also change the space itself.

Such a definition of space has been adapted and presented in this thesis by means of *a virtual design space as an expansion to the concept design space* through which a

study of creativity in concept generation, guided by the principles of *a situated nature of design* has been carried out. The constructed virtual space has helped managing, arranging and storing abundant visual data for a possible triggering of creative occurrence through agents that formalize and conceptualize the retrieved data through the visual bombardment. The selection of virtual as the medium to ground an expansion to the design space has shown great compatibility with the idea of the design space's relativity and interchangeability in as much the virtual

In order to promote designer actions during the concept generation in this virtual space, *analogies have been used as the agents/knowledge transformers* that canalize design behaviors. Analogy making has made it possible for a mutually reinforcing relationship to exist between the *focus on creative occurrence and the experience of a synthesis of various elements into a design concept*. By and large, in the implementation of the system as a supportive tool for creativity, analogies have served as the mechanics of the basis of designer actions in the situated design space.

A pilot study indicated that the meaning associated with the design concept was of crucial importance which held a close connection with the nature of the creative concept generation phase. That is why the study was based on *phenomenological interviews* with eight design consultants to understand their attitude towards the "concept" and the subsequent *concept generation phases in the proposed design space* Black Box. Designer actions in the proposed design space were coded in accordance with their being carried out in the *generative phase* or in the *exploratory phase* of the concept generation where the former stands for the experiential process in the virtual space and the latter stands for the acts on the traditional pen-paper environment.

As a consequence, a qualitative analysis of the interviews in relation with the exploration of the actions in the concept design space yielded a multifaceted explication of the experience of the creative process as it unfolds through time and *eight different thinking paths have been traced*.

Tracing of the thinking paths was realized through decomposition of the spatial experience of the designers. The representation of the thinking maps lead to the discovery of a set of components of the *thinking paths* to be defined; *nodes* and *lines*, nodes referring to pre-inventive structures which are perceived as underlying attributes of concepts and lines referring to the type of these pre-inventive structures. As was anticipated through the spatial relativity, that designers construct their surrounding space of formal and informal deviations in a subjectively relative manner, the thinking paths also displayed different focalizations and scatterednesses according to a convergent or divergent approach the designer has taken.

The *synthesis of the eight thinking paths* in Black Box into a *general thinking path of creative design* was made possible through an investigation of the similarities and differences of designers' construction of their design paths in the concept generation. It has been shown how keywords, images are translated into design concepts and generally developed first in verbal manner and then sketched. The designers' progresses from the abstract to the more concrete level through multiple paths including conceptual and visual characteristics of a concept were revealed through protocol studies and retrospective interviews and represented in the thinking path. This model of thinking path represented the designers' various attempts at manipulating the material at hand through transformation, association and re-representation and the construction of their thinking process in a concept design.

The findings indicate that, rather than simply attempting to identify uniform sets of traits or inclinations amongst creators, it is important to consider the range of individual differences associated with creativity and the acquisition of a model of thinking path can be used for further developments. Overall, the thesis indicates the value of considering experiential and existential aspects of the design space in order to enhance creativity through virtual expansion.

5.2 Research Questions Revisited

This section covers the answers to the research questions set in the first chapter which have been attained through the results and process assessments of Black Box study.

5.2.1 Designers' Preferences to Enhance Concept Generation Phase and Support Creativity

As far as we are concerned with the specific phase of concept generation in design, three key aspects of processes appear to be common to all eight designers in the attempt to support their creativity during this phase: 1) use of internet to diverge around a vast content of visual and conceptual data; 2) need for alienation from the design subject in order to prevent or get over fixation, e.g. take a walk, watch a movie, have a casual talk with a friend etc.; 3) use of surroundings as a source of inspiration (domain related or not related). Yet, at the individual level the role of individual differences is undeniable where some of the designers are much more domain oriented with an analytical approach towards designing in that they prefer field research for supporting their creative abilities and some of them deliberately stay away from the direct domain in order to prevent some influence that may end with an unconscious imitation.

Now, in the light of these analyses it can be said that Black Box providing a concentrated segment of everyday images and concepts in addition to domain related input has provided the designers with the ability to diverge in distant or close phenomena meeting the first common preference. Furthermore, with the alternative set-ups of the worlds with different concepts and the way it serves the data, Black Box can be seen as a medium of a relaxing and alienating experience which sort of maps the surrounding data into its structure through multiple representations meeting the two other common preferences of designers as well.

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5.2.2 Scope of the Effects of Externally Provided Media on Creativity

Despite the fact that all of the designers agreed on the use of visual media as an inspirational source, the attitude towards the scope of use of externally provided data such as images, magazines, internet and books etc., as a source for creativity showed a tripartite approach. The first group found externally provided media as a very powerful source of inspiration which can be used directly in designing. The second group stated that they only use the sectorial data in order to confirm their designs without any concern of creativity and the third group indicated that their use of external data is definitely unrelated with the design experience but based on a relaxation and/or alienation to the problem at hand which they thought is a way to get over conceptual blocks giving way to creative spark.

In addition to these observations, most of the designers alleged that there might not be much time for an extensive search in most of the design projects caused by the client's time limitations. That's why a tool that has been already formed into a collection of external data might be of great use for designers, a Black Box for different concepts varying in the data it contains.

5.2.3 Types of Mentally Simulated Paths of Different Designers

As a result of the Black Box study and in the lights of the traced thinking paths of different designers, two types of mentally simulated paths have been observed. The first type was the *design path through subjective input* where the associations and mappings for the design concept were made through frames of references from the designer's self knowledge base which is composed of his/her own experiences and preferences. The nodes referring to the pre-inventive structures of design on the subjective design path were retrieved from events and entities of individual experiences but the recalling process might be triggered through an agent, a concept, a word or an image from Black Box. The frames of references of the designers for their concept attained through the subjective path might also be absolutely independent of being triggered to be recalled through an element drawn from Black Box content which is then defined as a *mentally fixed image* of the designer which

was already there at the beginning of the design path relying only on personal fixation with a subject. The second type of the mentally simulated path was the *design path through predicative input* where the associations and analogies were formed through frames of references from the Black Box content. This path of design has been named as predicative as in the situated design context of this study, the content of Black Box was determined in advance with no reference to any designer's preferences but it was organized in high order rankings of generic databases of images and verbal expressions.

It would be unfair to state that these two design paths are followed strictly in a separated manner. On the contrary, these two parallel paths of thinking do connect to each other through the connecting and cross-referencing of the nodes placed on them. As for the output concept, it can be said that the two different paths might end in representations of concepts through pictorial or verbal expressions separately or a combination of the two can be observed in the formation of the concept.

5.2.4 Ways of Enhancing Designers' Divergent Thinking during Concept Generation through a Virtual Tool

Many people still find the concept of "the virtual" a highly abstract one, in part because it implies total intangibility, and in part because it is most often associated with computers. Yet an undeniable fact is that virtual has opened a space for designers and non-designers as well through the opportunity of the *infinite.* A virtual tool in this respect can enhance designer performance in divergent thinking through the following aspects which have been observed through the implementation and results of the Black Box study.

1. A virtual tool providing a concentrated and unknown experience and preventing disturbances of mental processes with the implementation of suitable scenarios can place the user in a state of relaxation which encourages creativity during concept generation phase. This state can be changed by variation of the virtual environment and be directed into an arousing series of visual stimuli to let the designer think in ways s/he is not used to.

2. A virtual tool providing immense amount of data in terms of visual references can act as a visual-virtual library for designers that will provide a new search space for the designer which is developed and expanded for diverging ideas.

3. A virtual tool that permits information to be presented visually, acoustically and, in the future, haptically can help use of multimodal stimuli to trigger unusual associations in the knowledge memory and cause a divergent thinking.

4. The combination of a virtual tool with genetic algorithms can offer a new perspective in divergent thinking. In a form of "computer brainstorming", the designer would have the possibility of controlling the process by assessment and selection of the generations of the computer.

5.3 Implications of the Study

Implications of the Black Box study are presented according to the tools' implementation within as a support in design education and in professional design life of a designer.

5.3.1 Implications for Design Education

An ideal way to cognitively interact with one's own design path is to discover as many hidden visual/spatial features in the process as possible. Doing this, removing the shadow on the design thinking process, will provide a designer with clues about him/herself leading a higher possibility of a creative idea to take place in that s/he will be aware of how s/he is stimulated. The thinking paths that have been constructed can be used as a part of the design process to better understand one's own capabilities in addition to recognizing several different types of thinking paths of designers to adapt, providing a means for divergent thinking which will enhance creativity. The results of this thesis have also shown hints on how to discover latent emergent structures in everyday objects through relations, visual features with the

help of analogical reasoning. These could be used as plausible ways to educate novice designers about concept generation.

5.3.2 Implications for Design Support

Improvement of the quality of design processes can be facilitated by appropriate and useful support by computational tools. The presented research has implied the significance of enhancement of cognitive and perceptual interaction with a wide range of data of different domains through a virtual tool.

From the gathered feedback, it can be concluded that the operationality of the tool facilitates thinking about a variety of relations, multiple associations, exploration of visual metaphors and abstractions triggering creativity in a positive manner. Being an alternative to systematic approaches of supporting creativity, this study and the implemented tool can be used in the early design phase for supporting concept generation. The author is considering semantic networks, neural networks, and fuzzy logic to support the envisioned functionality of the tool. Interaction with the designer can be formed in giving him/her feedback on the actions s/he has executed showing how s/he shifted between ideas or parts of the one idea which will result in a more effective use of the tool in supporting creativity in early phases of design.

5.3 Suggestions for further Study

A further investigation into perception and its consequences in similarity based reasoning, on the methods of relaxation of different individualities and on context dependent design problems can be used in simulating and constructing new virtual spaces for designers but with a more three dimensional quality. The effect of perception on design is undeniable especially if the concept is going to be formed through analogical mapping based on associations. The virtual being a tool and also a medium which is capable of imparting complex entities where the high immersion of user is achieved through influencing perception and thus his/her consciousness can cause variations in the types of associations and retrievals. Virtual design rooms can be constructed having different qualities based on the use of knowledge within the

rooms. For example a concept of a table to evoke sad feelings can be tried to be sought in a design room that is filled with virtual material awakening sad feelings allowing the designer to experience in a denser way causing him/her to associate more accurately when structural relations are taken into consideration. The idea of a virtual tool to expand the design space that collects a wide range of visual and verbal data to support associative thinking can thus be developed into the idea of a real expansion of design space for generation of creative concepts.

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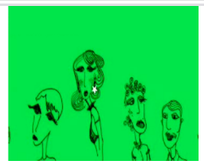
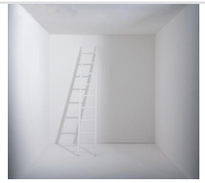
APPENDICES

APPENDIX A: Designer A Black Box Map and Concept Space Map

Table 4.2 Designer A Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
1:08 min	Perceptual	Cognitive	T	Thinking Moves the mouse over the animation sequence	World 1: World of Innovation Animation 1			
1:36 min	Expressional	Drafting	S	Sketching Doodles a **blackness** and leaves **white** parts in it	World 1: World of Innovation Animation 1		Blackboard	Conceptual
1:41 min	Expressional	Drafting	NT	Note Taking writes down: **"blackboard,** irregular figures"	World 1: World of Innovation Animation 1		Irregular figures as time indicators	Physical
2:05 min	Perceptual	Navigational	SdNav	Stopping during navigation	World 2: Natural Chroma World			
2:45 min	Perceptual	Cognitive	T	Thinking (aloud) Times of our lives-times of the day	World 3: Old Times World		Times of our lives	Conceptual
4:17 min	Expressional	Drafting	NT	Note Taking writes down: "old photos, each replacing a number; pushpins"	World 3: Old Times World Image12		Memory board	Conceptual and Physical
5:47 min	Expressional	Verbal	Vex	Verbal Expression Randomness of the scattered ladybugs appears attractive	World 4: Empty World Image3		Random orientation	Physical
6:17-6:59	Perceptual	Navigational			World 7: Colors World			

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
7:19 min	Expressional	Drafting	NT	Note Taking “passing, walking away”	World 8: World of Times Image 6			
7:30 min	Expressional	Drafting	S	Sketching Draws circles that are connected to each other, randomized manner not forming perfect circle	World 8: World of Times Image 6		A connected network of images	Physical
7:54 min	Perceptual	Cognitive	T	Thinking aloud	World 8: World of Times			
9:00-10:39	Perceptual	Navigational			World 9: Minimal World			
11:10 min	Expressional	Drafting	NT	Note Taking “wall mounted blackboard”	World 10: White World Room1 Image 6		A space for the installation of the blackboard	Structural and Physical
11:30 min	Expressional	Drafting	NT	Note Taking “different colors”	World 10: White World Room2 Image 11		Retro-reminiscent shapes Filleted rectangles	Physical
11:35 min	Expressional	Drafting	S	Sketching Derives form from image 11	World 10: White World Room2 Image 11			
14 :52 min	Perceptual	Cognitive	T	Thinking Moves the mouse over the image sequence	World 11: d-1 World			
14:54 min	Expressional	Verbal	Vex	Verbal Expression Avoids worlds directly related with clocks or	World 11: d-1 World			

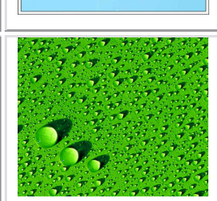
				designed objects to escape formal influence.				
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
16:09 min	Expressional	Verbal	Vex	Verbal Expression Different images makes one recall different things	World 6: Cardboard world			
17:47 min	Perceptual	Navigational	RP	Returning to a prev. visited pic. /animation	World 1: World of Innovation Animation 1			

Table 4.3 Designer A Concept Space Map

Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea reference**
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	Draws a blackboard based on the association of white figures on black background	Action 1:36
	Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component	Draws irregular time indicating figures on the blackboard based on the visual effects caused by the human sketches	Action 1:41
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	Based on the concept of time ,constructs the idea of a clock that is segmented into 12 different parts of a person’s life	Action 2:45
	Conceptual	Mapping	MIS	Maps an idea with the inherent structure of a world component	Draws a clock dial that can be used like a memory board and times that are to be signed are to be indicated with push-pinned notes, photos etc.	Action 4:17
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The network of circles of the World 8 and the randomness concept are combined into the random connected circles idea	Actions 7:19 and 7:30
	Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component	Thinks of young people bedrooms for the installation of the blackboard inspired by the cubical white rooms	Action 11:10

APPENDIX B: Designer B Black Box Map and Concept Space Map

Table 4.7 Designer B Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
0-2:15mins	Perceptual	Navigational			World 1: World of Innovation			
2:15 min	Expressional	Verbal	Vex	Verbal Expression Water drops and their minimal appearance Transparent drops on colored backgrounds	World 2: Natural Chroma World Image 5		Water drops	Physical and Conceptual
2:45 min	Perceptual	Navigational	SdNav	Stopping during Navigation	World 2: Natural Chroma World Image 11-12	 	Minimalism transparency	Physical
3:10-4:30	Perceptual	Navigational			World 3: Old Times World			
4:30-5:20	Perceptual	Navigational			World 4: Empty wWorld			
5:20 min	Perceptual	Navigational	SdNav	Stopping during Navigation Stopping the word chains, searching for an interesting combination of words	World 5: Words World	Armadillo-mercury-anime-myaaaww		
5:40 min	Perceptual	Cognitive	T	Thinking aloud What he could produce using the words	World 5: Words World	He is interested in planet names		
7:34-9:14	Perceptual	Navigational			World 6: Cardboard world			

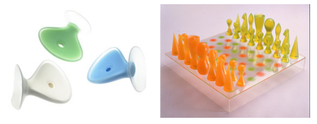
9:14-10:00	Perceptual	Navigational			World 7: Colors world			
10:00-11:00	Perceptual	Navigational			World 8: World of Ttimes			
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
11:00-13:05	Perceptual	Navigational			World 9: Minimal World			
13:05 min	Perceptual	Navigational	SdNav	Stopping during Navigation	World 10: White World Room2		Smooth horizontal surface	Physical
14:28-15:43	Perceptual	Navigational			World 11: d-I World			
17:17 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 12: d-II World point: grasses		Plexiglass	Physical
18:38 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 12: d-II World point: average			

Table 4.7 (continued)

Table 4.8 Designer B Concept Space Map						
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	MFI	Maps a mental fixed idea as the design concept	Reed role mechanism as the basic mechanism of the clocks hour and minute hands movements on the dial	Personal interest
	Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component	Two drops on a smooth surface as minute and hour hands	Action 2:15
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The idea of minimalism and transparency are mapped into the physical appearance features of the clock with the selection of material as plexiglass transparent/translucent or of various colors	Actions 2:45, 17:17, 18:38
	Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component	The horizontality of the cd player on white surface the erection of an horizontal standing clock	Action 13:05

APPENDIX C: Designer C Black Box Map and Concept Space Map

Table 4.12 Designer C Black Box Map

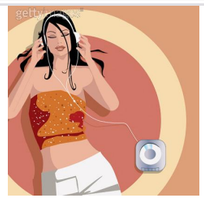
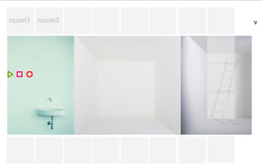
Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
0-2:41mins	Perceptual	Navigational			World 1: World of Innovation			
2:41-4:15 mins	Perceptual	Navigational			World 2: Natural Chroma World			
4:15-5:26	Perceptual	Navigational			World 8: World of Times			
5:26-6:40	Perceptual	Navigational			World 7: Colors World			
6:40 min	Perceptual	Cognitive	T	Thinking	World 4: Empty World			
8:06 min	Perceptual	Navigational	RP	Returning to a prev. visited pic. /animation Watches the animation two times	World 4: Empty World			
8:06-9:17	Perceptual	Navigational			World 10: White World			
10:45 min	Expressional	Verbal	Vex	Verbal expression That the clock has to be wearable at anything anyplace on the human body or clothing	World 11: d-1 World			
11:28	Perceptual	Navigational	SdNav	Stopping during navigation	World 9: Minimal World			
14:16-17:12	Perceptual	Navigational			World 12: d-II World			
17:12-17:42	Perceptual	Navigational			World 6: Cardboard World			

Table 4.13 Designer C Concept Space Map						
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	MFI	Maps a mental fixed idea as the design concept	Clock as a wearable fabric-like accessory	

APPENDIX D: Designer D Black Box Map and Concept Space Map

Table 4.15 Designer D Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
3:05 min	Expressional	Verbal	Vex	Verbal Expression How Mc. Donald's started the business with Milk-shake idea	World 1: World of Innovation Animation1			
3:32 min	Expressional	Verbal	Vex	Verbal Expression He wants to navigate in all the worlds thoroughly	World 1: World of Innovation Animation2			
5:02-8:00	Perceptual	Navigational			World 2: Natural Chroma World			
8:00-11:00	Perceptual	Navigational			World 3: Old Times World			
11:00 min	Perceptual	Cognitive	T	Thinking Reads the lines of Sylvia Plath carefully	World 4: Empty World			
12:00-14:00	Perceptual	Navigational			World 5: Words World			
14:00-16:00	Perceptual	Navigational			World 6: Cardboard World			
16:00-17:05	Perceptual	Navigational			World 7: Colors World			
17:05-18:00	Perceptual	Navigational			World 8: World of Times			
18:00-20:00	Perceptual	Navigational			World 9: Minimal World			
20:00 min	Expressional	Drafting	NT	Note taking Perceptual illusion/	World 10: White World		Fading images	Physical and Conceptual
20:10 min	Expressional	Verbal	Vex	Verbal Expression A clock that is misguiding in its perception	World 10: White World		Misguiding clock	Structural and Conceptual

				Inspired by the fading squares in the scene				
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
20:10-25:19	Perceptual	Navigational			World 11: d-I World			
25:19-29:19	Perceptual	Navigational			World 12: d-II World			

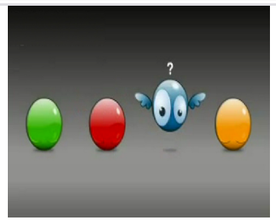
Table 4.15 (continued)

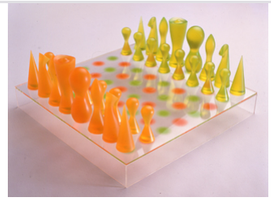
Table 4.16 Designer D Concept Space Map

Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	MIS	Maps an idea with the inherent structure of a world component	Maps the idea of fading and appearance of the Black Box content in World 10 to the idea of a clock which stops when not looked for a certain amount of time	Action 20:00

APPENDIX E: Designer E Black Box Map and Concept Space Map

Table 4.19 Designer E Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
1:17 min	Expressional	Verbal	Vex	Verbal Expression Bouncing emoticon like characters	World 1: World of Innovation Animation 1		Emoticon shape	Physical
3:05 min	Expressional	Verbal	Mv	Music Turns music volume up	World 1: World of Innovation Animation 1			
3:60 min	Expressional	Verbal	Vex	Verbal Expression Suddenness, the clock shows nothing unless approached and then suddenly it shows the time	World 1: World of Innovation Animation 1		Suddenness	Conceptual
4:30 min	Expressional	Drafting	S	Sketching Draws the emoticon like thing and .rings around it indicating sudden movement	World 1: World of Innovation Animation 1			
5:57 min	Expressional	Verbal	Vex	Verbal Expression Mentions of bonsai planting, how it is a long process. Bonsai grows very slowly and each time to an unpredicted form. The clock may make time appear slower by exclusion of minute hand	World 2: Natural Chroma World Image		Bonsai tree	Conceptual
6:15 min	Expressional	Drafting	S	Sketching Doodles a cross-section of a tree as the dial of a	World 2: Natural Chroma World			

				clock				
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
8:04 min	Expressional	Drafting	NT	Note Taking	World 3: Old Times World			
16:12 min	Expressional	Verbal	Vex	Verbal Expression Recalls previous experience with a lighter in the form of deer Thinks of a clock in the form of a ladybug	World 4: Empty World		A clock in the form of ladybug	Physical
18:38 min	Perceptual	Navigational	Sd Nav	Stopping during navigation Tries to find a meaningful series of words	World 5: Words World	Upright, pacman, way, furious, dovetail		
21:40 min	Expressional	Sound	Mv	Changes Music	World 6: Cardboard World			
21:40-23:00	Perceptual	Navigational			World7: Colors World			
23:10 min	Expressional	Verbal	Vex	Verbal Expression States interest in old type clocks	World 8: World of Times			
25:00-26:10	Perceptual	Navigational			World 9: Minimal World			
26:10-30:00	Perceptual	Navigational			World 10: White World			
30:00-32:00	Perceptual	Navigational			World 11: d-1 World			
32:00 min	Expressional	Verbal	Vex	Verbal Expression Chess timer Expresses that he always wanted to see how much time he spent for a certain work.	World 12: d-II World		A clock that acts like a timer	Structural

Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
37:08 min	Expressional	Drafting	S	Sketching Draws visual corresponding image for a chesstimer	World 12: d-II World			
37:19 min	Expressional	Verbal	Vex	Verbal Expression The convention of tying a string around a finger as a visual reminder can be used in a clock A watch with adjustable parts as reminders	World 12: d-II World		A clock that acts like a reminder	Structural and Physical
37:40 min	Expressional	Drafting	S	Sketching Sketches the image in his mind corresponding to the clock idea with reminders	World 12: d-II World			
40:12 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation Tries to think of a clock concept for the spaces/rooms he sees	World 10: White World Room1			
45:15	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 3: Old Times World			

Table 4.20 Designer E Idea Space Map

Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	MPS	Maps an idea with the physical structure of a world component	Emoticon-like shaped clock	Action 1:17
	Conceptual	Mapping	MIS	Maps an idea with the inherent structure of a world	The activation mechanism of the emoticon-clock with the	Action 3:60

				component	suddenness concept of the emoticons' appearance on the animation frame (World of Innovation-Animation1)	
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	Bonsai concept derived from a tree trunk is the driving concept of the clock that shows time as if it is so precious that it can not be expressed with minutes but with larger amounts of time	Action 5:57
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	Timers associated with the chess game forms the basic idea of a clock that acts like a timer between deadlines of work and other types of occupation	Action 32:00
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The timer idea triggers the idea of marking times to remember that something is up to be done until then. The reminder clock idea is associated with the habit of tying strings around a finger to remember significant moments of daytime.	Action 37:19

Table 4.20(continued)

APPENDIX F: Designer F Black Box Map and Concept Space Map

Table 4.26 Designer F Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
0:00-2:59	Perceptual	Navigational			World 1: World of Innovation			
2:59-4:56	Perceptual	Navigational			World 2: Natural Chroma World			
4:56-6:13	Perceptual	Navigational			World 3: Old Times World			
6:25 min	Expressional	Verbal	Vex	Verbal Expression He finds the image series impressive	World 4: Empty World			
7:18-8:46	Perceptual	Navigational			World 5: Words World			
8:46-9:16	Perceptual	Navigational			World 6 : Cardboard World			
9:16-10:14	Perceptual	Navigational			World 7: Colors World			
10:24 min	Expressional	Verbal	Vex	Verbal Expression Planetary movement	World 8: World of Times		Planetary movement	Physical and Structural
12:00-13:55	Perceptual	Navigational			World 9: Minimal World			
13:55-16:52	Perceptual	Navigational			World 10: White World			
16:52- 20:26	Perceptual	Navigational			World 11: d-I World			
20:26-22:15	Perceptual	Navigational			World 12: d-II World			

Table 4.27 Designer F Concept Space Map						
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The visual and graphical structure of World8: World of Times, the differing circles that are connected to each other and many others appearing and disappearing gradually reminded the idea of planetary movement.	Action 10:24
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The planetary movement triggered the idea of expressing time with planets	Action 10:24

APPENDIX G: Designer G Black Box Map and Concept Space Map

Table 4.30 Designer G Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
0:00-2:00	Perceptual	Navigational			World 1: World of Innovation			
2:00-2:44	Perceptual	Navigational			World 12: d-II World			
2:44-3:25	Perceptual	Navigational			World 11: d-I World			
3:25-3:48	Perceptual	Navigational			World 10: White World			
3:48-4:03	Perceptual	Navigational			World 9: Minimal World			
4:03-4:20	Perceptual	Navigational			World 8 : World of Times			
4:20-4:38	Perceptual	Navigational			World 7: Colors World			
4:38-5:10	Perceptual	Navigational			World 6: Cardboard World			
5:10-5:15	Perceptual	Navigational			World 4: Empty World			
5:15-5:25	Perceptual	Navigational			World 5: Words World			
5:25-5:30	Perceptual	Navigational			World 3: Old Times World			
5:30 min	Perceptual	Navigational	SdNav	Stopping during Navigation	World 2: Natural Chroma World Image 4			
5:30 min	Perceptual	Cognitive	T	Thinking	World 2: Natural Chroma World			
6:16 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 3: Old Times World			
7:05 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 11: d-I World			
11:14 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 4: Empty World			
11:45 min	Perceptual	Navigational	RP	Returning to a previously visited picture/animation	World 7: Colors World			

Table 4.31 Designer G Concept Space Map						
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Fixation	MFI	Maps a mental fixed idea as the design concept	The fact that time does not mean anything to him and his personal avoidance for looking at what time it is at the actual moment has been transformed to the idea of a clock that does not show the time in an evident manner.	

APPENDIX H: Designer H Black Box Map and Concept Space Map

Table 4.33 Designer H Black Box Map

Action Time	Action Level	Action Category	Action Type	Action Definition	Action Coordinate	Action Related Black Box Content	Pre-inventive Structure	Type of Pre-inventive Structure
0:00-5:24 min	Perceptual	Navigational			World 1: World of Innovation			
5:24-5:54	Perceptual	Navigational			World 2: Natural Chroma World			
5:54-7:00	Perceptual	Navigational			World 3: Old Times World			
7:00-8:10	Perceptual	Navigational			World 4: Empty World			
8:10 min	Expressional	Verbal	Vex	Verbal Expression Words can recall many different things	World 5: Words World			
8:20 min	Expressional	Drafting	NT	Note Taking “DNA, Dali”	World 5: Words World		DNA shaped clock	Conceptual and Physical
8:20-9:10	Perceptual	Navigational			World 6: Cardboard World			
9:10-10:58	Perceptual	Navigational			World 7: Colors World			
10:58-12:15	Perceptual	Navigational			World 8: World of Times			
13:09	Expressional	Drafting	NT	Note Taking “mouse”	World 9: Minimal World Image 5		Mouse shaped clock	Physical
14:34-15:57	Perceptual	Navigational			World 10: White World			

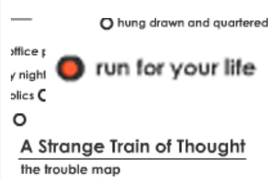
15:57-16:38	Perceptual	Navigational			World11: d-I World			
Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Action Coordinate**	**Action Related Black Box Content**	**Pre-inventive Structure**	**Type of Pre-inventive Structure**
18:29 min	Expressional	Drafting	NT	Note Taking “run”	World 12: d-II World		Time concept in relation with being in hurry, running from one state towards the other	Conceptual
18:41 min	Expressional	Drafting	NT	Note Taking “path”	World 12: d-II world			Conceptual

Table 4.33 (continued)

Table 4.34 Designer H Concept Space Map

Action Time	**Action Level**	**Action Category**	**Action Type**	**Action Definition**	**Idea Definition**	**Idea Reference**
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component	The human figure drawings in the first animation recalled the paintings of Salvador Dali and the idea of a clock that has a melted-like appearance evoked	Action 8:20
	Conceptual	Mapping	MPS	Maps an idea with the physical structure derived from a world component	A clock that revolves around the y-axis like the DNA structure which has struck the designer in Words World	Action 8:20
	Conceptual	Mapping	MPS	Maps an idea with the physical structure derived from a world component	A clock that is shaped like a mouse, having a tail as the pendulum	Action 13:09
	Conceptual	Mapping	Assc	Maps an idea with an association derived from a world component		

APPENDIX I: Pilot Study Pre Interview Sheet

This questionnaire is intended to assess the designer's approach to design process. It may be used freely with acknowledgement to the author. For each of the following statements, please circle one of the points on the scale to indicate how much you agree or disagree with it.

On Personal

1. Age & Sex

…… F M

2. Grade

…….

On Concept

1. I find the "concept generation phase" of the design process essential to go further with a design.

Strongly disagree ○	Disagree to some extent ○	Neutral ○	Agree to some extent ○	Strongly agree ○

2. I find externally provided media; such as images, words to be inspirational during the concept generation phase.

Strongly disagree ○	Disagree to some extent ○	Neutral ○	Agree to some extent ○	Strongly agree ○

3. I like to name my designs.

…….

If yes, can you name a few?

…….

4. Have you ever used a visual or verbal analogy in your design projects during your academic life?

…….

If yes, please explain.

…….

APPENDIX J: Pilot Study Post Questionnaire Sheet

This questionnaire is intended to assess the designer's approach to design process. It may be used freely with acknowledgement to the author. For each of the following statements, please circle one of the points on the scale to indicate how much you agree or disagree with it.

1.I find the "black box" interesting to navigate within

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

2.I find the "black box" innovative to increase creativity

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

3.The navigation process in the "black box" was very helpful for me.

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

4.The images and the words provided in the "black box" were very inspiring for me.

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

5.The images "……." and/or the words "……" exceptionally triggered my initial design idea.

6.World "……..” was much more inspiring to me when compared to others.

7.I could use analogy/analogies in my design in accordance with the provided media in the “black box”.

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

8.I feel satisfied with the end idea I have created.

strongly disagree	Disagree to some extent	Neutral	Agree to some extent	Strongly agree
○	○	○	○	○

APPENDIX K: Black Box Main Study Pre Interview

On concept…….

1. Do you find the concept generation phase of the design process essential to go further with a design?

2. Do you find it necessary to generate a concept for all your design projects?

3. In your approach to concept design, do you consider yourself to be an analytic thinker or an associative thinker?

4. Do you use any methods to support the concept generation phase?
If so, what are these methods?
.....
.....

5. Do you use externally provided media, such as magazines, websites, books, for inspiration during your concept generation phase?

If yes, please explain the type of media that you use, your way of using these media and how you select material from this media?
.....
.....

6. Do you give names to your designs? If yes, what do you base these names on, how do you come up with a name?
.....
.....

7. Do you use visual analogies in your design projects?

If yes, please give examples.

.....

8. Do you use verbal analogies in your design projects?

If yes, please give examples.

.....

.....

9. How do you decide on whether the idea you come up with is the final concept for your project?

.....

.....

10. In general, how long does the concept generation phase take for you?

.....

.....

11. How do you continue with the design process when the concept generation phase is over?

.....

.....

APPENDIX L: Black Box Main Study Post Assessment Questionnaire

On Black Box Experience…….

1. Which worlds did you mostly prefer to navigate in?

W1 : World of Innovation			W7 : Colors World	
W2: Natural Chroma World			W8: World of Times	
W3: Old Times World			W9: Minimal World	
W4: Empty World			W10: White World	
W5: Words World			W11: d-I World	
W6: Cardboard World			W6: d-II World	

2. Which images in particular triggered ideas for a design concept?

   .....

3. Which words in particular triggered ideas for a design concept?

   .....

4. Which type of images did you find more effective; intra-domain images (images related to the design context) or outer-domain images (images not related to the design context)?

   .....

On Black Box…….

1. To what extent did you find the worlds of Black Box to be inspiring in terms of content?

0	1	2	3	4

2. To what extent did you find the contents of Black Box diverse enough for the given project and the amount of time?

0	1	2	3	4

3. To what extent did you find the diversity of image resources attracting?

0	1	2	3	4

4. To what extent did you find the diversity of image resources distracting?

0	1	2	3	4

5. Do you find it easy to navigate within Black Box?

0	1	2	3	4

6. Could you evaluate Black Box according to the given criteria;

- Set-up/Scenario

0	1	2	3	4

- Use of graphics and animations

0	1	2	3	4

- Use of music

0	1	2	3	4

Please indicate any further suggestions that you may have to improve Black Box.

……

……

……

APPENDIX M: Black Box Observation Sheet

	0-2mins	2-4mins	4-6mins	6-8mins	8-10mins	10-12mins
w1	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w2	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w3	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w4	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w5	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w6	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w7	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w8	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w9	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w10	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w11	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc
w12	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc	S NT T SdNav RP RW MPS MPI Assc