UNIVERSITY OF SOUTHAMPTON

FACULTY OF BUSINESS & LAW

Winchester School of Art

Design rationality revisited: describing and explaining design decision making from a naturalistic outlook

by

Ariel Leonardo Guersenzvaig

Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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The overall aim of this research is to improve the understanding of decision making during design activity, especially at the initial stages of the design process. This thesis presents keys to increase the theoretical understanding of the design decision-making processes and integrates empiric models of decision making, rooted in the cognitive sciences and in psychology, into the study of design activity and design cognition, as this integration can be beneficial to the field of design research.

Several normative, prescriptive and descriptive models of decision making are analysed and key related concepts such as rationality, problem solving, rational analysis and intuition are introduced and discussed. One of these models, the *naturalistic decision making* (NDM) framework, is adopted as a suitable theoretical framework to describe design activity. NDM is a recent current in cognitive science, which studies the phenomena that occur when people take decisions in *real-world* environments, meaning outside laboratories and artificially crafted experimental situations. This thesis shows that several salient hypothesis of the NDM framework, such as the focus on the rapid generation of courses of action, the convergence between problem solving and decision making, and the synthesis of solution patterns, match findings from the field of design research and can improve our understanding of design decision making. The NDM framework offers a broad theoretical framework that can yield richer interpretations of existing results and guide further research.

This thesis supplies theoretical naturalistic analysis of findings from the field of design research as well as a series of analyses of real design work that is described from a naturalistic perspective. It also includes several philosophical considerations regarding where we are in the field of design decision making, where we want to go, and what is desirable according to values and interests related to rationality and what constitutes rational design decision making.

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AUTHOR'S DECLARATION

I, Ariel Leonardo Guersenzvaig,

declare that the thesis entitled

Design rationality revisited: describing and explaining design decision making from a naturalistic outlook

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- none of this work has been published before submission.

Signed: ....

Date:..

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This thesis is, above all, dedicated to Clara, my ineffable partner, for her ceaseless fuelling and love, and to Selba and Eloisa, my fearless and ferocious daughters.

LIST OF ABBREVIATIONS

ACM: Association for Computing Machinery
CTA: Cognitive Task Analysis
DFTS: Data/frame Theory of Sensemaking
NDM: Naturalistic Decision Making
RPD: Recognition-Primed Decision
SEU: Subjected Expected Utility
SIGCHI: Special Interest Group on Computer-Human Interaction

PREFACE

This thesis consists of a total of nine chapters divided in three parts.

Part I sets the stage presenting the research problem and the domain
Chapter 1 gives an overview of the research problem and provides a justification for conducting this research. It clarifies what this thesis is and what is not. It includes a preliminary introduction to its main theoretical underpinning regarding decision making and a review of related research. It also provides some terminological clarifications.
Chapter 2 introduces the domain of design and interaction design. A case in interaction design methodology is presented and put under scrutiny.

Part II discusses several theories and models
Chapter 3 deals with different views on rationality, decision making and problem solving, exploring its main critical features and delves into the psychological plausibility of existing models of decision making.
Chapter 4 presents the main theoretical framework used in this thesis: the naturalistic decision making framework. In this chapter several naturalistic models that account for different sub-processes related to decision making are also explored and reviewed.
Chapter 5 offers a critical review of different models and theoretical views of design activity.
Chapter 6 contains an examination of different models and theories regarding design decision making.

Part III proposes and introduces a naturalistic outlook on design decision making
Chapter 7 contains an in depth analysis and discussion of parallels drawn between the naturalistic decision making framework and theories and models from the field of design research. A theoretical link is established and a model that integrates these theories is put forward.
Chapter 8 offers an analysis of three design cases from a naturalistic outlook in order to render the discussion less abstract and show the relevance of the naturalistic framework for describing and explaining design activity.
Chapter 9 includes a personal stance regarding the adoption of the naturalistic framework as well on analytical rationality in design decision making. It contains a discussion of the relevance of this thesis, recommendations for further research and a general conclusion to summarise the main findings.

Part I
Introduction

‘The designer asks himself, in effect,
“What if I did this?” where “this”
is a move whose consequences and
implications he traces in the virtual
world of a drawing or model.’
Donald Schön (1984)

CHAPTER I

The research problem

In this chapter, the aims of the research will be established and the scope will be defined. A discussion and a clarification of few barriers posed by some authors from the field of design will be presented, as well as a review of related work and a very short introduction to the main theoretical framework. Finally, a definition of ambiguous terms is included.

1.1 The aims of the research

The overall aim of this research is to improve the understanding of decision making during the design activity, especially at the initial stages of the design process. Decision making is one of the most common of human cognitive activities; however, it is often overlooked in design research (Zannier, Chiasson and Maurer, 2007).

To display the objectives of this thesis, I will present keys to increase the theoretical understanding of the design decision-making processes and as well as to integrate opposed perspectives concerning the description of the processes constituting design thinking. Design thinking can be understood as 'the study of the cognitive processes that are manifested in design action' (Cross, Dorst & Roozenburg as cited in Bousbaci, 2008, p.38). I will also integrate empiric models of decision making, rooted in psychology and the cognitive sciences, into the study of design activity and design cognition, as this integration can be beneficial to the field of design research. The field of design research can be seen as design epistemology, design praxiology and design phenomenology (Cross, 2008). I am a designer and a design educator; this is, therefore, a work from *within* the field of design.

Several empirical models of decision making will be explained further on, but for now it is sufficient to say that they are included because these models may be useful to explain how design decisions involving ill-structured design problems – especially those made at the very beginning of the design process –, are made in complex, ambiguous, unstable, real-world situations. To avoid misunderstandings, the notion of problem might require an initial clarification: 'problem' should be understood as a question to be considered, solved, or answered, not as a difficulty or a harmful situation. At this moment, I consider this definition sufficient for the first part of this introductory chapter, albeit brief and incomplete. This and other terminological issues will be considered in depth in § 1.7.

My main presupposition is that the designer's decisions are not sealed in a black box and that design decision making can be understood, modelled and explained. Another assumption is that the inclusion of these empirical models can serve to achieve a deeper understanding of the cognitive processes that occur during the design activity in order to broaden the theoretical models of design decision making.

Finally, in order to improve and extend existing descriptive models of design decision making and in order to contribute to what Donald Schön (Schön, 1983) calls an 'epistemology of practice', I will present an extension of an existing model of design decision making. I will also derive conclusions that are aligned with the nature of design activity as it occurs in real design situations. These recommendations are anchored in the theoretical frameworks that serve as the basis of this work, but also on my own experience as a practising designer.

1.1.1 Is design decision making or problem solving?

The decision-making and problem-solving processes are often the object of study in cognitive science and psychology, although traditionally they have been considered different processes. Using everyday language we could say that problem solving consists in using pre-established or *ad hoc* methods or rules in order to find solutions to given problems. On the other hand, decision making is commonly viewed as the cognitive process resulting in the adoption of a course of action among several alternative options or choices. Yet, notwithstanding these informal definitions, it will be shown that there are new currents in psychology and the cognitive sciences that see no clear and defined separation between these two processes. I will deal extensively with these issues in Part II, in which formal definitions of the topics, as well as theories, will be considered.

From the field of design research, several authors deem the design process as a form of problem solving. According to this view, the activity is focused on defining, structuring and hierarchizing problems and sub-problems, for example by generating lists of requirements (Ball, Lambell, Reed and Reid, 2001). Some authors such as Goel and Pirolli (1992), Goel (1995) or Koberg and Bagnall (2003) explicitly consider the concept of problem solving. Others such as Alexander (1964) do so implicitly and the idea of problem solving can be inferred from his proposed rationalistic approach (analysis-synthesis). Concurrently, authors such as Darke (1979); Dorst (2006); Lawson (2004b, 2006) characterise design as an activity where the designer's work is focused both on the generation, selection and refinement of alternatives, and on structuring the problem. In the words of Dorst (1997, p.17):

> Creative design is more a matter of developing and evolving both the formulation of a problem and ideas for a solution, while constantly shuttling between them. The aim of the designer is to generate a matching problem-solution pair.

From the cognitive viewpoint, the design activity includes a series of activities such as mental representation, mental stimulation, problem solving and decision making. However, despite its impact, decision making receives little attention from researchers (Hassard, 2011) and we have little understanding of how designers make decisions (Zannier et al., 2007). Rowe (1987) and Akin (1986) characterise design thinking as a decision-making activity, although not offering a framework for decision making. Motte and Bjärnemo (2004) – in a literature survey of sixty papers and books on the cognitive aspects of design activity – commented that problem solving is the main aspect under study; knowledge, imagery and memory are also considered, but no mention is made of decision making.

1.2 Scope of this thesis

As a student I was taught linear methods of design based on general rules such as: first, understanding the problem at hand, then gathering information, then analysing information, then generating solutions, then evaluating them, etcetera. As I was approaching my graduation year I found myself using these rules in an apparently 'chaotic' fashion. I was sometimes generating an initial, rough solution and then gathering information, not the other way around. I thought I was being a bad student but since my marks were still good, I could not really tell what was happening.

Currently, as a practising designer I often find myself in situations where I have to describe to a client how a design project will be carried out. Something similar happens when I try to teach design students about the design process. Usually, at least with new clients and beginner students, I stick to the linear account of the tasks, since the non-linear makes them feel uneasy; after all, it presents a somehow 'illogical' process. But, when I tell them that many designers and even myself have difficulty adhering to linear processes, the inevitable question is always posed: *how can an intermediate solution precede information gathering?*
This thesis is about answering this question.

From the field of design research we know that this seemingly illogical behaviour happens especially with expert designers (this behaviour was noted e.g. by Cross, 2007a; Dorst, 2006; Lawson, 2006; Lawson and Dorst, 2009). But, how and why does it happen?

To move forward in understanding design practice as it occurs in daily professional activity, I analyse and discuss the *naturalistic decision making* (NDM) framework. I adopt the NDM framework as a suitable theoretical framework to describe design activity. NDM is a recent current in psychology and the cognitive science that studies the phenomena that occur when people take decisions in naturalistic environments – outside laboratories and artificially set up situations. The NDM framework covers the characteristics of the task, those of the environment, and contemplates the decision maker in a holistic manner. In this sense, a radical distinction is made versus the rationalistic decision making, which only considers the internal alternatives of the decision and omits its context. One of such rationalist approach is subjective expected utility theory (SEU), which will be briefly reviewed in the next chapter.

Researchers such as Zsambok and Klein (Klein, 1998; Zsambok and Klein, 1997) are two of the pioneers of the movement which – since the late 1980's – have dealt with understanding the decision processes that occur in natural contexts (outside the laboratory) with real and poorly formulated problems, involving decisions with dynamic and badly structured objectives, changing situations, time pressure and a large amount of uncertainty.

I intent to show that several salient aspects of the NDM framework, such as the focus on the rapid generation of courses of action, the convergence between problem solving and decision making and the synthesis of solution patterns, might serve to explore and understand design cognition which, according to Cross (2007a), involves: (1) the formulation of the problem, (2) the generation of solutions, and (3) the process strategies used by the designers.

My intention is to contribute a combination of concrete analyses of various examples of my own work that will be described and used to test and show the relevance of the NDM framework practical philosophical considerations regarding where we are in the field of design decision making, where we want to go, and what is desirable according to values and interests related to rationality and what constitutes rational design decision making. My analyses are thus essentially teleological in nature, as I hope they can impact design methodology's by-products such as methods and techniques. The final potential beneficiary of this work is then the designer, the design methodologist and the design educator. As we will see further on, the views of the NDM researchers go in a similar direction to that proposed by Donald Schön (1983, p.49):

> Let us search [...] for an epistemology of practice implicit in the artistic, intuitive processes which practitioners [from design and other professions] bring to situations of uncertainty, instability, uniqueness and value conflict.

1.3 Outside the scope of this thesis

This thesis is not an effort to develop a grand theory of design decision making, nor do I claim that the presented theories account for all phenomena related to design decision making. I am not interested in devising any kind of *a priori* logical or axiological model of the design process, nor do I intent to prescribe how the design process should be.

The focus of this work lies solely in the cognitive processes and structures – knowledge and representation – that are involved in individual design decision making. In this thesis I hardly address the collective, emotional, political and geographical aspects of design. Nonetheless, I entirely recognise that these aspects influence decision making or problem solving. Although design problem solving and decision making do indeed occur in groups (Lawson, 2006), it is not clear if or how groups affect the basic individual mental activities and operations implemented in design: generation, transformation and evaluation of solutions (Visser, 2006). The work of Stompff (2012) on team consciousness and team mind might be ground-breaking as it offers a framework and a vocabulary for describing and understanding cognitive activities occurring within design teams. It is also clear that emotion influences design activity (for a short overview see Visser, 2006). Design can also be positioned as a vital form of political action (Fry, 2011) and it is affected by geography, as there are significant variations in how design occurs in different societies (Heskett, 2002).

Belonging to the field of design research, this thesis is anchored somewhere between science and practice. I understand that its findings cannot and should not be generalised in a *positivistic* manner as they cannot be verified by the standards of the natural sciences. The relevance of this enquiry relies on the theoretical and analytical generalisations that will be carries out. The issue of the generalisability and validity of the findings and recommendations will be revisited in the final chapter.

This thesis is neither directly interested in the final products of design, nor in hands-on approaches. This work is primarily about design as a process and it is concerned with how this works at a generic level of basic activities and operations.

1.4 A preliminary introduction to NDM

In spite of considering the naturalistic decision making framework extensively in chapter 3, it is now necessary to offer a brief introduction in order to clarify its key aspects before carrying on. NDM is defined by Zsambok and Klein (1997, p.5) as:

> Naturalistic Decision Making asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organisation in which they operate.

The adjective 'naturalistic' must not be understood as 'natural', but rather as a description of a focus enhancing empiricism, the exploration of hypotheses by on-site observation and the collection and categorisation of data. The focus is called naturalistic in the sense of seeking to study cognition in real-time and in real decision contexts.

Within the NDM framework, researchers propose studying decisions that involve several, but not necessarily all, of the following aspects (Orasanu and Connolly, 1993):

1. *Poorly formulated problems*: there is no aim to study artificially or well-structured problems, all too frequently studied in experimental psychology.
2. *Situations of uncertainty in dynamic environments*: there is no attempt to study static situations.
3. *Changing objectives*: the researcher seeks to study situations where the objectives are unclear, unstable, badly formulated and mutually conflictive.
4. *Loops of actions*: it is not a question of studying a single decision, but rather a chain of decisions.
5. *Decision with time pressure*: when the decision makers do not have much time.
6. *Much at stake*: situations not studied without consequences for the decision maker, but rather those in which the decision maker has something to lose.

7. *Decisions of multiple decision makers*: as opposed to research focused on individual decisions.
8. *Decisions framed by organisational rules and objectives*: as decisions do not occur in a vacuum.

In addition to these characteristics, Orasanu and Connolly (1993) list the following factors that are important for naturalistic research:

1. Participants have expertise in the area where decision making occurs.
2. The research goal is to discover how participants actually take decisions in real-life environments, i.e. outside the laboratory.
3. The main interest of the research is the decision-making episode as a whole, and not only the process of choosing among alternatives.

These aspects and characteristics are the pillars of the NDM research framework and appear virtually throughout the whole of the literature regarding NDM that has been consulted for this work (e.g. Elliott, 2005; Klein, 1998, 2001; Zsambok, Beach and Klein, 1992; Zsambok and Klein, 1997).

The RPD model and the DFTS model are two naturalistic decision models that will serve as a basis for this work and will be dealt with in § 4.2 and in § 4.3.

1.5 An initial barrier: criticism of the cognitive approach

Well-cited authors from the field of design research such as Nigel Cross and Bryan Lawson are sceptical about the contribution that psychology can make to the field of design methodology. These authors argue that psychologists commit the frequent mistake of dealing with design as if it was a well-structured problem, while it is quite the contrary. Nigel Cross writes:

> It has become clear that designing is not 'normal' problem solving. [...] Designing involves 'finding' appropriate problems as well as 'solving' them and includes substantial activity in problem structuring and formulating, rather than merely accepting the 'problem as given'. (Cross, 2007a, p.99)
>
> One of the dangers in this new field of design research is that researchers from other, non-design disciplines will import methods and approaches that are inappropriate to developing the understanding of design. Researchers from psychology or computer science, for example, have tended to assume that there is 'nothing special' about design as an activity for investigation, that is just another form of 'problem solving' or 'information processing'. (Cross, 2007a, p.126)

Lawson (2004b, 2006), in a similar tone, posits that cognitive psychology and the cognitive sciences have little to contribute to design methodology and that knowledge acquired by it, regarding cognition, is based on cryptoarithmetic experiments or other kinds of well-structured problems, whereas design problems are essentially ill-structured problems:

> Unfortunately both these fields [cognitive psychology and cognitive science], have tended to try to explain this process [of problem solving] largely by reference to well-structured problems. [...] It has appeared as if this understanding applies to all instances of problem solving and thus to design. Sadly this is not so. Designers [...] solve not well-formulated problems but ones which are ill-structured, open ended and often referred to as 'wicked'. (Lawson, 2004b, p.19)

Probably for the same reasons, Cross (2007b, p.5) does not seem to welcome the methodological or theoretical contributions of other sciences either: '[d]esign as a discipline means design studied on its own terms, within its own rigorous culture, based on a reflective practice of designing'.

The arguments against the contribution of cognitive science and psychology to design research given by Lawson and Cross are rather simplistic. Both authors level their criticism at cognitive science or psychology *in general*; however, the literature review will show that there is no such only view in cognitive science nor a sole psychological model of problem solving. In later chapters I will describe the different currents in cognitive psychology that criticise the classical experimental focus and which pose exactly the same criticisms as Cross and Lawson of the experimental method based on well-defined problems that occur in highly implausible situations and which give results that are not very useful for explaining true human behaviour (see e.g. Gigerenzer, 2001, 2008a, 2008b).

1.6 NDM and design: background

The references to an instrumental application of the NDM models in design abound, specially in designing interfaces, information systems and expert recommendation systems (e.g. Crandall, Klein and R., 2006; Hoffman, 2007; Klein, 1993). In this application of the NDM framework, the naturalistic models are taken as a basis for empirical recommendation to help designers in the work of designing systems that are more effective and efficient. In this instrumental application, the NDM framework is used as an informative source to design systems that adapt to the way in which users of these systems make decisions.

Ball et al. (2001) are probably the first authors to explicitly connect in a published paper the NDM framework and design research in order to explain design decision making. They draw out several parallels between hypotheses from the fields of NDM and design research with regard to the area of solution exploration. The authors stress the potential of NDM in explaining professional design activity:

> We would argue that an NDM approach to understanding real-world decision making has much to offer researchers interested in the underlying cognitive mechanisms associated with the generation and evaluation of design solutions. In particular, the NDM emphasis on the fundamentally adaptive and efficient aspects of *satisficing*[1] strategies in professional activity seems very appealing, as this places a more positive light on designers' overarching tendencies toward minimal solution exploration, fixation on initial design concepts, and partial design evaluation. (Ball et al., 2001, p.9)

Ball et al. (2001, p.9) point out the divergence between the prescriptive models of design and the reality of practice, and recommend a further examination in the prescriptive design models:

> Such satisficing approaches to design diverge markedly from the prescriptions of design theorists and educationists – who emphasise the need for the systematic evaluation of a wide range of solution alternatives in professional design practice. However, the fact that minimal solution exploration is such a central feature of the task processing evidenced by experienced designers working individually and well-established design teams, calls into question the normative status of prescriptive and educational dictates concerning effective methods of design development.

The NDM framework has received attention from other authors who have carried out with the research line proposed by Ball et al. in the area of design decision making. Zannier and Maurer (2006) in a study of 12 cases, showed how NDM dominates the decision process, although in certain cases NDM is supported by classical decision-making strategies. Another study shows that the structure of the design problem determines which aspects of rational and naturalistic decision making are used (Zannier et al., 2007). The work of Hassard (2009, 2011), focusing on how designers use analogical reasoning to quickly scope the solution space down to one viable solution, and the phenomenon of the persistence of

[1] Although the concept of *satisficing* will be dealt with in § 3.1.2, I offer here a temporary definition, as the word might seem strange to some readers. Satisficing, a portmanteau of satisfy and suffice, is the search for decision alternatives that might be satisfactory in the sense of reaching a minimum threshold or aspiration level of a use. SIMON, H. (1956) 'Rational choice and the structure of the environment', *Psychological Review,* 63(2), 129-138.

initial solutions – analogical persistence – during the design process, is another important research precedent of the application of the NDM framework in studying design cognition in order to update it and bring it closer to naturalistic decision theories. Some of the work by Kolko (2010a, 2010b, 2011a), represent other sources regarding the integration of specific theories from the NDM framework in the field of design research. Kolko's focus lies on integrating different theories and proposing a series of generative practical methods and techniques that are part of his theory of synthesis. Kolko's theory of synthesis will be reviewed in § 6.4.

1.7 Terminological clarifications

I introduce this section to clarify several terms, not trying to produce a glossary, but in order to avoid possible misunderstandings. Most of these terms will be newly considered later in their specific sections and given a more extensive treatment in their relation with the issue at hand.

Designer

Defining the word 'designer' is as elusive as defining the word 'design', explored in § 2.1 and § 2.2. Even sources as *How Designers Think* (Lawson, 2006) or *Design Dictionary* (Erlhoff and Marshall, 2008) do not offer an explicit definition of the word 'designer', not an index entry has been created either. According to the *Oxford Dictionary of English* (2010), a 'designer' is a 'person who plans the look or workings of something prior to it being made, by preparing drawings or plans'. This definition goes in the right direction, but is insufficient since, according to it, everybody designs to some extent every day: by buying and arranging furniture in a room or defining the way one dresses. In this work, the word 'designer' refers to *professional* designers. A designer is somebody who, as a profession and in a more or less sustained way (i.e. not occasionally), designs 'for other people rather than just for themselves' (Lawson, 2004b).

Model

In this dissertation the word 'model' stands for a representation of a phenomenon, where 'phenomenon' is used as an umbrella term covering a fact or situation that is observed, inferred or assumed to exist or happen, being put in question.

The notion of 'model' has crucial importance in many scientific and professional contexts. Frigg and Hartmann (2012) state the following:

> Models can perform two fundamentally different representational functions. On the one hand, a model can be a representation of a selected

part of the world (the 'target system'). Depending on the nature of the target, such models are either models of phenomena or models of data. On the other hand, a model can represent a theory in the sense that it interprets the laws and axioms of that theory. These two notions are not mutually exclusive as scientific models can be representations in both senses at the same time.

Most models presented in this thesis are *idealised models* belonging to the type of the so-called Aristotelian idealisations. An idealisation is a simplification of something complicated with the objective of making it more tractable. They are Aristotelian in the sense that the model maker only models those and only those properties that she believes are relevant to the problem at hand.

The ontology of models is not simple, the variety of things referred to as models is vast: 'physical objects, fictional objects, set-theoretic structures, descriptions, equations, or combinations. However, these categories are neither mutually exclusive nor jointly exhaustive' (Frigg and Hartmann, 2012). Models can be *physical*, such as a scale model of a Spitfire fighter aircraft from WWII, or *fictional* such as the model of the atom. Fictional models do not have to be physical in order to achieve their representational function. That is why they are so useful to scientific research; one can somehow *manipulate* them, even though they are not physical. When a scientist presents a model, she is offering a more or less stylised *description* of the relevant target system (Frigg and Hartmann, 2012). Most of the models used in this document are graphical or textual descriptions.

Models still generate considerable interest and debate among philosophers of science, regarding what models are and how they work. Many authors have discussed different models in philosophy of science (e.g. Giere, 1988, 2006; Hacking, 1983). See Frigg and Hartmann (2012) for a discussion of current issues.

Problem

As it was mentioned at the beginning of this chapter, the term 'problem' is not used by its common meaning, which according to the *Oxford Dictionary of English* (2010) is 'matter or situation regarded as unwelcome or harmful and needing to be dealt with and overcome'.

The term 'problem' is used and it has been up to this point by a meaning deriving from cognitive psychology, where problem is 'a technical term with a precise definition: it qualifies people's mental representation of their task' (Visser, 2006). In this thesis, I recurrently use the term 'problem' with this meaning (i.e. a representation of a question to be solved). This specific meaning of 'problem' becomes very evident when the term that is being used is 'problem solving'.

However, in § 4.1, the NDM framework's concept of 'problem detection' is presented. In this case the naturalistic researchers do use the term 'problem' as a synonym of difficulty or anomaly. I adopt the term 'problem detection' as it is widely used by other NDM researchers. Despite adopting this term, in my opinion, the use of the term 'difficulty' or 'anomaly' would have been more appropriate. In fact the term 'anomaly detection' is occasionally used alongside 'problem detection'.

Process

The term 'process' is used throughout this work. Especially in two specific cases: 'design process' and 'cognitive process'. The concept of 'design process' is widely used within the design community and it might not require further clarification than stating that it refers to all action taking place during a design project, regardless of specific methods and techniques (see definitions below). The term 'cognitive process' refers to the cognitive operations that occur while thinking, reasoning or deciding. In all other cases, the word process does not have a particular technical sense and its meaning does not differ from common usage.

Project

In this work, the meaning of the word 'project' goes in the direction of its common usage. The *Oxford Dictionary of English* (2010) provides the following definition: 'an individual or collaborative enterprise that is carefully planned to achieve a particular aim'. A useful complementary note is supplied by design methodologist Martí i Font (1999): 'a project is a finite series of decisions'. A 'project' means thus an endeavour with defined start and end dates, to achieve specific goals.

Other terms

The term 'method' does not have a particular technical sense and it can be understood as a prescribed and formalised design approach or procedure consisting of steps or stages. A 'method' tells the designer how to approach a process as a whole.

The term 'methodology' refers to the study of methods.

A 'technique' is a way of executing a particular task, it is what the designer applies to move from one step of the process to the other. Techniques are the building blocks of a process; each step is made up of one or more techniques (Spool, 2010).

In this chapter, I have established the aims and the scope of my research, which is not to develop an exhaustive theory of design or prescriptive methods or models, but to show several models of decision making and design activity that could enable moving towards a naturalistic account of observed design practice in order to better describe and explain it. The naturalistic decision making framework is presented as the main theoretical framework that may serve as a useful tool for a description of the richness and diversity of design practice.

In the next chapter, the domain of design and interaction design will be explored and a case in interaction design will be presented in order to make the discussion less abstract.

CHAPTER 2

The practice

In this second chapter, the reader will find a general introduction to the domain of design and to the discipline of interaction design. Also, a particular case of interaction design methodology will be presented and discussed.

2.1 Defining the common aspects of design

It might be redundant to state that – except in pristine nature – we are surrounded by the outcome of design. So, if design is 'the human capacity to shape and make our environment' (Heskett, 2002, p.5), one cannot avoid wondering how can design and the designer accommodate to such a variety of requirements. Walter Gropius, the founder of the Bauhaus, asserted – in what has become a very famous quote in the field of design – that architects (i.e. architectural designers) construct 'from the spoon to the city'. After reading this statement, one cannot avoid wondering how can design afford such a variety of domains and how the activities of designing a bridge or designing a pen can be considered to be intrinsically the same activity. I shall try to probe into these issues, even though the questions will probably remain partially unanswered.

Design comprises several disciplines: product, interior, graphic, fashion… just to name a few. Within each of these disciplines there are sub-disciplines or specialisations: within graphic design one can find editorial design, information design, branding, etcetera. Some sub-disciplines are related or are even shared by two disciplines such as packaging, which can be considered product or graphic design or both; or interior lighting design, which can be considered product or interior design or both. Then, does it make sense to talk about design as a unique activity? Or, is it reasonable to consider common aspects of design such as design decision making or design cognition when designers are facing and tackling problems so apart from one another as the design of toothbrushes and car dashboards?

Lawson (2006, p.9) asserts that 'we must be cautious […] in assuming that all design fields can be considered to share common ground'. But then he posits a notion with tremendous implications: 'what is certain is that design is a distinctive mental activity'. Here Lawson asserts that design as a mental activity is different from the rest. Nigel Cross goes further and refers to *designerly* ways of knowing when positing the distinctiveness of design activity and a common cognitive approach among designers (Cross, 2007b, 2011). Designerly can be defined as: 'the deep, underlying patterns of how designers think and act' (Cross, 2007a, p.11). The designerly ways of knowing will be revisited in § 6.1.

Design methodology tries to be domain-independent (Dorst, 1997; Lawson, 2006), but a domain-agnostic design methodology makes sense if, and only if, designers share cognitive features regarding their approach to design. If there is not such a thing as a designerly way of knowing, pursuing a domain-independent design methodology shall remain a chimera and the development of descriptive models of design would become an impossibility.

2.2 Defining design

Every good dictionary (e.g. *The Oxford Dictionary of English*) defines design as both a noun and a verb. The noun refers to a plan or drawing intended to show the look and function or workings of an artefact, while the verb usually means 'to do', 'to plan' or 'to decide' on the look and functioning of this artefact (i.e. 'the design'). The ambiguous nature of the word is illustrated by a seemingly nonsensical sentence:

> 'Design is to design a design to produce a design' (Heskett, 2002, p.3)

Design is a ubiquitous word; we see it often and in many different contexts: schools of design, designer clothes, design prizes, design shops, and everywhere we look we see *design* and *designs*. Some theorist even claim that '[a]ll what we [humans] do, almost all the time, is design, for design is basic to all human activity. The planning and patterning of any act toward a desired, foreseeable end constitutes the design process' (Papanek, 1985, p.3).

It seems fair to reckon that since everyone seems to be doing it, then everyone should know what design is, and therefore what designers do and how they do it – or at least have a vague idea – but this is hardly the case. The troublesome definition of design remains elusive. Lawson (2006, p.33) asks rhetorically:

> Do we really need a simple definition of design or should we accept that design is too complex a matter to be summarised in less than a book? The answer is probably that we shall never really find a single satisfactory definition but that the searching is probably much more important than the finding.

Even in a canonical source such as the aforementioned one, the reader has to wait until page 31 for an attempt to a definition of what design is and is not. After citing and reflecting on definitions by other authors, Lawson (2006, p.33) finally refers to Jones (1970) in a phrase that Jones himself regarded as the 'ultimate definition' of design: 'to initiate change in man-made things'. This definition is not instrumental at all, but every designer should probably agree, at least intuitively and to some extent, that it resembles to what we do. Nigel Cross does not provide a definitive definition of design in *Designerly Ways of Knowing* (Cross, 2007a) – his compilation of canonical papers – either, but instead he offers a fragmented description of characteristics that can be put together as follows: 'design is rhetorical' (p.51), 'design is exploratory' (p.52), 'design is emergent' (p.52), 'design is abductive[2]' (p.53), 'design is reflective' (p.53), 'design is ambiguous' (p.54), and 'design is risky' (p.54).

A definition always focuses on certain aspects of the object the author wishes to explain. Often this focus lies in the process or planning of change such as in the aforementioned definitions by Papanek or Jones. The British Design Council also puts forward a definition by Sir George Cox that involves a final goal: 'Design [...] shapes ideas to become practical and attractive propositions for users or customers. Design may be described as creativity deployed to a specific end' (Design Council, year n/a).

Simon (1996, p.111) poses a very famous and short definition that combines the view of design as a common human activity with a goal orientation: 'every one designs who devises courses of action aimed at changing existing situations into preferred ones'. Simon (1996, p.114) takes his teleological view further and adds the artefact as a means to achieving goals: '[d]esign [...] is concerned with how things ought to be, with devising artifacts to attain goals'. Other authors, point on the final results of the activities without focusing on end goals: 'the process of creating tangible artifacts to meet intangible human needs' (Moran and Carroll cited in Visser, 2006, p.115). Visser (2006) mentions other definitions that go in this direction and neglect to mention the crucial difference between the specification and the artefact product itself. This difference is what separates design from craft and it is at the very basis of design methodology (Jones, 1992).

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[2] The theory of abduction was formulated by C. S. Peirce. According to him, the form of abduction is this: 'The surprising fact, C, is observed; But if A were true, C would be a matter of course, Hence, there is reason to suspect that A is true' (p.231) PEIRCE, C. S. (1998) *The essential Peirce, Vol. 2 (1893 - 1913),* Bloomington: Indiana University Press.

The following all-encompassing definition (Visser, 2006, p.116) provides an accurate image of the domain at hand:

> Design consists in specifying an artifact (the artifact product), *given requirements* that indicate – generally, neither explicitly, nor completely – one or more functions to be fulfilled, and needs and goals to be satisfied by the artifact under certain conditions (expressed by constraints). At a cognitive level, this specification activity consists of constructing (generating, transforming, and evaluating) representations of the artifact *until they are so precise, concrete and detailed* that the resulting representations – 'the specifications' – specify explicitly and completely the implementation of the artifact product. This construction is iterative: many intermediate representations are generated, transformed and evaluated prior to delivery of the specifications that constitute the final design representation of the artifact product together with its implementation. The difference between the final and the intermediate artifacts (representations) is a question of degree of specification, completeness and abstraction (concretization and precision).

See Heskett (2002) for a general introduction to design and the design disciplines. See the beginning of chapter 5 of this thesis for an overview and pointers to canonical sources in design research and design methodology.

2.3 Defining interaction design

Before defining interaction design it is necessary to clarify the notion of interaction and interactivity.

2.3.1 Definitions of interactivity

The Merriam-Webster Dictionary (2013) defines interaction as 'mutual or reciprocal action or influence'. This source defines interactive as 'involving the actions or input of a user; especially: have, relating to, or being a two-way electronic communication system (as a telephone, cable television, or a computer) that involves a user's orders (as for information or merchandise) or responses (as to a poll)'. The *Oxford Dictionary of English* (2010) offers a definition of interactivity regarding computers and electronic devices that goes in the same sense: 'allowing a two-way flow of information between it and a user; responding to the user's input [...]'. Both dictionaries offer definitions grounded in the fields of computer science and electronics; this is a sign of the ubiquity and pervasiveness of interactive digital technologies.

However, interaction has different meanings in other scientific fields. Jensen (1999) offers a few definitions: (1) from sociology, 'the relationship between two or more people who, in a given situation, mutually adapt their behaviour and actions to each other' (p.166), (2) in the communication and media studies, '[the concept of interaction] is often used to refer to the actions of an audience or recipients in relation to media content' (p.167), and (3) in the field of informatics (i.e. computer science) the concept of interaction refers to the relationship between people and machines (but not communication between people mediated by machines)' (p.169).

A classic definition of interactivity is that of Rogers (1986, p.34) who defines it as: 'the capability of new communication systems (usually containing a computer as one component) to "talk back" to the user, almost like an individual participating in a conversation'.

The intention here is not to cover and to analyse all possible definitions and taxonomies of interaction and interactivity. I will rather offer a single definition and taxonomy proposed by Jensen (1999). This definition and classification have been chosen because they are especially useful in understanding the degrees of influence a user can exert on mediated communication. Jensen (1999, p.183) defines interactivity as: 'a measure of a media's potential ability to let the user exert an influence on the content and/or form of the mediated communication'. The four types of interactivity defined by Jensen are:

1. *Transmissional interactivity*: a measure of a media's potential ability to let the user choose from a continuous stream of information in a one way media system without a return channel and therefore without a possibility for making requests (e.g. video streaming, internet radio).
2. *Consultational interactivity*: a measure of a media's potential ability to let the user choose, by request, from an existing selection of 'preproduced' information in a two way media system with a return channel (e.g. Spotify, Wikipedia.)
3. *Conversational interactivity*: a measure of a media's potential ability to let the user produce and input her own information in a two-way media system, be it stored or in real time (e.g. Facebook, Twitter).
4. *Registrational interactivity*: a measure of a media's potential ability to register information from the user and thereby also adapt and/or respond to a given user's needs and actions, whether they are the user's explicit choice of communication method or the system's built-in ability to automatically 'sense' and adapt (e.g. contextual ads in search engines, use of 'cookies' to recognise returning visitors to a website).

For an extensive treatment of interaction see Jensen (1999) and Svanaes (2013) for a philosophical discussion on the notion of interaction.

2.3.2 Definitions of interaction design

Interaction design is a field and an approach to designing interactive experiences (Shedroff, 1999). Interaction design refers to the design of interactive technologies, in which form, function, content, and behaviour are inextricably linked. The concept of interactive technology should be understood broadly to include not only products – such as a website or a mobile app –, but environments, media and fashion as well. Preece, Rogers and Sharp (2007, p.xviii) define the domain of interaction design as 'designing interactive products to support the way people communicate and interact in their everyday and working lives'. Initially, interaction design was largely concerned on the screen as an interface with point-and-click controls, but in the last decade it has taken an interest in other modes of interaction; notably, voice-activated controls, aural feedback (i.e. auditory) and haptic interaction (i.e. the use of gestures) (Kettley, 2006). Also the design of services, as they have become more interactive, is being related to interaction design. This section can be summed up with the following definition:

> Interaction Design (IxD) defines the structure and behavior of interactive systems. Interaction Designers strive to create meaningful relationships between people and the products and services that they use, from computers to mobile devices to appliances and beyond. (Reimann and Forlizzi, 2001)

Usability, traditional design and engineering disciplines have influenced interaction design. Nonetheless, it has its own unique methods and practices and besides it is very much a design discipline, with a different approach than that of scientific and engineering disciplines (Reimann, 2008). Interaction design lies at the junction of several design disciplines – as it is currently practiced – and its biggest influences are software development, graphic design and, to some extent, industrial design; psychology, ergonomics and business are other influences as well[3] (Saffer, 2007).

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[3] There is a more complex reading on influences and boundaries. As this topic is only tangential to this thesis, a short commentary is included in this footnote. Interaction design is a young discipline that has been around for less than two decades. It is still defining itself and figuring out its place among other disciplines such as information architecture, industrial design, graphic design, user-experience design, user-interface engineering, human-computer interaction, usability engineering, and ergonomics. In addition, many of these other disciplines are also new and still discovering their boundaries. SAFFER, D. (2007) *Designing for Interaction: Creating Smart Applications and Clever Devices,* Berkeley: New Riders.

However, interaction design is not only concerned about how the interactive technology looks: 'many of the challenges of designing an interactive product go right to the heart of what a digital product *is* and what it *does*' (Cooper, Reimann and Cronin, 2007). In particular, interaction design is a discipline concerned with: (1) defining the form, (2) anticipating how the use of products will affect human relationships and understanding, and (3) exploring the dialogue between products, people, and contexts (Cooper and Reimann, 2003)

In the foreword to *Designing Interactions*, Gillian Crampton Smith (Moggridge, 2007) puts forward a four-dimensional model of the interaction design language. This model was turned into a five-dimensional model by Silver (2007):

1. *Words*: interactions.
2. *Visual representations*: typography, diagrams, icons, and graphics with which users interact.
3. *Physical objects or space*: with which or within which users interact.
4. *Time*: within which users interact.
5. *Behaviour*: action, or operation, and presentation, or reaction.

As it has been already mentioned, interaction design is tied to technology: web sites, mobile phones, software, etcetera. Nowadays, there is a new area of interest for interaction designers: the design of services. Mager (2008, p.355) defines the locus of service design and the task of service designers as follows:

> Service design addresses the functionality and form of services from the perspective of clients. It aims to ensure that service interfaces are useful, usable, and desirable from the client's point of view and effective, efficient, and distinctive from the supplier's point of view.
> Service designers visualize, formulate, and choreograph solutions to problems that do not necessarily exist today; they observe and interpret requirements and behavioral patterns and transform them into possible future services.

Service design feeds from the tradition of product and interface design, enabling the transfer of proven analytical and creative design methods to the world of service provision. There are close ties to the dimensions of interaction and experience design. Some authors (e.g. Saffer, 2007) support the idea that service design is a new area of work for interaction designers, due to the introduction of new interactive technologies and devices into services. Others, such as the members of the Service Design Network – initiated in 2004 – consider service design to be a new autonomous design discipline as they aim to develop and share service design knowledge and practice and to consolidate a common service design culture and language (Service Design Network, 2004).

2.3.3 Approaches in interaction design

In order to facilitate the understanding of the cases and the examples that should be presented in the following pages, I offer a short overview of various perspectives on approaches in interaction design.

Saffer (2007) defines four main approaches to a design project. Most designers feel more comfortable with one particular design approach, although most of them mix approaches as they work. A designer's temperament, personal philosophy, and view of the work and of a project's users will help to evaluate which is the most appropriate for the designer. The approaches can be classified as follows:

- *User-centred design*: the philosophy behind this approach is simply this: users know best. The people who will be using a product or service know what their needs, goals, and preferences are, and it is up to the designer to find out those things and design for them. Goals are really important in user-centred design; through user research designers focus on what the user ultimately wants to accomplish in order to gain insights from which a solution can be generated. The designer then determines the tasks and means necessary to achieve those goals, but always with the users' needs and preferences in mind. For example, one shouldn't design an interactive service for selling coffee without first researching among coffee drinkers.
- *Activity-centred design*: this approach does not focus on the goals and preferences of users, but on activities. Activities can be loosely defined as a cluster of actions and decisions that are done for a purpose. Like user-centred design, activity-centred design relies on user research as the basis for its insights.
- *Systems design*: this is a very analytical way of approaching design problems; it uses an established arrangement of components to create design solutions. Whereas in user-centred design, the user is at the centre of the design process, here a system is a set of entities that act upon each other. Systems design outlines the components that systems should have. Therefore, the task of the designer becomes designing those components. In this way, systems design eliminates the guesswork and fuzziness of the other approaches and provides a clear roadmap for designers to follow.
- *Genius design*: the fourth major design approach relies almost solely on the wisdom and experience of the designer to make design decisions.

> Designers use their best judgment to define what users want and then design the product based on that judgment. User involvement, if it occurs at all, comes at the end of the process, when users test the results to make sure it works as the designer has predicted.

Designer Jared Spool (2010) has a similar view to Saffer's regarding the types of approach. However, Spool's *design decision styles* are laddered and the designer 'advances' from one type to the other as she gains experience. The design decision styles are:

- *Unintended*: the designer is not adhering to any approach
- *Self-design*: self-referential design (i.e. the designer thinks everyone is like her).
- *Genius design*: same to Saffer's description.
- *Activity-focused design*: same to Saffer's description.
- *Experience-focused design*: focuses on users' flow and complete experiences, in between the specific activities.

There are several sources that offer a comprehensive treatment of interaction design and its methods (see Kolko, 2011b; Löwgren and Stolterman, 2007; Preece et al., 2007; Saffer, 2007)

2.4 A case in methodology

Several years ago, my work was featured in the ACM interactions magazine, published bi-monthly by the Association for Computing Machinery (ACM), the largest educational and scientific computing society in the world. ACM interactions is the flagship magazine for the ACM's Special Interest Group on Computer-Human Interaction (SIGCHI), with a global circulation that includes all SIGCHI members (SIGCHI, 2013). According to its editors, ACM interactions is a publication of great influence in the fields that envelop the study of people and computers. Accompanying my featured work, there was a short article regarding my work process. Below I include a slightly edited (shortened) version of this article (Guersenzvaig, 2002). It describes my work process at the time and it includes some reflections that I consider to be relevant. The article uses the first person plural because I wrote it on behalf of the design studio in which I was employed at the time. The work process is described primarily from an interaction design perspective; however, other disciplines involved in the project are mentioned as well. The letters that are at the right side of the text work as a key for the commentary and discussion that is included afterwards.

Philosophy of Design

[a] Typically we wish for our designs to be effective, aesthetically pleasing, and useful. Sometimes we want them to be compelling and innovative as well.

[b] Our main areas of expertise are design, marketing, engineering, and content creation. We use a multidisciplinary approach for our work; we believe that by facing the design process from different perspectives we achieve a richer solution. At SQR no one owns the design process.

[c] We use the term design to refer to interface and interaction design. SQR has two different kinds of designers: interaction designers and graphic designers. Simply put, interaction designers take care of how the interface works and graphic designers define how the interface looks. Both kinds of designers work closely together since form follows function follows form…

[d] Some of us see computers as media; others regard computers as tools. Tools are there to be used, to control, to manipulate things. Media are meant to express, to engage.

[e] Design has to happen first. By design we do not mean adding nice colours or cool effects but finding solutions. The problem definition is always two-sided: the problem as seen by the user on the one hand and the problem as understood by our clients on the other. Starting with the users' goals and continuing with our client's business goals we arrive at design solutions that work for both users and clients.

Design Process

[f] Our design process consists of four phases:

1. discovery
2. concept
3. design
4. implementation

[g] We try to stick to this approach, but we adapt it to suit the client's needs. We first decide what to design and then we iteratively move forward toward how to shape and build it.

[h] In the *discovery* phase the client and us try to get to know each other. We hold one or more workshops in which we discuss the design brief and learn about the client's goals and the site's mission. The result is a vision statement for a product or service.

[i] In the *concept* phase, we conceive ways of interaction and define the product's visual identity and usability requirements. Usually the line of approach for this phase is a combination of user-centred design (UCD) and marketing approaches. The chosen approach depends on the nature of the project.

[j] In a UCD-driven project we start by interviewing users and, if possible, doing contextual inquiry. We create several personas and scenarios that provide us with detailed understanding of the key goals different users wish to accomplish as well as their skills, attitudes, and context of use. Using task analysis we produce a provisional functional specification.

[k] The concept phase in a marketing-driven project has many similarities to creating advertisements. An art director and a design team create a concept based on perceived needs, branding strategies, and trends in fashion. Target groups are explicitly defined, albeit there is no direct contact with users.

[l] During the *design* phase we prototype the ideas that are generated during the concept phase and do usability tests and card sorting with users. We use various prototypes to explore, test, and demonstrate ideas: storyboards, screen mock-ups, wire frames.
Deliverables for this phase are high-resolution screen prototypes, a site map, and a detailed functional specification.

[m] In the *implementation* phase we build the system. Building often also means having to iterate the designs. We don't usually do formal usability tests during this phase. We try to allocate all resources for user studies in the early stages of design. We do usability tests with working systems when we reassess them (i.e., before redesigns).

[n] The design process is constantly under revision. Looking back we see that an enormous change has taken place: a couple of years ago we used to focus on technology and aesthetics whereas nowadays we focus on the user.

[o] We love technology, but we want to make it invisible. We want our field to achieve what book publishers accomplished long ago: people reading books instead of users using technology. We want to design for people, not for users. We want to deliver value, not technology. Getting closer to that is our design challenge.

Commentary and discussion

A number of conclusions can be drawn after reflecting on this article.

[a] It can be argued that the activity is directed by some kind of guiding principle, the effectiveness, aesthetic quality or the usefulness of the design are very important. There are other guiding principles – the need to be compelling and innovative –, but are secondary.

[b] The article depicts a design studio in which 'the problem' can be tackled from different perspectives bearing in mind that this approach can yield a richer solution. This suggests that the solution depends on how the problem is tackled. The use of the term 'richer' indicates that there is more than one solution to the design problem. Well-defined problems – such as the arithmetical ones – have, most of the times, only one correct solution. Then, design must be a not well-defined problem.

[c] It also speaks of two design disciplines, their focus, and the way they are interrelated. It is interesting to note the use of ellipsis in the phrase 'form follows function follows form…' This is a clear manifestation of the iterative nature of design as well of the complex nature of the design problems. An interaction designer solves part of the problem (sub-problem A) and a graphic designer solves another part (sub-problem B), these sub-solutions interact with each other so that one or both designers have to generate a new (sub-)solution.

[d] The way designers consider computers, either as media or as tools, is also a sign of a principled view on design and an expression of a personal set of values.

[e] The two-sided view of problems is another indication that design problems are seen as complex and not well-formed.

[f] This design process fits into the categories seen in § 2.3.3, especially into the user-centred design and the activity-centred design categories, but there is also room for genius design.

[g] The approach can be adapted, meaning that the designers adopt an 'opportunistic' approach depending on the situation.

[h] The brief is discussed, meaning that it is modified and not taken as given. As a result of 'one or more' workshops, a vision statement is crafted. The core of the design is already there. This vision statement is a recorded way of expressing shared tacit information, such as assumptions and hypothesis.

[i] Again, an opportunistic approach is detected as a combination of UCD and genius design approaches are used.

[j] The use of the phrase 'if possible' can be seen as another sign of opportunism regarding the approach. User research is a classical technique to gather information to drive insight generation (Saffer, 2007). The use of personas and scenarios – fictional characters created to represent different user types and a narrative that describes foreseeable interactions between a persona and the system, respectively – indicates that there are tools that can be used to speculate about possible futures (i.e. mental simulation). See Guersenzvaig (2004a, 2004b) for an overview of the use of personas and scenarios.

[k] This approach can be characterised as genius design.

[l] A wide range of results is produced in this stage. The use of 'prototypes to explore, test, and demonstrate ideas' suggests a move from problem formulation to solution generation. These solutions seem to be partial attempts to address facets of the problem as it was defined.

[m] Once more, during implementation – something that technical experts and programmers do – the designer needs to go back to the drawing board and iterate.

[n] A sign of guiding principles.

[o] Another sign of the use of guiding principles. Also a clear use of a high-level referent (i.e. the book as transparent technology) can be detected.

In this chapter, the domain of design and particularly interaction design have been introduced and several important aspects of this thesis such as the fuzzy nature of design problems, the iterative nature of design, and the existence of different approaches to solve a design problem have been considered in an introductory fashion in order to frame the ways in which rationality is invoked, often uncritically, within the design decision-making process.

The next chapter deals critically with different views on rationality, decision making and problem solving, exploring and discussing its internal differences and paradoxes.

Part II
Theories and models

'You are not thinking; you are just being logical!'
Niels Bohr (as cited in Frisch, 1979)

CHAPTER 3

Views on rationality, decision making and problem solving

The third chapter is about analysing three central concepts to this thesis: rationality, problem solving and decision making. Different perspectives and models of each of them will accompany the analysis.

3.1 Rationality

The notion of rationality is at the basis of the study of decision making. In this chapter, rationality will be analysed from cognitive perspectives and related disciplines: cognitive science and psychology. I am aware that this subject may also be dealt with from other disciplines and perspectives, such as philosophy, sociology, or even from other currents of psychology.

In this thesis, the notion of rationality has a precise meaning closely related to the decision-making processes. It is an instrumental view of rationality. According to March (1994) rationality can be defined as a class of procedures to decide. In this procedural view of rationality, the rational is applied to the thought method used and not to the conclusions of our thought (Baron, 2008). A decision implies a certain previous margin of uncertainty: we require this margin of indeterminacy for it to make sense to talk about a rational decision; the agent must be faced with several alternatives to choose from and must have specific preferences or targets (Mosterín, 2008). An agent displays instrumental rationality insofar she adopts suitable means to her ends; instrumental rationality is thus at the basis of any intention or reasoned action. This instrumental view, however, appears to threaten the rational authority of morality. This aspect of instrumental rationality is worth noting:

> [I]t has been argued that instrumental rationality is not only a part, but a special part, or even the whole, of practical rationality. [...] It seems possible that acting morally on some occasion might not be a suitable means to an agent's ends. If so, then according to this thesis, it would not be irrational for her to refuse to act morally on such an occasion. (Kolodny and Brunero, 2013)

I will not tackle the debate about whether instrumental rationality is the only kind of practical rationality nor will I further address philosophical aspects regarding morality. Instead, I will present two different views on rationality involved in decision making.

3.1.1 Unlimited rationality

The French astronomer and physicist Pierre-Simon Laplace (1749 – 1827) devised a fictional intelligence that has become famous under the name of *Laplace's demon*. This demon possesses unlimited computational powers and can know absolutely everything about the past and present and can calculate the future with absolute certainty. Laplace's demon incarnates perfectly the view of unlimited rationality. This omniscient, omnipotent and deterministic view is what characterises unlimited rationality (Gigerenzer, 2008b).

In human terms, unlimited rationality refers to optimisation, always choosing the *optimal* (best) strategy (Gigerenzer, 2008b). One optimises by maximising some criterion. Well-known optimisation strategies are the maximisation of *expected value* and *expected utility*. Expected value – also called mathematical expectation – can be understood as:

> [T]he future value of a certain course of action, weighted according to the probability that the course of action will actually occur. If the possible course of action produces income of £10,000 and has a 10% chance of occurring, its expected value is 10% of £10,000 or £1,000. (*Dictionary of Economics*, 2003, p.70)

Before defining expected utility, it is first necessary to define 'utility'. Utility is 'the usefulness of a product or service, the satisfaction that a consumer gets from a good or service he or she has bought, or the way in which a good or service contributes to a consumer's welfare' (*Dictionary of Economics*, 2003, p.210). Then, the notion of expected utility can be understood as 'the satisfaction to a consumer from something where the benefits are uncertain, as in shares in risky companies or betting on a lottery' (*Dictionary of Economics*, 2003, p.70).

A rational choice is thus the process – the strategy, not the outcome – by which, from a set of possible actions, an agent chooses the best course of action, for example the one that maximises expected utility. As human decisions are assessed with respect to an ideal of perfection, the goal of a rational decision maker is to find the best strategy possible amongst all. According to this view, it is only rational to act in accordance to probabilistic laws: when the decision maker moves away from what is prescribed by these models of unlimited rationality, the decision maker is not maximising and can be characterised thereby as irrational.

The models of unlimited rationality describe deciding behaviour in an axiological manner from general assumptions concerning what a rational decision maker should do. However, these models have been shown to be inadequate for discovering and resolving situations in the real world, both in describing human decisions and in correctly prescribing action (Gigerenzer, 2008b; March, 1994).

3.1.2 Bounded rationality

The hypotheses of unlimited rationality have been criticised by Herbert Simon, who brings in the notion of *bounded* or limited rationality. Simon (1976, p.67) demystifies the maximisation ideal:

> It is obviously impossible for the individual to know 'all' his alternatives or 'all' their consequences, and this impossibility is a very important departure of actual behaviour from the model of objective rationality.

Due to the high informative complexity surrounding them, decision makers must discard information without previously analysing it in order to be able to achieve their goals on time (Simon, 1955). The necessary calculations are made by procedures aimed at saving effort, even though the solutions might not be adequate or might not follow an optimisation or maximisation criterion. These procedures are called *heuristic*. According to Tversky and Kahneman (1974, p.1124) heuristics 'reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations'.

To find a theory of rationality that is psychologically plausible, it is necessary to soften the requirement of optimisation. In this sense, Simon (1955) proposed the notion of *satisficing*. This concept offers a new notion of rationality, where the concept of optimisation is replaced with behaviour that seeks to choose the first option that is minimally acceptable and adequate to satisfy a goal or criterion. In general, humans, instead of trying to maximise their choices, aim at satisficing when they search for alternatives that are good enough. Satisficing, however, does not guarantee that the chosen alternative is the best one, neither that the considered goals might be achieved. Simon stressed as well the distinction between 'substantive rationality' and 'procedural rationality', which respectively referred to the rationality of the result and to the procedure with which the result is achieved. Procedural rationality is a more plausible and operative goal than substantive rationality (Doyle, 1999).

Two frameworks of bounded rationality

Due to its inherent vagueness, the Simonian concept of bounded rationality has been claimed by two different frameworks: (1) heuristics and biases and (2) ecological rationality (Gigerenzer, 2008b).

The framework of heuristics and biases maintain that the use of heuristics, being quite useful, often leads to systematic errors called *biases*. The cognitive limitations that humans have are expressed in their behaviour through cognitive errors or illusions. The study of these biases and the cognitive processes underlying these errors is therefore the study of bounded rationality. Authors such as Amos Tversky and Daniel Kahneman have documented experimental cases in which the decision makers, regardless of their experience and expertise in a domain, fail to behave in accordance to the rational ideal of optimisation and maximisation (Kahneman, 2003; Kahneman and Tversky, 1979; Tversky and Kahneman, 1974, 1981).

On the other hand, the ecological rationality framework is characterised by the metaphor of the scissors proposed by Simon (1990, p.7): '[h]uman rational behaviour is shaped by a [pair of] scissors whose blades are the structure of task environments and the computational capabilities of the actor'. We understand that a pair of scissors only works well if the blades fit each other correctly. In the same way that it is not possible to understand how scissors cut by examining only one blade of them, it is not possible to understand human reasoning by only examining cognition; for this reason it is necessary to recognise and understand how the blades fit each other. A strategy is rational only in relation to a specific physical or social environment (Gigerenzer, 2008b). This framework regards bounded rationality not as a discrepancy between the achieved result and the optimal result, nor as an inferior form of rationality, but rather as an alternative action in a world of uncertainty by abandoning the idea of maximisation and the calculation of probabilities and utility (Gigerenzer, 2008b; Gigerenzer and Stelten, 2001).

3.2 Problem solving

According to Newell and Simon (1972) a problem arises when a person wants something and does not know immediately what series of actions should be performed to get it. Duncker (1945, p.1) elaborates on the conditions for problems:

> Whenever one cannot go from the given situation to the desired situation simply by action [i.e., by the performance of obvious operations], then there is recourse to thinking. Such thinking has the task of devising some action, which may mediate between the existing and the desired situations.

Duncker's quote eloquently states that if a person knows exactly what to do in a given circumstance to reach the desired situation, then this person is not really solving a problem. Most researchers describe problem solving as an activity that begins with the acknowledgement of a gap and ends with an implemented solution to fill that gap (León, 1994). This situation of not exactly knowing what to do is what constitutes a problem. Solving a problem is transforming a given situation into a desired situation or goal (Hayes, 1989).

To solve a problem, a representation of it must be generated, or a pre-existing representation accessed (León, 1994; Simon, 1999). This representation includes: (1) a description of the initial situation, (2) operators or actions to change the situation, and (3) tests to determine whether the goal has been achieved or not. The use of operators creates new situations, that can define a branching tree of achievable situations: the so-called *problem space* (Simon, 1999). Problem solving amounts to searching through the problem space for a situation that satisfies the tests for a solution (VanLehn, 1989). According to Robertson (2001) the solution can refer to two aspects of problem solving: either the definitive solution or the means of finding the answer, which means the procedure itself.

Problem solving is characterised by four common aspects (Ashcraft, 1998): (1) goal orientation, (2) sequence of steps, (3) need for cognitive operations, and (4) breakdown of goals into sub-goals.

3.2.1 Problem solving stages

According to León (1994) problem solving has been conceptualised in cognitive psychology as a process consisting of three stages:

1. *Preparation*: in this stage the subject tries to understand the problem, the initial data, the rules and what constitutes a rule violation, the solution or the goals and the criteria that must be met.
2. *Production*: this stage consists in the generation of possible partial or total solutions that bring us closer to the goal. Reasoning can be performed algorithmically – for instance when we solve a multiplication – or heuristically, by simplifying procedures based on general principles.
3. *Evaluation*: the possible solutions generated in the previous stage are analysed in terms of fulfilment of the rules and how well they match the goal.

Example: a person who owns several hundred books realises that she needs to arrange them in an orderly fashion to be able to rapidly find specific titles when she searches for them, so she decides to organise her personal library. She could use, among other strategies, an alphabetic or a thematic classification scheme to arrange the books. She arranges the books and when she is finished, she checks that all books are in the correct placement on the shelves, according to the chosen classification plan.

Most models of problem solving include the abovementioned stages, albeit in a different number. In this sense, another frequent model is the four-stages model: (1) input stage, (2) processing, (3) output stage, and (4) evaluation stage. For a discussion of other traditional models of problem solving that range from two to eight stages see Lipshitz and Bar-Ilan (1996). For a comprehensive treatment on problem solving see Newell and Simon (1972) and Robertson (2001).

3.2.2 Types of problems

From its degree of definition, specification and verification of the initial and final state, a problem can be classified into two overarching categories. Problems are designated as well-structured if the situations, operators, and tests for a solution are all sharply defined; on the contrary, problems are ill-structured to the extent that they are vaguely defined (Simon, 1999). Blending white and black paint to achieve an specific shade of grey or solving a Sudoku puzzle is a well-structured problem. Playing the ancient Chinese game Go is an ill-structured problem, as it requires failure-prone reasoning to seek and evaluate moves. Designing a magazine is a highly ill-structured problem, as there are no clear rules or operators and there exist many acceptable end solutions. Ill-structured problems are consequently open-ended in the sense that the solutions are not unique. In this sense, verifying if a problem has been correctly resolved is problem solving in itself. For instance, to verify if a Sudoku puzzle has been correctly resolved is a simple, well-structured problem, but trying to verify whether the problem of designing a magazine has been correctly solved is much harder as there are no unique or standard criteria to test the solution. Criteria can be internally in conflict; a magazine can be a success from an editorial design perspective, yet a failure from a commercial one.

Visser (2006) notes the difference between routine and non-routine problems: the first kind is one which its representation evokes a well-known procedure that would solve the problem. But a non-routine problem does not evoke a procedure and thus the person must develop one.

A very special type of ill-structured problem related to design, the 'wicked' problem, will be considered in § 5.2.1.

3.3 Decision making

Shafir (1999, p.220) defines decision making as a term with a broad meaning: 'the process of choosing a preferred option or course of action from among a set of alternatives'. According to another definition, decision making is a process with a final goal, the commitment to an action with the aim of obtaining a satisfying outcome (Yates, 2001).

A classical decision-making model is as it follows: the process starts with (1) a stage of collecting information, continues with (2) subprocesses of estimating probabilities and deliberation, and concludes with (3) a performance of a choice (Shafir, 1999). The generic model of decision making is visualised below:

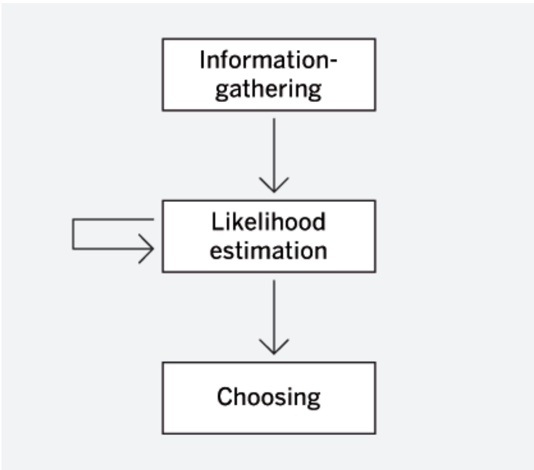

Figure 1: Classical model of decision making

In the classical view of decision making, for a decision to be rational the decision maker should maximise a criterion (e.g. expected utility) and calculate and choose the best alternative (i.e. optimising). I will reflect on this model later, but for the moment, it is useful for illustrating a dimension of the decision: the one based on the choice between alternatives from a simultaneous evaluation or comparison. Further on, we will see how in real-life decision environments it is not possible to simply talk about choice among pre-existing alternatives, but also that decision making is a constructivist task that also involves defining the alternatives.

Decisions can be immersed in a context of uncertainty. Henrion (1999) distinguishes three sources of uncertainty: (1) inaccuracy or non-completeness of the information, (2) linguistic inaccuracies, and (3) disagreement on the sources of information. Four types of issues can also be distinguished regarding informational uncertainty (Schmitt and Klein, 1996): (1) unavailability of the information, (2) little credibility of information, (3) informative ambiguity or conflict, and (4) complexity of the information. Also, the available information is frequently insufficient to be able to precisely assess the consequences of possible courses of actions or alternatives (Cañabate Carmona, 1996).

3.3.1 Models of decision making

In the literature, we find a frequent classification into three types of decision-making models (Baron, 2008; Elliott, 2005; Shafir, 1999):

1. Normative models
2. Prescriptive model
3. Descriptive models

The normative models define *what is to decide well.* These models are based on probabilistic considerations and assume the involvement of a a rational decision maker who has well-defined and stable preferences that obey certain axioms of rational behaviour (Shafir, 1999). A rational decision has three features: (1) the existence of alternatives represented in possible courses of action, (2) a utility function that assigns a value to each possible action based on its outcome, and (3) probabilities as to which outcome will occur in case of the selection of a particular alternative (Simon, 1955).

The prescriptive models establish *how we should decide* in order to decide correctly. They depict a maximisation ideal based on the normative models. In this sense, a prescriptive model always has a normative model behind. This kind of models try to improve decision making in order to bring it to the normative ideal of a correct decision (Shafir, 1999). Most books on improving decision making are a collection of prescriptive methods that are based on normative models (Klein, 1998).

The descriptive models describe *how people decide in the real world*. These models refer to phenomena and decision processes observed in real-life settings. Evidence indicates that people's choices are often at odds with the normative assumptions of the rational theory (Shafir, 1999). Elliott (2005) distinguishes two subtypes of descriptive models: (1) descriptive analytical models, which are maintained within the normative framework by evaluating human decisions in accordance with the degree to which the decision maker approaches or moves away from the maximisation rule, and (2) descriptive naturalistic models.

These normative, prescriptive and descriptive models will be dealt with in more detail below, except for the naturalistic models, which will be treated separately in chapter 4.

3.3.2 Normative and prescriptive decision-making models

The axioms of expected utility theory, formulated by Von Neumann and Morgenstern (1947) and complemented some years later by Savage (1954) became the normative framework for the modern prescriptive models (Shafir, 1999) under the name of subjective expected utility theory (SEU).
When the axioms[4] of expected utility theory are met, then the individual is said to be rational and her preferences can be represented by a utility function that assigns values to each outcome (Plous, 1993). SEU theory combines the classical theory of expected utility and probability theory and assumes that each alternative in a choice has a subjective expected utility for the decision maker. The central hypothesis is that rational decision makers maximise the expected utility from a series of mathematically formulated axioms. The expected utility principle asserts that given a choice under uncertainty (e.g. a gamble), the decision maker will select the one with the highest expected utility (Lichtenstein and Slovic, 1971). For a detailed treatment of expected utility and SEU see Plous (1993) or Baron (2008).

Although the model of maximisation of expected utility has been the prevailing normative framework in research in cognitive psychology and in decision theory doubts have arisen concerning its psychological plausibility and the applicability of these normative models to describe human conduct. The systematic violations of basic axioms of SEU theory has been empirically demonstrated most prominently first by Allais (1953) and then by Ellsberg (1961). A series of experiments conducted by Lichtenstein and Slovic (1971, 1973), casts serious doubts on the descriptive validity of expected utility models of decision making under uncertainty. These and other violations of SEU theory have been discussed by different authors (i.e. Kahneman and Tversky, 1979; Klein, 2001; Plous, 1993; Shafir, 1999).

As we have already seen, Simon (1955) was an early critic of the rationalistic approaches due to human beings' inherent computational limitations that result in a bounded rationality. Authors like Klein (2001) and Gigerenzer (2008b) deeply criticise the normative models and fail to recognise these models as valid for describing human behaviour and to function as a plausible standard against which human decisions are to be measured. They point to a series of internal ambiguities and impossibilities at the very concept of optimisation through the maximisation of the expected utility (extensively discussed in Klein, 2001). One

[4] These axioms are: *completeness*, *transitivity*, *independence* and *continuity*.

of these ambiguities is: does optimisation refer only to the outcome, selecting the best, or also to the methods used? What are we actually optimising? Klein argues that for a decision maker to be able to maximise the utility without violating the axioms, it is necessary to remove all psychological or motivational content and provide the decision maker with unlimited rationality.

3.3.3 Descriptive-analytical models

In the face of the failure of the classical decision theory, a series of descriptive theories and models were brought out regarding decision making. One of the first models was the previously discussed satisficing model proposed by Herbert Simon. Other models have appeared since Simon, such as those proposed within the heuristics and biases paradigm that was discussed before (see p.35). These models expose and explain the divergences between the conduct shown by human beings and what the normative models prescribe as what a rational decision maker should do. Tversky and Kahneman have produced several classical articles (see Kahneman and Tversky, 1979, 1984; Tversky and Kahneman, 1974, 1981) showing how people's behaviour differs greatly from expected utility theory. There they offer empirically validated models, such as prospect theory, which describes how people chooses under risk when probabilities of outcomes are known, and expose deviations from the norm, such as the so-called *loss aversion* phenomenon, a tendency to prefer avoiding losses to acquiring gains[5].

In the paradigm of heuristics and biases, human beings are overwhelmed by the complexity of the situations in which they have to decide and turn – in order to make decisions more efficiently – to heuristic rules, intuitive rules based on experience or on what seems logical and reasonable at any given moment. According to this paradigm, the heuristics are useful in the sense that they enable the decision maker to reach a decision, but also lead to biases or cognitive errors. Baron (2008) compiles more than 50 heuristics and biases that do not comply with different normative models (e.g. formal logic, SEU, Bayes' theorem).

The heuristics and biases paradigm has been criticised, amongst others, by Klein (1998) who mentions that the decision biases are reduced or simply disappear when experienced people are studied in realistic contexts. In different situations, the apparent bias might later be reinterpreted as a reasonable judgment when a

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[5] Prospect theory predicts that a person who loses £1000 will feel more distress than the satisfaction she will feel when gaining £1000 as losses are psychologically stronger than gains. This motivates a behaviour in which people prefer avoiding losses to making gains. According to expected utility theory, a rational agent should be indifferent to the reference point and she should only care about absolute wealth.

more complete validation analysis has been already carried out and it includes the informative structure of the environment (Gigerenzer, 2008b). When the information is represented in natural frequencies and not in probabilities, the subjects are less liable to bias and deviation, which means that the deviation from a correct *bayesian* reasoning is much smaller than what is shown by Tversky and Kahneman's experiments (Cosmides and Tooby, 1996; Gigerenzer and Edwards, 2003).

See Baron (2008) and Plous (1993) for a comprehensive overview of descriptive analytical models and theories.

Criticisms of the heuristics and biases paradigm

Klein (2001) rejects the path followed by the decision research field. Instead of examining and understanding the origin and application of heuristic reasoning to discover in what way human beings use their experience and expertise to function in real decision environments, the heuristics and biases movement contented itself with drawing up an inventory of human errors identified in experimental situations. The maximisation of expected utility continues to be seen as the standard upon which the decision must be evaluated. Therefore, a careful and exhaustive analysis of the options would be considered rational, whereas the application of heuristics would not, above all, due to the possibility of the occurrence of biases, which are considered errors insofar as they diverge from what the norm prescribes.

A critique of the heuristics and biases paradigm is also a critique of the normative model that lies underneath. The naturalistic researchers suggest replacing optimisation as a normative criterion with a new one: 'to select a course of action that is not clearly inferior to any other option, given a reasonable examination of the situation' (Klein, 2001, p.117). This standard maintains the ideal of optimisation, but only as a guideline: look for the best, but limit the search to what is reasonable; what is reasonable is determined by subjective criteria on the part of the decision maker and involves different factors such as the time available to choose, the decision maker's experience, her values, etcetera. Klein's notion of reasonableness clashes with the definition of reasonableness that exists within the normative model: optimising by choosing the alternative that maximises expected value.

3.4 Are problem solving and decision making the same after all?

In this chapter problem solving and decision making were considered as separate activities. Problem solving is a group of activities meant to analyse a given situation and to generate, to evaluate and to implement solutions. Decision making is a way of making choices and normally has been seen as a part of problem solving. But it could be argued that a person solves problems in order to implement a decision (e.g. *How can we send a human to Mars?*), or it could be also claimed that a person makes a decision in order to solve a problem (e.g. *What materials should we choose for the spaceship?*). In any case, it is safe to say that decision making is a constant part of problem solving.

In naturalistic settings, the differences between problem solving and decision making become blurry (Klein, 1998). Problem solving and decision making are often intertwined. The linear models shown in page 37 have been heavily criticised by Klein (1998) as being too mechanistic and too centred on well defined goals (e.g. solving puzzles). Rittel and Webber (1973, p.5) tackle the same issue from a different perspective:

> By now we are all beginning to realize that one of the most intractable problems is that of defining problems (of knowing what distinguishes an observed condition from a desired condition) and of locating problems (finding where in the complex causal networks the trouble really lies). In turn, and equally intractable, is the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be.

In the linear account of problem solving the first stage is the definition of goals (i.e. solution). But on the contrary, in ill-defined problems this goal, per definition, can never be defined in advance, meaning thus that the problem solver should remain at that stage forever and that the problem shall remain unsolved. The (re)solution of ill-defined problems requires a constructivist, non-linear approach, in which the problem and the goals are being formulated along the process of problem solving. A traditional view on problem solving cannot account for the constructivist tasks of goal clarification that occurs when people try to solve ill-defined problems.

In this chapter rationality, decision making and problems solving have been explored, discussed and contextualised. A notion of instrumental, procedural rationality and psychologically plausible decision making models have been discussed, as well as the notions of problem and problem solving and the important subclass of ill-structured problems – frequent in design theory – has been introduced.

Before exploring design activity and design decision making, several models and theories behind the naturalistic decision making framework, this thesis' main theoretical underpinning, will be considered in the following chapter.

CHAPTER 4

Descriptive-naturalistic models

The present chapter will analyse descriptive-naturalistic models intended to model human behaviour as it happens in real decision situations based on descriptive research. A dissection of the NDM framework and the process of *macrocognition* will be developed along with two key naturalistic models: the RPD and DTFS. To conclude, a consideration about the role of intuition and analysis in decision making and problem solving can be found

In the early 1980's, a series of applied programs appeared where the focus was on studying human cognitive effort in real contexts of action. Due to digitalisation, increased complexity and automation of the work environments, the study of human performance in situations in which previously unknown complex socio-technological interactions were given has become essential (Crandall et al., 2006). The study of cognition in real environments causes a crisis among the goals of cognitive science. More than understanding human cognition in a general or abstract way, researchers must study human commission and the context in which it occurs (Crandall et al., 2006), as well as the role played by experience and expertise in a certain area (Klein, 1998).

The locus of this chapter lies on the NDM movement, which was briefly introduced in § 1.4. I will not deal with other naturalistic programs and models such as situated cognition or ecological rationality. For a general treatment of these and other naturalistic programs and models see Crandall et al. (2006). For a specific treatment of the situated cognition program, see Seifert (1999) or Robbins and Aydede (2008). For ecological rationality see Todd and Gigerenzer (2000), Gigerenzer and Stelten (2001) or Gigerenzer (2008b).

4.1 Naturalistic decision making

A talk given in Dayton (Ohio, USA) in 1989 sparked the NDM movement (Lipshitz, Klein, Orasanu and Salas, 2001a). Its initial focus was on the study of decisions, but this focus was later extended to include other cognitive processes and functions related to the decision, such as problem detecting, planning, situation awareness and sensemaking (Klein, Orasanu, Calderwood and Zsambok, 1993). Sensemaking is the mental process by which people gain awareness and understanding of a situation by giving meaning to experience. This concept will be explicitly dealt with in § 4.3.

Naturalistic researchers argue that in order to understand and explain decision making, rationality and the cognitive functions have to be put in context. Even traditional experimental psychologists agree that the decision makers do not perceive and remember isolated of their environment, as they interpret new information in the light of past experience and the context of the situation (Plous, 1993). The naturalistic view of cognition assumes that this process is goal-directed and does not happen in an experimental vacuum, but rather in a *cognitive landscape* whose principal features are: (1) the purpose of the cognition, (2) the use of previous experience, (3) the situation itself, (4) the nature of the faced challenge, (5) the tools available for dealing with the challenge, (6) the presence or absence of teamwork, and (7) the institutional frameworks where the decision makers operate (Crandall et al., 2006; Orasanu and Connolly, 1993).

To summarise, the NDM movement focuses on studying the real behaviour of decision makers in complex, untidy situations, which by definition are difficult to reproduce in experiments or controlled situations. The main object of study of the NDM movement is *macrocognition*, a term coined by Cacciabue and Hollnagel (1995) as a way of describing cognitive work as it occurs in real-world settings.

4.1.1 Macrognition

Macrocognition comprises the mental activities that must be successfully accomplished to perform a task or achieve a goal (Klein, Ross, Moon, Klein, Hoffman and Hollnagel, 2003); it contrasts with the traditional study of the basic cognitive processes that occur in the human mind and are investigated by cognitive psychology in order to model the basic and universal blocks of human cognition (e.g. memory, perception). These basic cognitive processes may be understood as *microcognition* (Crandall et al., 2006; Klein et al., 2003). Since NDM seeks to understand and describe how human beings decide and why macrognition may be useful to them in achieving their goals, the study of macrognition rarely deals with the specific internal mental processes of the subjects or participants (Cacciabue and Hollnagel, 1995), as it fundamentally deals with interaction between the decision maker and the situation.

There are 12 macrocognitive functions and processes: (1) naturalistic decision making, (2) sensemaking, (3) planning, (4) adaptation/replanning, (5) problem detection, (6) coordination, (7) managing attention, (8) identifying leverage points, (9) managing uncertainty and risk, (10) mental simulation, (11) developing mental models, and (12) maintaining common ground (Crandall et al., 2006). Naturalistic decision making is central to this work and therefore will be dealt with extensively in § 4.1.2 and § 4.2. Sensemaking is considered in § 4.3. In the following paragraphs I will briefly introduce several other functions and processes that are specially relevant to this thesis. This introduction is mainly based on Klein et al. (2003) and Crandall et al. (2006), except when referenced otherwise. See aforementioned sources for a discussion of all macrocognitive functions and processes.

Planning

Planning is the process of modifying action to transform a current state of affairs into a preferred future state. Due to uncertainty, time pressure and other factors such as having to deal with massive amounts of – sometimes conflicting – data, planning can be seen as a complex cognitive task. Many researchers agree that in such cases, a recognitional approach to planning based on pattern matching and experience supersede rational, deliberate planning processes (Ross, Klein, Thunholm, Schmitt and Baxter, 2004; Schmitt and Klein, 1999).

Problem detection

The ability to detect problems[6] and incidents at an early stage is critical in most field settings. Experienced decision makers can detect anomalies when there is still time to avoid or minimise consequences. The accumulation of problem indicators surpasses a threshold of tolerance and the decision maker becomes more alert in order to monitor events closely and detect new evidence.

Adaptation/replanning

Organisations devote a lot of time adjusting or replacing a plan that is already being implemented. This activity largely depends on the detection of problems, which is noticing that the plan is falling apart. An important feature of adaptation is goal negotiation, considering substitution or abandonment of initial goals.

Developing mental models

According to Johnson-Laird and Byrne (1991) deductive reasoning is carried out by mental models, not by logical or content-specific rules. Mental models are mental representations that correspond in structure to the situations that they represent (Thagard, 2005). Events in the mental model are formed on the basis of abstract knowledge of domain concepts and principles (Crandall et al., 2006). The notion of mental models is similar to the psychological notion of *schema* (pl. *schemata*), a framework or body of knowledge about some topic that is stored in

[6] As mentioned in § 1.7, in this particular case, the word 'problem' is not used as a technical term to refer to a person's mental representation of her task, but it is used with its everyday meaning: a difficulty or an unwelcome situation that needs to be dealt with.

memory, including its attributes and the relations among these (Ashcraft, 1998; Hogg and Vaughan, 2008). Mental models differ from schemata in the sense that they are not stored like templates and retrieved from memory. They are actively and deliberately formed each time a data set or situation is perceived (Crandall et al., 2006).

Simulation

Through simulation the decision maker hypothesises about possible future scenarios in order to explore alternatives. This process plays a key role in sensemaking, anomaly detection and decision making. Mental models and causal reasoning provide an understanding of how past events have turned into the current situation; therefore, simulation is about how the current situation can evolve. The simulation can end in a closed state or with an open ending.

Kahneman, Slovic and Tversky (1982) define five different types of simulation scenarios:

- *Prediction*: a type of simulation in which one, starting from the present situation, speculates about the future. *Example*: imagining the course of a meeting between two people you know well, who have never meter before.
- *Assessing the probability of a specified event*: in this type of simulation, starting from current reality, one tries to estimate the probability of occurrence of a specified target state. *Example*: assessing the likelihood of American armed intervention to secure oilfields in country X within the next decade.
- *Assessing conditioned probabilities*: this is more complex than the previous type in the sense that it starts from a hypothetical state, which may diverge from current reality. *Example*: if a civil war breaks out in country X, what are the most likely consequences?
- *Counterfactual assessments*: in which a person simulates an alternative to the past and explores how things could have turned out differently. *Example*: what would have happened if Germany had developed the atomic bomb before the Americans?
- *Assessments of causality*: to test whether A caused B, one may undo A and observe whether B still occurs in the simulation. *Example*: it can be imagined that the current economic downturn would be still happening, even if Lehman Brothers had not collapsed, as this economic crisis is systemic and not caused by any particular institution.

Evidently, a simulation may or may not be successful. External factors such as time pressure or uncertainty interfere with the simulation; also internal factors such as confirmation bias[7] can lead the decision maker to discard information that contradicts her interpretation. For more on simulation see Kahneman et al. (1982) and Klein (1998).

Identifying leverage points

Crandall et al. (2006) note that 'identifying leverage points is the ability to identify opportunities and turn them into courses of actions'. According to her, expert decision makers do not generate options through searching the problem space, but rather by using their experience and memory to find promising leverage points from which to develop a plan that is thought to be likely to succeed.

4.1.2 Central hypotheses of the NDM framework

Klein (1993, 1998), Orasanu and Connolly (1993) and Zsambok et al. (1992) make the following hypotheses on the process of naturalistic decision making:

- *Experts perform sensemaking:* in naturalistic environments, decision makers use a large part of the decision process understanding the situation, structuring the problem and defining which cues of the environment will be valuable for approaching it. Sensemaking is initiated when a person realises the inadequacy of the current understanding of events and is often a response to a surprise or a failure of expectations (Klein, Phillips, Rall and Peluso, 2007). Sensemaking will be considered with further detail in § 4.3.
- *Decision makers construct and modify a single course of action without comparing alternatives*: decision makers do not generate and evaluate multiple courses of action at the same time, but rather a single one, or just a solution according to how well they fit in with a prototype in which the decision situation has been classified. No alternative is considered, unless it contains a course of action that appears highly viable. This *singular evaluation approach* is related to mental stimulation, which is the tool that is used to determine the viability of the course of action.
- *Decision makers satisfice*: the singular evaluation approach implies a satisficing behaviour focused on achieving a satisfactory alternative that works sufficiently well. This constitutes a radical divergence from the

[7] Confirmation bias 'refers to a preference for information that is consistent with a hypothesis rather than information which opposes it' PLOUS, S. (1993) *The psychology of judgment and decision making*, New York: McGraw-Hill.

classical decision models that prescribe optimisation and an exhaustive analysis of all alternatives.

- *Decision makers act in uncertainty*: it can be safely assumed that in a changing environment, decision makers will have to cope with different kinds of informational uncertainty and must act without having complete or totally coherent information.
- *Decision making and problem solving are interrelated*: in naturalistic environments, the clarification of goals, the generation and evaluation of solutions – processes typically dealt with as problem solving – are mixed with the search for information, deliberation and selection of alternatives, which are seen as decision-making processes.
- *The process is constructivist*: by using analogies and prototypical cases, the decision makers frame the problem and generate solutions. They do not behave accordingly to the normative and prescriptive models (see § 3.3.2) in which a decision maker is limited to evaluating and choosing among alternatives not constructing them.

4.1.3 Experts and expertise

In naturalistic research, the participants are subjects with skills in the area in which they have to decide (Klein, 1998). Expertise can be understood as the skilled execution of highly practiced sequences of procedures (Ericsson, Charness, Feltovich and Hoffman, 2006). The development of experience can be seen as the acquisition of a cognitive skill (Elliott, 2005). According to Crandall et al. (2006), in order to develop expertise and skill, exposure is required to a varied range of situations, as well as an attitude of paying attention to experiences and moving forward actively in developing the skill.

Klein and Militello (2004) distinguish experts from beginners regarding their capacity to solve problems according to the following attributes: (1) use of richer and more adequate mental models, (2) greater perceptive capacities, (3) sense of typicality, and (4) greater declarative knowledge. Experts not only know more, but they know in a different way. Lipshitz and Shaul (1997) found three specific distinctive phenomena between experts and beginners:

1. Experts seek more information than beginners during sensemaking and in order to identify goals.
2. Experts have more specific expectations and detect problems more frequently.
3. Experts make more simulations than novices.

To perform sensemaking and simulation, the decision maker needs to have schemata and mental models. Experts also seek more information, but the existence of a more developed mental model guides the search and leads to a more efficient sensemaking.

A naturalistic expert decision is rather similar to what Dreyfus and Dreyfus (1986, p.36) call *arational* behaviour: 'action without conscious analytic decomposition and recombination'. Dreyfus and Dreyfus (1986) proposed a phenomenology of human learning and expertise with a particular emphasis placed on the linkage between knowledge and context. Dreyfus and Dreyfus do not belong to the NDM framework, but since their phenomenology is aligned with NDM, I will briefly review the Dreyfus model of expertise and intuition as it directly addresses the issues of context-dependence and non-analytical approaches in expert decision making.

The Dreyfus model states that there are five levels in the process of skill acquisition:

1. *Novice*: at this level the person shows a total adherence to taught general rules and plans; there is no contextual o situational perception that affect decision making.
2. *Advanced beginner*: the person behaves according to general rules but begins to apply them to related conditions at her discretion; this behaviour requires the identification of situational elements or aspects.
3. *Competence*: at this level the person senses that the amount of general rules becomes excessive and begins to apply organizing principles to assess the information by its relevance to a longer-term goal. There is conscious, deliberate planning and standardised and routinised procedures.
4. *Proficiency*: the proficient performer sees the situation holistically rather than in terms of aspects, detecting intuitively what is most important and what is going on in a given situation through pattern recognition, and perceiving deviations from the normal pattern (anomalies). The person uses analytical decision making and general rules but the general rules and principles are adapted according to the situation.
5. *Expertise*: the expert does not rely on rules but uses intuition to make decisions. Pattern recognition covers planning and acting as well as diagnosing the situation. Dreyfus and Dreyfus argue that at this level experts are not actually making decisions or solving problems, but doing what works based on a vision of what is possible to do. Analysis is only performed during novel situations or when anomalies are detected.

This model describes a progression from acting consciously on the basis of context-free and general rules at the novice level, to the application of situational rules at the proficient performer. At the expert level, behaviour flows naturally as the actions fit the demands of the situation without analytical reasoning. When experts deal with typical situations, they are not 'making' decisions but carrying out actions that are likely to be successful. Dreyfus emphasises the holistic nature of expert behaviour, in which problem, goal, plan and decisions are appraised simultaneously.

4.1.4 Studying NDM: cognitive task analysis

To understand which cognitive processes occur in decision making, it is necessary to understand how people decide in real settings. When these decisions are infrequent, difficult and/or complex, this is not achieved by merely observing behaviour in a lab and it is necessary to discover what decision makers think and know, how they organise and structure information they receive and what they seek to do. For a more thorough understanding of the NDM framework and the type of methods that are used within the movement, I will briefly introduce cognitive task analysis (CTA), one of the principal research tools within NDM (Crandall et al., 2006).

CTA is a family of methods for accessing these mental processes, for organising them and giving meaning to the observable behaviour. These methods describe the cognitive processes underlying the performance of tasks and the cognitive skills necessary for acting ably in complex situations. Chipman, Schraagen and Shalin (2000) define CTA as follows:

> Cognitive task analysis is the extension of traditional task analysis[8] techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance.

Hoffman and Militello (2008) give the following definition:

> CTA is a methodology for the empirical study of workplaces and work patterns, resulting in: (a) descriptions of cognitive processes and phenomena accompanying goal-directed work, (b) explanations of work activity in terms of the cognitive phenomena and processes, and (c) application of the results to the betterment of work and the quality of working life by creating better work spaces, better supporting artifacts (e.g. technologies), and by creating work methods that enhance human

[8] Traditional task analysis is aimed at studying the performance of the person in carrying out a task intended to achieve a goal.

> satisfaction and pleasure, that amplify human intrinsic motivation, and that accelerate the achievement of proficiency.

CTA techniques have been developed independently by researchers around the world; there is a considerable variety of approaches, emphasis, and resource requirements (Militello and Klein, 1997). As it is a family of methods, there is no single established way to implement this method, nonetheless, three generic phases can be distinguished: (1) knowledge elicitation, (2) data analysis, and (3) knowledge representation (Crandall et al., 2006). These phases are described below.

Knowledge elicitation

This is the process of eliciting information about cognitive events, structures and models. Four types of groups of data collection methods can be indicated: (1) structured, semi-structured or unstructured interviews, (2) self-reports, (3) observations of performance, and (4) automatic collection of behavioural data. Participants are generally people who have shown great skill and knowledge, i.e. subject-matter experts (Crandall et al., 2006).

Data analysis

This is the process of inspecting the data, selecting, simplifying, abstracting and transforming the information, in order to develop explanations and hypotheses. CTA allows for the use of qualitative and/or quantitative data analysis methods. The stages in the analysis phase are: (1) preparation, (2) data structuring, and (3) meaning discovery (Crandall et al., 2006).

Knowledge representation

This is the process of exhibiting the obtained data and describing the detected interrelationships and developed hypotheses. The process of this phase can be overlapped with the previous analysis. The types of analytic results of CTA typically delivers include: (1) textual descriptions, (2) tables, graphs and illustrations, (3) qualitative models such as flow-charts, and (4) quantitative models (Crandall et al., 2006).

For an overview of several naturalistic methods see Cooke (1994) or Crandall et al. (2006); see Schraagen, Chipman and Shalin (2000) for a discussion of methods and case studies.

4.2 The RPD model

The recognition-primed decision (RPD) model describes how people use their experience in order to make good decisions (Klein, Calderwood and Clinton-Cirocco, 1986). The RPD model was initially developed by Klein et al. (1986) and is one of the models in NDM that has received most attention; but there are other models (for an overview see Lipshitz, 1993; Lipshitz, Klein, Orasanu and Salas, 2001b).

The model covers three kinds of situations (Klein, 1993, 1998):

1. Situations that can be recognised as prototypes
2. Situation of assessment and sensemaking
3. Situations of mental simulation, evaluation and adjustment

These situations are described below.

Situations recognisable as prototypical

This is a type of situation in which the decision maker immediately understands the priorities and goals that are key to the environment that is worth exploiting, what to expect from the evolution of the situation (to realise anomalies) and what the typical ways to act are. This situation may be represented by a simple rule like: 'If S then C', where C is a course of action that is seen by the decision maker to be suitable for a situation S.

Once the decision maker seizes of the situation, she monitors for *cues* and recognises *patterns*, which activate routines for responding: the so-called *action scripts*. The pattern tells the decision maker what to do and the action script indicates how to do it. An action script is thus a kind of routine for making things happen; it is a general course of action, not one that can be carried out algorithmically as a sequence of steps. In fact, it needs to be contextualised and adapted to the situation in order to be adopted, requiring experience to be executed. In general, experts have a greater collection of actions scripts at their disposal (Klein, 2003).

Example: a person who works in a business formal environment needs to decide what to wear to go to a business reception. She recognises the situation as familiar and chooses a typical way of responding (i.e. choosing a formal business suit).

Situation of assessment and sensemaking

These are situations where the decision maker must examine the situation in a deeper manner and perform sensemaking before deciding on a course of action.

These kinds of situations can be characterised by a rule of the type 'If S? then C', where the decision maker first needs to determine the nature of the situation S before choosing a course of action.

Example: a person is invited to a birthday reception. She sets to find out what kind of reception it is, what kind of people are attending, at what time it is, etcetera. Once she has made sense of the gathered data, she is ready to decide what to wear.

Situations of mental simulation, evaluation and adjustment

These are situations where the focus is on mental simulation, evaluation and adjustment of courses of action. The rule in this case is 'If S then Y?', where the decision maker considers the relevance and adequacy of a course of action based on a simulation and adjusts the course of action accordingly.

Example: the person from the previous example and her best friend arrange to meet in town and go to the reception together. When she meets her friend, she realises that they are wearing the same dress. She imagines herself at the reception wearing the same outfit someone else is wearing, and she thinks she needs to tweak her outfit. She decides to find a shop in order to buy a brooch and a scarf to make the dress look different.

4.2.1 Integrated RPD model

The model principally depicts two integrated macrocognitive processes (Klein, 1993, 1998):

1. *Sensemaking*: the decision maker evaluates, values and diagnoses the situation to produce a course of action.
2. *Mental simulation*: the decision maker generates a course of action and performs a mental simulation of it in order to evaluate its usefulness.

The three types of situations seen in § 4.2 are integrated in the model depicted in Figure 2 (seen next page).

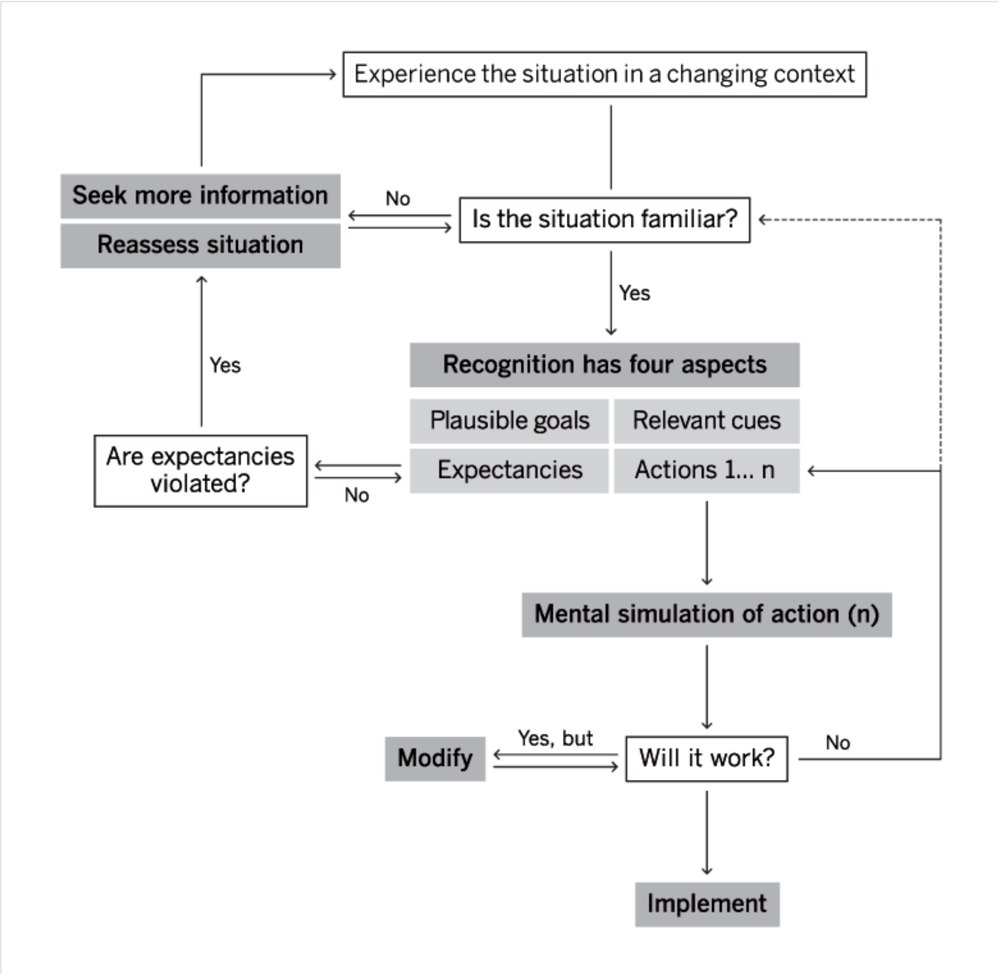

Figure 2: Model of recognition-primed decision (adapted from Klein, 1998)

This model affords the combination of the three types of situations seen before. When the situation can be seen as familiar, the decision makers match the present situation with a prototype stored in memory. In more complex situations – when the situations are not familiar or when expectations are breached, for instance – the decision makers use sensemaking and/or mental simulation process to decide. It is also possible to imagine complex situations in which one goes back and forth from sensemaking to simulation processes or a situation in which one first recognises a situation as prototypical but later detects anomalies and needs to perform sensemaking.

Another critical aspect of RPD is the ability to detect anomalies. Expert decision makers can detect anomalies when there is still time to avoid or reduce negative consequences. According to Crandall et al. (2006) the accumulation of evidence passes a critical threshold and signals an alarm. The detection of early indicators that problems are occurring or expectancies are being violated heightens the person's awareness so that new indicators of anomalies can be quickly detected.

An expectancy is a sense of what is going to happen in a situation, therefore expectancies are based on experience and on the mental model of a situation. When a decision maker reads a situation correctly, the expectancies should match the events.

4.2.2 Inclusion of mental models and schemata

The initial RPD model was extended by Lipshitz and Shaul (1997) with the inclusion of the concept of schemata and mental models to better adapt it to represent the differences between the behaviour of experts and beginners. The degree of 'familiarity' of the situation is determined through schema guided situation awareness and the automatic recognition of cues for familiar patterns. The schema helps determine which information we should be considering, what information is missing and where it might be found (Elliott, 2005). The situation assessment – a combination of previous and current knowledge – results in the formation of a mental model of the situation. At this stage, goals are defined and expectancies are formed; from this mental model the decision maker will project the environment's status into the future (i.e. mental simulation) (Elliott, 2005).

4.2.3 Simplified model

Even though Klein did not explicitly include the concept of mental model in his early model (see Figure 2), he did acknowledge its importance (Klein, 1998, pp.152-153). In a later version of the model, Klein (2003) proposes a simplified version of the RPD model that includes mental models and action scripts. Figure 3 below illustrates the simplified model.

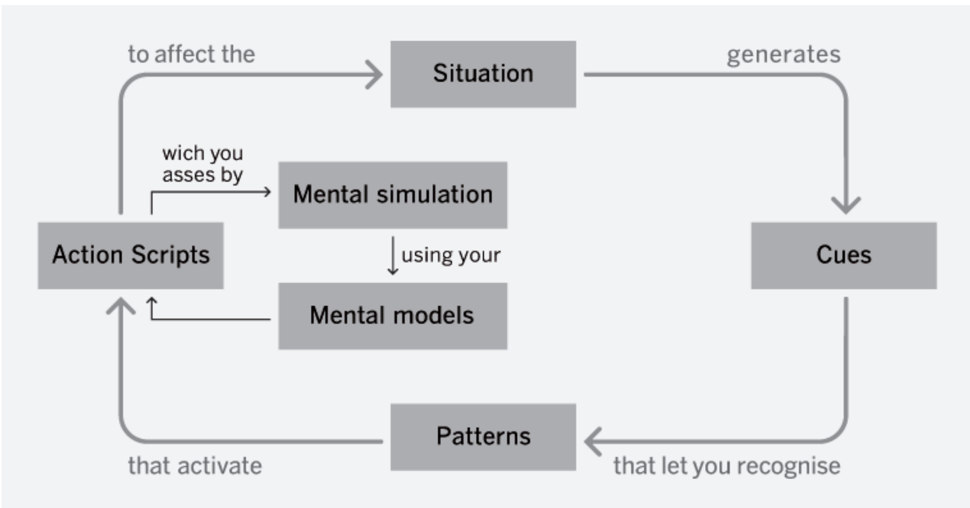

Figure 3: Simplified model of recognition-primed decision (adapted from Klein, 2003, 2009)

This new model unifies and integrates the macrocognitive processes that are responsible for expert decision making. It shows as well how 'decision makers use their experience to recognise an effective option and evaluate it through mental simulation' (Klein, 2009, p.91). The simplified model depicts four steps (Klein, 2003):

1. Cues allow decision makers to recognise patterns.
2. Patterns activate action scripts.
3. Action scripts are assessed through mental simulation.
4. Mental models drive mental simulation.

The model remains covering the three cases seen at the beginning of § 4.2. The steps of cue detection and pattern recognition describe situation assessment and sensemaking (*If S?*). The loop between mental model and simulation covers situations of mental simulation and evaluation (*then Y?*). When the situation is recognisable as prototypical the decision maker will only apply action scripts, staying on the outer circuit of the loop (*If S then Y*). The cycle of prototypical decisions is illustrated in Figure 4 below:

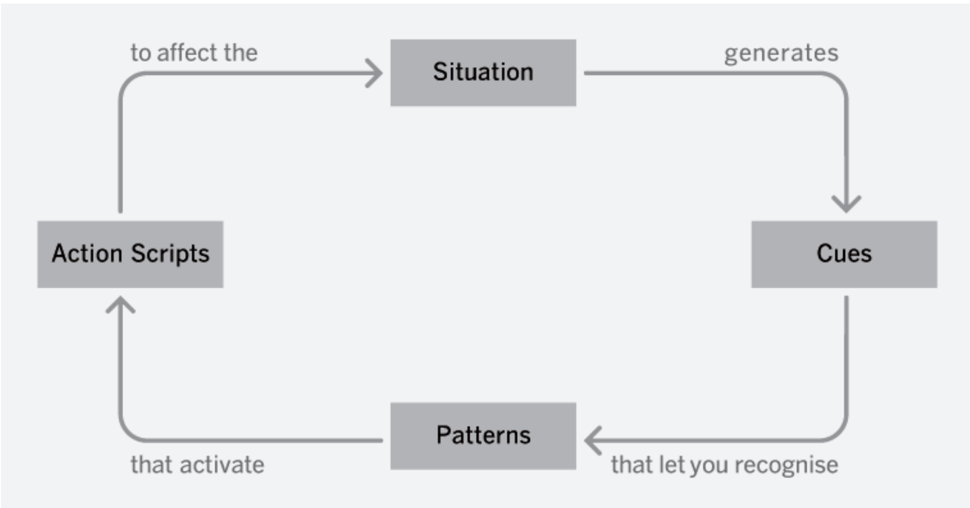

Figure 4: Pattern-recognition process behind recognition-primed decisions (adapted from Klein, 2003)

In this particular case, the decision maker translates her experience into judgements and decisions based on a process of pattern-recognition and pattern-matching (i.e. recognising what is going on a situation and implementing a typical action script with which to react). This phenomenon can be seen as *knowing* what to do, effortlessly and without deliberate analysis (Klein, 2003).

4.3 Data/frame theory of sensemaking

Sensemaking can be understood as 'the deliberate effort to understand events' (Klein et al., 2007, p.114); this effort is commonly initiated by the detection of anomalies or surprising changes in the expected course of events. During sensemaking, people adopt a particular perspective from which a situation is examined. Klein et al. (2007) define sensemaking as:

> A process of framing and reframing, of fitting data into a frame that helps us filter and interpret the data while testing and improving the frame and cyclically moving forward to further adapt the frame.

The notion of frame requires further examination. Minsky (1974) defines the concept of frame as follows:

> A frame is a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child's birthday party. Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some is about what one can expect to happen next. Some is about what to do if these expectations are not confirmed.

According to Tversky and Kahneman (1981, p.453), a decision frame is 'the decision maker's conception of the acts, outcomes, and contingencies associated with a particular choice'. These authors argue that frames are controlled by the formulation of the problem on the one hand, and by norms, habits, and personal characteristics of the decision maker on the other hand.

Klein et al. (2007, p.119) define the function of the frame as follows:

> The purpose of the frame is to define the elements of the situation, describe the significance of these elements, describe their relationship to each other, filter out irrelevant messages, and highlight relevant messages. Frames can organize relationships that are spatial (maps), causal (stories and scenarios), temporal (stories and scenarios), or functional (scripts).

According to Klein et al. (2007, p.120), a frame is not only something with what we think, but also something about what we think:

> Data are the interpreted signals of events; frames are the explanatory structures that account for the data. People react to data elements by trying to find or construct a story, script, a map, or some other type of structure to account for the data. At the same time, their repertoire of frames – explanatory structures – affects which data elements they consider and how they will interpret these data. We see sensemaking as the effort to balance these two entities – data and frames.

The frame gives shape and defines what constitutes relevant data and the available data determine the adaptive change of the frame (Klein, Moon and

Hoffman, 2006). The attempt to connect data and a frame, fitting data into a frame and framing and reframing in order to match the data may be seen in the following model:

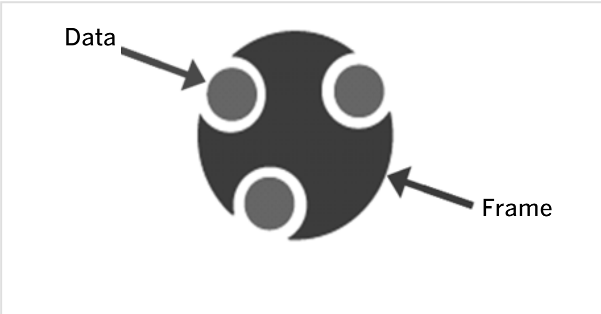

Figure 5: Sensemaking attempts to connect data and a frame (Klein et al., 2007)

The data/frame theory of sensemaking (DFTS) postulates a sequence of transitions between the processes of (1) forming mental models, which is retrospective and explanatory, and (2) mental stimulation, which is prospective and anticipatory (Klein et al., 2006; Klein et al., 2007). Sensemaking is a chain of closed loops and each loop is activated by the perception of a sub-event, which leads to the effort of redefining an existing mental model. At this point, it is possible to generate a retrospective explanation or perhaps at least to speculate on the evolution of the situation.

4.3.1 Hypothesis of the data/frame model

The data/frame model (Klein et al., 2006; Klein et al., 2007) postulates the following hypotheses:

1. Sensemaking is the process of matching data to a frame and a frame to the available data.
2. The data are inferred from the frame and are not perfect representations of the world, but rather approximate constructions.
3. The frame is inferred from a few *anchors*. An anchor is the initial information people use to make subsequent judgments. According to Klein et al. (2007) when a person encounters a new situation or detects an anomaly, she uses the first or second experienced data elements as anchors for creating an understanding. These anchors facilitate the initial frame, and she uses that initial frame to search for more data elements.
4. The inferences carried out during sensemaking are the result of logical and abductive reasoning. Abductive inference is a type of reasoning different from both induction and deduction; it is the process of facing an unexpected fact, applying a rule – already known or created *ad hoc* – and, as a result, proposing or hypothesising a case that may be.

5. Sensemaking ceases when the frame and data have fitted congruently and sufficiently.
6. Experts have a larger available repertoire of frames than beginners.
7. Sensemaking is applied both to achieve a functional and an abstract understanding of a situation.
8. Deciders can rely on *just-in-time* mental models, which are developed especially for the occasion.
9. Sensemaking has different forms and dynamics. Sensemaking is not a single process, but rather several integrated subprocesses.

The DFTS model is displayed visually in the following model:

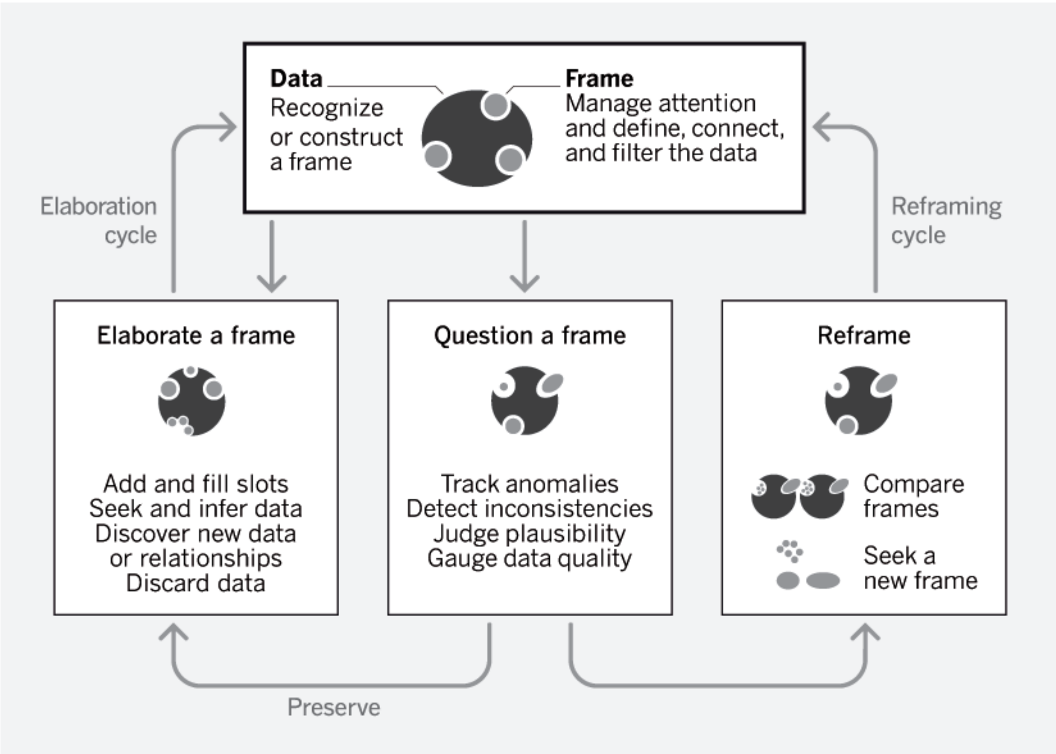

Figure 6: Model of the Data/Frame theory of sensemaking (adapted from Klein et al., 2006)

Sensemaking is an active process. It is not only situation awareness – which is a function of sensemaking – neither the mere evaluation of the situation, nor the search for information. It is a model of abductive reasoning in which data and frame fit each other. Different sub-processes occur in this fitting: (1) frame elaboration, (2) frame questioning, and (3) reframing. A perfect unconscious fit between data and a frame is not sensemaking because it is automatic; it is rather pattern matching (Klein et al., 2007). See Klein et al. (2007) for a comprehensive treatment of sensemaking.

4.4 The role of intuition

In the RPD model, experts do not necessarily engage rationally in an analytical sense: they have developed their expertise and knowledge to such an extent that they do not require conscious, volitive or explicit reasoning. Experts seem to usually *know* what to do in a given situation without necessarily defaulting to rational thought and inference. This behaviour is usually referred to as 'intuition' and, as it was already signalled by Glöckner and Witteman (2010), it is obvious that the intuitive processes are crucial for making decisions The concept of intuition needs further exploration in order to clear it from the magical or mystical connotation it has in everyday language.

Intuition refers to: (1) an evaluation of which we are rapidly consciously aware, (2) with reasons of which we are not fully conscious, and (3) sufficiently strong to make us act thereon. Intuition works thanks to the application of heuristics intended to operate within limits of time, knowledge and computational capacity, without applying calculation of probabilities or utility, as prescribed by the classical models (Gigerenzer, 2008a; Todd and Gigerenzer, 2000). Herbert Simon (1992, p.13) offers a definition of skilled intuition:

> In everyday speech, we use the word intuition to describe a problem-solving or question-answering performance that is speedy and for which the expert is unable to describe in detail the reasoning or other process that produced the answer. The situation has provided a cue; this cue has given the expert access to information stored in memory, and the information provides the answer. Intuition is nothing more and nothing less than recognition.

It is interesting to note that this definition is accepted by authors belonging to opposite paradigms such as Gary Klein and Daniel Kahneman (Kahneman and Klein, 2009).

Klein (1998, p.31) argues that '[i]ntuition depends on the use of experience to recognise key patterns that indicate the dynamics of the situation'. The patterns are subtle and may evade conscious awareness, which means recognising reality without knowing that we are recognising it or how it is happening (Gigerenzer, 2008a; Klein, 1998). Most of the processes that we frequently call intuition are processes of recognition (Simon, 1999). The capacity of recognition comes from experience: often what is recognised is the deviation from a pattern or expectation more than the recognition of a prototype as such. For recognition, experts use patterns of cues more than the recognition of a particular isolated cue (Klein, 1998).

There are different models of intuition based in the so-called dual processing, which indicates a clear distinction between intuitive, automatic processes on one hand and deliberate, conscious processes on the other. Stanovich and West (2000) propose a system 1 and a system 2 dual-process theory, which was adopted by authors such as Kahneman (2003), who describes system 1 as being highly associative, fast, automatic and usually emotionally charged (i.e. intuition). It is implicit – meaning that it is not available to introspection – and governed by habit and therefore difficult to control or modify. The system 2 of reasoning is slow, costly in cognitive terms, likely to be conscious and controllable in most situations (Kahneman, 2003). For a detailed treatment of dual-process theory see Osman (2004).

Authors such as Glöckner and Witteman (2010) argue that intuition is not an even concept but rather a group of different cognitive mechanisms: (1) *intuitive association* based on simple learning retrieval processes, (2) *matching intuition* based on comparison with prototypes, (3) *accumulative intuition* based on evidence accumulation, and (4) *construction intuition* based on the construction of mental representations.

Two processes that are related to intuition are those of the activation of action scripts and pattern matching, which can occur in an instant and without conscious reasoning (Klein, 2003). Figure 4 from page 60 can be taken as a naturalistic model of intuitive decision making based in pattern-recognition. See Glöckner and Witteman (2010) for a comprehensive overview of categorisation of processes underlying intuitive judgement and decision making

4.5 The role of analysis

The normative and prescriptive approaches of decision making do not consider decision in a holistic manner, but in a more restricted view, limiting decision making to analysis of choice alternatives and ignoring the structuring or definition of these alternatives. According to Beaney (2012) analysis might be defined as:

> A process of isolating or working back to what is more fundamental by means of which something, initially taken as given, can be explained or reconstructed. The explanation or reconstruction is often then exhibited in a corresponding process of synthesis.

Pure analytical reasoning is independent of experience; therefore mathematics, formal logic and statistics can guide analysis regardless of the area of study or the context of the decision. However, the naturalistic decision processes are intrinsically related to experience and context. The NDM framework suggests that neither intuition nor analysis alone is sufficient in making decisions. Intuition offers an initial understanding of the situation through the recognition of patterns, whereas analysis plays a fundamental role in many other situations (Klein, 2003):

1. during mental simulation;
2. when the decision is computationally complex;
3. when conflicts have to be resolved between members of the team: analysis might externalise the intuitions and offer shared evaluation criteria;
4. when it is necessary to optimise and find better solutions: analysis offers criteria for evaluating the advantages and disadvantages of different solutions;
5. when it is necessary to offer plausible justifications: analysis enables these justifications to be generated later.

In this chapter, the main theoretical framework behind this thesis, the NDM framework, was surveyed and commented upon. Also several naturalistic models were explored and discussed. The main question that was answered was: *How do people make decisions and solve problems under natural conditions?* Three key decision-making processes have arisen from this analysis: pattern recognition, mental simulation and sensemaking. These processes and related sub-processes and functions can account for how people make complex decisions in dynamic and uncertain situations.

In the following chapter, several models of design will be explored and analysed in order to frame relevant theories from the design field. This analysis will serve to contextualise specific theories that will be put against the NDM framework in later chapters.

CHAPTER 5

Models of design and decision: from rationalism to reflective practice

The objective of the present chapter is to review several theories and models concerning the nature of the design process and the notions of rationality, problem and solution related to design.

5.1 Models of design

Since the early 1960's, many models of the design process have been defined; the definition and analysis of design process models has become a central issue to academic design research since the beginning of the Design Methods Movement in 1962 (Cross, 2007a). In these more than fifty years, the definition and analysis of design process models has been a subject frequently dealt with by several authors: Hubka and Eder (1996), Jones (1984), Lawson (2004b, 2006), Margolin and Buchanan (1995) and Martí i Font (1999) are some sources with a historical perspective. Bayazit (2004) and Cross (2007b) review forty years of design research and discuss the principal models and currents; Dubberly (2005) presents a referenced inventory of over 80 models of design appeared in the last five decades.

Further on, I will discuss several views of design activity models focused on rationality, decision making and problem solving. The intention in this case is not to outline and analyse all categories in which design activity has been placed, nor to review all the models of design that have been devised in different ways by many authors. I shall rather present and discuss several theories and models of design that are relevant to the analysis at hand. These particular models have been chosen because their underlying theories are directly related to naturalistic decision making.

5.1.1 Prescriptive models

Prescriptive models indicate how the design process ought to be. These models try to persuade designers to adopt a 'proper' way of working, which is generally algorithmic and systematic, with the intention of ensuring that the problem is thoroughly understood in order to be able to derive logical actions from its definition (Cross, 2008). Prescriptive models generally follow the view of the *designer as a computer* (or *glass box*) defined by Jones (1970, 1992). This view focuses on the need to make a rigorous rational analysis before generating concepts. Here, much in the tradition of unlimited rationality, the designer is assumed to have some kind of cybernetic mind that can carry out a perfectly discernible design process ready to be rationally explained. A sequential process is given of analysis → synthesis → evaluation that produces an optimal result. This view is illustrated below:

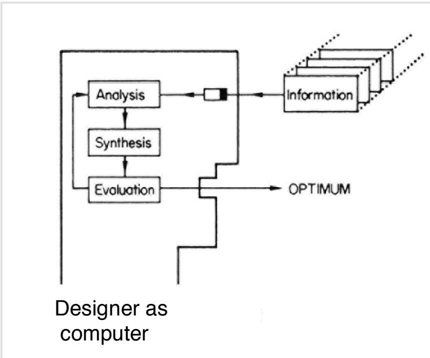

Figure 7: The designer as computer (Jones, 1992)

In this model we see three clear stages: (1) a stage of *analysis* consisting in a list of requirements and a performance specification, (2) a stage of *synthesis* consisting in finding solutions for every performance specification, and (3) evaluating these solutions according to various criteria (e.g. manufacturing, operational, etcetera) (Cross, 2008). The characteristics of this model are: (1) objectives and criteria are fixed in advance, (2) analysis is completed before solutions are sought, (3) evaluation is logical (not experimental), and (4) strategies are fixed in advance (Jones, 1992).

A classical example of these prescriptive models is the *Design Guideline 2221* of the Verein Deutscher Ingenieure (VDI, 1987), a prescriptive model in which it is proposed that the specification and functional structure of a product must be defined before seeking design principles and generating solutions. The prescriptive focus aims to derive logical specifications from the formulation of the problem, a later rational analysis and a selection of the optimal solution. Despite seeming reasonable, these procedures are not usually followed in practice (Cross, 2008).

The most modern prescriptive models adhere to the view of bounded rationality and insist mostly on the convenience of generating a range of alternatives and on avoiding the premature selection of those – because they rarely drive designers to try to achieve optimal solutions – in order to optimise within certain limits. It is therefore a question of identifying the best solution 'within' a finite, handleable groupe of alternatives (Ball et al., 2001). Over the years design methodologists have defined a large number of prescriptive models from several design disciplines; however, Lawson (2004b) argues that none of them has managed to provide evidence that these models bear some kind of relation with actual design practice.

For an overview of many prescriptive design strategies and models based on rational analysis, see Roozenburg and Eekels (1995). For a philosophical take on prescriptive models and where they came from, see Gedenryd (1998). See also the general sources mentioned in the beginning of this chapter.

5.1.2 Descriptive models

Developed from empirical research, descriptive models aim to show the sequence of activities as they occur in design practice. These models identify the generation of a solution concept in the early stages of the design process. The early generation of concepts and focus on the solution are characteristic of the designer (Lawson, 2004b) and are given after a more or less brief initial exploration of the problem space, which is often poorly defined (Buchanan, 1992). When these initial solutions contain errors, the cycle can go back to the beginning; there exists, however, a *fixation* effect induced by existing solutions. Designers may remain attached to existing designs, instead of generating new design features (Cross, 2007a). The process is heuristic and based on experience and general rules. The designer moves on in the process in the hope of going in the right direction but without absolute certainty. The process is concluded with a final description or proposal that may be communicated to the client and/or producer of the artefact.

A descriptive simple four-stage model of the design process is illustrated below:

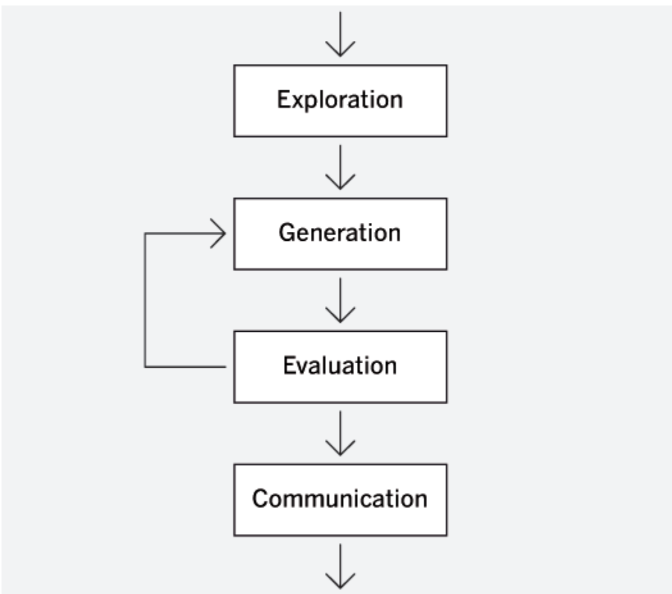

Figure 8: Simple four-stage model of the design process (Cross, 2008)

5.1.3 An integrative model

Cross (2008, p.41), argues that analytical prescriptive models cannot be commonly used in practice and proposes a constructivist view of the design process:

> [I]n most design situations, it is not possible, or relevant, to attempt to analyse 'the problem' *ab initio* and in abstract isolation from solution concepts, the designer explores and develops problem and solution together. Although there may be some logical progression from problem to sub-problems and from sub-solutions to solution, there is a symmetrical, commutative relationship between problem and solution, and between sub-problems and sub-solutions.

Cross (2008) proposes a integrative model that shows the dynamic and constructivist nature of the design process, where the understanding of the problem (i.e. its definition) is developed alongside its solution. In other words: the problem is explored, structured and understood through its very resolution. Kees Dorst (2006, p.17) contends that '[t]he aim of the designer is to generate a matching problem-solution pair'. The integrative model of co-evolution of problem and solution is illustrated below:

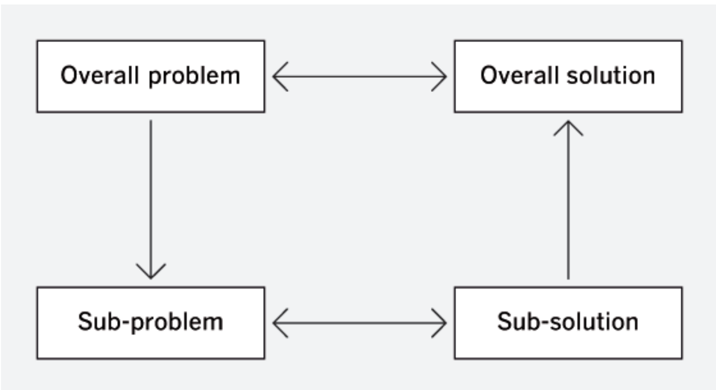

Figure 9: Model of co-evolution of problem and solution (Cross, 2008)

The left-hand side of the model contains the *problem space*, and the right-hand side the *solution space*. Total progress goes anticlockwise, but the horizontal arrows going in both directions suggest the existence of iterative activities between (sub-)problem and (sub-)solution (Cross, 2008). A clarification of this iterative activity appears in Cross (2007a, p.102):

> [The designers] consider the implications of the partial structure within the [solution space], use it to generate some initial ideas for the form of a design concept, and so extend and develop the partial structuring [...]

> They transfer the developed partial structure back into the [problem space], and again consider implications and extend the structuring of the [problem space].

A problem-solution pairing is fixed by an emergent idea. Designing appears thus to be a search for a matching problem-solution pair, rather than a propositional linear reasoning from problem to solution.

5.2 The generation game

Rationality also plays an important role in the suggestion of the *generation game* made by Rittel (1973). As a reaction to the artistic and *ad hoc* methods before 1960, the *first-generation* design methods proposed a scientific, logical design process, which was anchored in unlimited rationality and would release the designer from her bonds with the traditions from the past. The *second-generation* and *third-generation* methods moved away from this ambition of modelling an omniscient designer with unlimited rationality that characterised the first generation methods. Although the notion of problem is deeply revised, the second and third-generation methods maintain the view of design as problem solving. The problem solving view of design evolves from the rationalist conception of problem seen in the first-generation design methods, to the *wicked problems* view present in the third-generation methods (Buchanan, 1992; Rittel and Webber, 1973). The notion of wicked problem will be explored next.

5.2.1 Wicked problems

In § 3.2 two kinds of problems were introduced: well-structured and ill-structured. Problems are ill-structured to the extent that they are vaguely defined and open-ended. Horst Rittel formulated the notion of wicked problems in an attempt to describe a very special kind of ill-structured (planning) problems. This notion was spread in a seminal paper he co-wrote with Melvin Webber, where they state that:

> The kinds of problems that planners deal with – societal problems – are inherently different from the problems that scientists and perhaps some classes of engineers deal with. Planning problems are inherently wicked. (Rittel and Webber, 1973)

Rittel and Webber (1973) showed that because of many barriers (i.e. conflicting objectives, confusing information, etcetera) there is a fundamental indeterminacy in design problems, as there are no definitive boundaries to design problems, and enunciated ten properties of wicked problems in which this indeterminacy becomes evident.

Three of the properties of wicked problems are:

- Wicked problems have no definitive formulation.
- There is no stopping rule.
- The solutions to wicked problems cannot be true of false, but good or bad.

The authors use the word 'wicked' in a meaning akin to that of 'malignant' or 'tricky'; it is not that the problems are evil or ethically deplorable but rather resistant to solution, as they are never solved for good, at best they are re-solved. The opposite of a wicked problem is a 'tame' problem, and this is, according to Rittel and Webber, the kind of problems that scientists and engineers have usually focused upon. It can be safely assumed that they are referring to the natural sciences and not to the social sciences, because these mainly deal with problems that can be also characterised as wicked.

Almost twenty years after the publication of Rittel and Webber's paper, Richard Buchanan (1992) revisited the wicked problems approach and posed a very fundamental question that neither Rittel nor others had attempted to answer before: why are design problems indeterminate and, therefore, wicked? The answer to this question lies in 'the peculiar nature of the subject matter of design. Design problems are "indeterminate" and "wicked" because design has no special subject matter of its own apart from what a designer conceives it to be' (Buchanan, 1992, p.16). Whereas the scope of design is potentially universal, as it may be applied to any area of human experience, actual design is particular. Buchanan (1992, pp.17-18) comments that:

> [D]esign is fundamentally concerned with the particular, and there is no science of the particular.
>
> [...]
>
> Out of the specific possibilities of a concrete situation, the designer must conceive a design that will lead to *this* or *that* particular product.
>
> [...]
>
> The problem for designers is to conceive and plan what does not yet exist, and this occurs in the context of the indeterminacy of wicked problems, before the final result is known.

The wicked problem approach is another reaction against the rationalist tradition and classic linear problem solving. Design is poorly explained in terms of merely moving from problem definition to problem solution or from analysis to synthesis. It is obvious that any account of design needs the particular; after all expertise is personal and the framing of the problem is, per definition, case-specific.

5.3 Design paradigms

Dorst (1997) argues that design methods can be seen to belong to one of two types of paradigmatic views of design:

1. The paradigm of design as rational problem solving
2. The paradigm of design as reflective practice

Ritzer (2004, p.453) defines the notion of paradigm as follows:

> A paradigm is a fundamental image of the subject matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answers obtained. The paradigm is the broadest unit of consensus within a science and serves to differentiate one scientific community (or subcommunity) from another. It subsumes, defines, and interrelates the exemplars, theories, and methods and instruments that exist within it.

In the light of this definition of paradigm, it does not seem plausible to wish to place the research pragmatically in one or other paradigm according to the researcher's goals, and not even to voluntarily exchange between one and the other. A paradigm is a way to work and think that is deeply rooted in a scientific community, a community that acts within a paradigm. It is precisely the crisis of a certain paradigm and its overcoming by another which causes scientific revolutions, where previous knowledge is rebuilt and previous events are reassessed (Kuhn, 1971).

Herbert Simon introduced the paradigm of design as rational problem solving in the first edition of *The Sciences of the Artificial* (Simon, 1969), the paradigm's most influential work. Here design is understood as a rational search process: the designer defines the problem space that has to be examined in search of a satisfactory solution. This paradigm is registered within a positivist paradigm of science with a strong emphasis on rigour: objective observation and logical analysis must lead to general formal models of the design process. It is worth noting that Simon made profound changes to his own rationalist theory in the third edition of his seminal book (Simon, 1996), conceding that due to the limited cognitive capabilities, humans cannot oversee all aspects of a problem.

The paradigm of design as reflective practice is a constructionist epistemology, a radically different paradigm that arises in reaction to the rationalistic paradigm. Dorst (1997, p.70) characterises the paradigm as follows:

> In the paradigm of reflective practice design tasks may be analysed and subdivided in a number of different ways, and there is no *a priori* way to determine which approach will be the more fruitful. Therefore, design task and solution are always and inherently developed together.

Dorst (1997) argues that both the paradigm of rational problem solving and that of reflective practice are useful in approaching different design problems, and each of them can be applied to one of the two fundamental classes of design activities that he points out:

1. *Objective interpretation* activities in which the interpretations of design or solution are based on an impression caused by something beyond the designer, which prints meaning on the subject. In this case, the designer behaves according to the rational problem solving paradigm.
2. Activities that suggest *subjective interpretation* or the modification of the design tasks to print meaning or value on it – Schön (1984) calls it framing –, a particular way to perceive the situation. In this case, it is the subject that prints meaning on something. These kinds of activities can be better described by the paradigm of reflective practice.

The paradigm of design as a reflective practice will be explored below in greater detail.

5.4 Reflective practice

Many authors (Bousbaci, 2008; Cross, 2007a; Dorst, 1997) regard the publication of *The Reflective Practitioner* (Schön, 1983) as a point of inflection in design methodology. Before Schön, Cross (1981) had already favoured the development of a post-industrial paradigm to allow the so-called generation game to be overcomed and to provide a long-lasting way out to the crisis suffered by design at the time. The second and third-generation methods are superseded by the paradigm of the designer as a reflective professional, in which the design process can be seen as a *reflective conversation with the situation*. The reflective professional model is post-rationalist: the reflective turn moves away from technical rationality, and the separation of knowing from doing, towards a rationality of reflection in practice. In the words of Donald Schön (1983, p.79):

> Because of [...] complexity, the designer's moves tend, happily or unhappily, to produce consequences other than those intended. When

> this happens, the designer may take account of the unintended changes he has made in the situation by forming new appreciations and understanding and by making new moves. He shapes the situation in accordance with his initial appreciation of it, the situation 'talks back', and he responds to the situation's back-talk.
> In a good process of design, this conversation with the situation is reflective. In answer to the situation's back-talk, the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves.

In a certain way, this reflective conversation with the situation recalls the view of the designer as self-organisation system presented by Jones (1970, 1992). By controlling the process and controlling the control of the process at a meta-level, the designers reduce the number of possible alternative solutions and find shortcuts to allow them to skirt the uncertainty and complexity. This view is illustrated below:

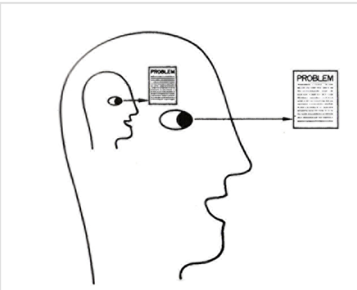

Figure 10: The designer as a self-organising system (Jones, 1992)

However, Jones's process is purely cognitive as the designer controls the process and controls the control of the process, whereas Schön's is ecological, the designer acts on the situation, the situation 'talks back' and the designer answers. Schön defends the uniqueness of each design problem and points to what enables the designer to determine how to handle each design problem. This essence of design practice called *artistry* by the mentioned author, cannot be described within an analytical frame. To describe the treatment of fundamentally unique problems, Schön proposes an alternative epistemology of reflective conversation with the situation (i.e. the reflective practice).

5.4.1 Reflection-in-action and on-action

Schön describes two types of reflective practice: (1) reflection-*in*-action and (2) reflection-*on*-action.

Reflection-in-action refers to the process that allows the designer to shape and reshape her work while she is working on it. It is more than simple trial and error since it is performed with intent – sometimes even before an error or problem occurs – and it is called upon when the designer detects that something is not going according to plan or when a surprising event is detected. Through this reflection the designer reassesses the understanding of the problem and implements changes in her design. Schön (1983, p.68) summarises the experiential nature of the reflective practice as follows:

> [T]he practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique. He reflects on the phenomenon before him, and on the prior understandings which have been implicit in his behaviour. He carries out an experiment which serves to generate both a new understanding of the phenomenon and a change in the situation.

Reflection-on-action is performed *after* the design situation. It consists in the ability to put one's own design processes and one's actions and thoughts under scrutiny. This activity enables the designer to enquire into the reasons why she acted as she did, in order to evaluate and improve her own process.

In this chapter several models of design were introduced and discussed. Design models can be classified following the same scheme used for decision-making models. The prescriptive models have been deemed inadequate to account for actual design behaviour in the same manner that prescriptive decision-making models were unable to account for decision-making phenomena in real-world settings. Several descriptive models of design, such as Cross' integrative model, Rittel's view of design as wicked-problems, Schön's reflective-practice view of design and Jones' view of the designer as a self-organisation system are directly related to naturalistic decision making, in the sense that they account for dealing with fuzzy problems in a constructivist way that does not admit unique solutions and in which expertise and the use of contextual knowledge plays a central role.

In the next chapter several theories and empirical findings regarding design activity and design decision making will be considered. The attention will be directed towards the satisficing strategies adopted by designers as an adaptive and efficient way of dealing with design problems, which are intrinsically fuzzy.

CHAPTER 6

Design decision making

In this sixth chapter, a presentation of descriptive models of several aspects of design cognition and design decision making will be carried out. The reader will find as well – without the pretension of being exhaustive – a definition of a conceptual framework of design decision making based on empirical research and reflection on design as a professional activity that will serve as the basis for ulterior analysis.

6.1 Designerly ways of knowing

Design problems have a particular nature that requires a specific way to confront them. The inherent poor structuring of design problems and the constructivist nature of the design process through which a solution is reached, is pointed out by Cross (2007a, p.99):

> It is often not at all clear what 'the problem' is; it may have been only loosely defined by the client, many constraints and criteria may be undefined, and everyone involved may know that goals may be re-defined during the project. In design, 'problems' are only defined in relation to ideas for their 'solution', and designers do not typically proceed by first attempting to define their problems rigorously.

This fuzzy attitude towards design problems is one of the main characteristics of design behaviour. In the following sections the main features behind these *designerly* ways will be analised.

6.1.1 Characteristics of design cognition

In the article *Understanding Design Cognition*[9] (Cross, 2007a, pp.17-31), Cross sums up and structures the main conclusions of several empirical studies of design activity. The following description is largely based upon this source.

Formulation of the problem

Cross summarises the results of several studies and distinguishes four aspects that characterise design cognition regarding problem formulation:

- *Fast goal analysis*: the key to effective behaviour seems to lie on reducing the focus and restricting the collection of information. The definition and

[9] Previously published as *Design Cognition: Results from protocol and other empirical studies of design activity*. Appearing in Eastman, C., McCracken, M. and Newstatter, W. (eds.) Design Knowing and Learning: Cognition in Design Education, Oxford: Elsevier. 2001

constant modification of goals is one of the elements inherent to the design activity.

- *Focus on the solution*: experience allows designers to identify a frame from which to approach the situation and suggest a fast solution without first defining and analysing the problem exhaustively.
- *Co-evolution of the problem and the solution*: design is an exploration in which problem and solution are co-evolving; therefore, it is not a linear process that goes from problem to solution. Designers formulate solution conjectures and use them as the means of increasing their understanding of the problem and developing a formulation. This characteristic of design behaviour is the basis of the integrative model considered in § 5.1.3.
- *Framing*: a key process of reflective practice indicated by Schön (1983) in which the designer determines what aspects of the problems will be explored and how. Designers select aspects of the problem they choose to attend through an activity called *naming*, and identify areas of the solution space in which they choose to explore with an activity called *framing*.

Generation of solutions

With respect to generating solutions, Cross distinguishes five principal aspects:

- *Fixation*: there is potentially negative fixation in certain aspects of solutions induced by pre-existing solutions. Designers may be too ready to re-use features of known existing designs, rather than to explore the problem and generate new design features.
- *Attachment to concepts*: designers create a bond with early solution ideas and concepts. Even though they change goals and reframe the problem as they design, they appear to stick on to solutions that were proposed earlier in the project.
- *Generation of a limited number of alternatives*: empirical research in design decision making studies has shown that the most frequent strategy is to generate a limited number of alternatives.
- *Creativity*: Cross argues that intuition is an element frequently mentioned by designers as a central element in design thought. He also cites research by Akin and Akin (1996) in which they conclude that a creative breakthrough depends simultaneously on breaking an existing frame of reference and specifying a new set of frames that restructure the problem in such a way that the creative process is enhanced.

- *Sketching*: the generation of sketches is the key cognitive tool for approaching the uncertain and ambiguous nature of the conceptual activity of the process.

Process strategy

With respect to the process strategy, Cross points out that a process structured flexibly gives better results than a process structured rigidly. An *opportunistic* deviation from an initial plan is a sign of expert behaviour. This concept can be understood as 'deviations from a structured plan or methodical process into the "opportunistic" pursuit of issues or partial solutions that catch the designer's attention' (Cross, 2007a, p.110). Designers show *modal shifts* between cognitive tasks: they alternate rapidly in shifts of attention between different aspects of their task, or between different modes of activity such as drawing, examining, gathering information, etcetera. These modal changes had already been pointed out by Cross, Christiaans and Dorst (1994) and Akin and Lin (1996).

6.1.2 Decision and problem

As we have seen in the previous section, Cross (2007a) points to the role of solution conjecture as a way to gain understanding of the design problem and the resulting need to produce different solutions as a means of analysing the problem.

Constructivist nature of the process

Cross (2007a) argues that to face wicked problems, designers have to have self-confidence in order to define, redefine and change the problem depending on the solution that emerges from their minds and hands. This constructivist way of thinking and acting is one of the aspects that characterise design cognition. Cross mentions authors such as John Chris Jones, Sidney Gregory or Herbert Simon, who before him insisted on the constructivist nature of design. Design is not a pattern summarising process, but rather one of pattern recognition; the solution is not available in a platonic space and accordingly does not exist *a priori*, but must be actively built. This constructivist and opportunist process that occurs in design is rarely reflected in the prescriptive models of the design process, such as the earlier mentioned example of the *Design Guideline 2221* (VDI, 1987).

The inherent poor definition of design problems cannot be resolved by an analytical approach of collecting and synthesising information. The architect Richard MacCormac (as cited in Cross, 2007a, p.52) observes:

> I don't think you can design anything just by absorbing information and then hoping to synthesise it into a solution. What you need to know about the problem only becomes apparent as you're trying to solve it.

The results of empirical studies presented in the article *Creative cognition in design I: the creative leap*[10] (Cross, 2007a, pp.65-82) indicate that the exploration and identification of sub-problems is carried out considering also the possible sub-solutions, and not only the sub-problems themselves. In this way, partial models are built from the problem and solution in parallel. These models enable a bridge to be built between problem requirements and solution proposal. A model for this constructivist view of design was presented in § 5.1.3.

The role of sketching in structuring the problem

According to Cross (2007a), sketching is a key activity to structure the problem by attempted solutions. This is the same as saying that the exploration of the spaces of problem and solution evolves in interrelation until the problem-solution pair comes together. Sketches enable designers to get around different levels of abstraction at the same time, thinking for example in parts of the general concept and detailed aspects of the implementation of the – still incomplete – concept at the same time.

Simulation and evaluation

Sketching allows the recognition of properties and characteristics emerging in the solution concept, it is the tool to explore and find possible unintended consequences or surprises. Goel (1995) also went in this direction by introducing ideas relative to analogical and creative reasoning based on sketching. The generation of a fast solution without going further into the analysis is a central aspect of the design activity. To simulate and hypothesise on future scenarios, the designer not only uses sketching, but also mental simulations from her own experience and knowledge. The designer explores the solutions and the problems in parallel and suggests concepts (i.e. sub-solutions) for each sub-problem. She evaluates and discusses the implications and possibilities of each concept. This kind of evaluative exploration can be very fast, Cross (2007a) describes experiments in which designers in short periods of time – as brief as one minute – suggest solution concepts, modify, develop and justify them. Cross (2007a, p.34) notes that 'a major part of the designer's work is [...] concerned with the evaluation of design proposals'. See Cross (2008) for a numerical method of analysis aimed to compare the utility values of alternative design proposals.

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[10] Previously published as *Modelling the Creative Leap*. Appearing in Gero, J. S., Maher, M. L. and Sudweeks. F. (eds.) Preprints of the international workshop Computational Models of Creative Design III, Key Centre of Design Computing, University of Sydney, Australia. 1995

Experience and expertise

According to Cross (2007b) expertise enables designers to generate fast conjectures of solutions by resorting to knowledge from previous examples. Novel designers, on the other hand, usually try to fully understand the problem before beginning to look for solutions. Beginners usually come down at first on a design approach where sub-solutions are identified and explored deeply, whereas experts prefer an approach that generates superficial sub-solutions that cover a wider solution space, which can be discarded at no greater cost and whose direct goal is not only to solve the problem but to understand, structure and define it. Cross (2007a) identifies three key strategic aspects that appear to be common in the creative expertise: (1) taking a broad 'systems approach' to the problem, (2) adopting a personal framing of the problem, and (3) designing from 'first principles'. This last aspect implies that designing is moving from function to form. Notwithstanding the axiological importance of the use 'first principles' to guide design, designers 'usually proceed by suggesting 'protomodels' of forms or structures, and evaluating these in order to amplify the requirements or desired functions' (Cross, 2007a, p.76).

The problem solving approach in new designers is usually 'trial and error', where designers generate, implement and then assess a solution to proceed iteratively to generate a modification, while expert designers make a preliminary evaluation of their tentative decisions before committing to any of them (Ahmed, Wallace and Blessing, 2003). Experts use foresight to judge whether it is worth moving forward in developing a solution (Cross, 2011). Lawson (2004b) proposes the following model of expertise acquisition: (1) acquisition of the design domain schemata, (2) development of a growing pool of precedents, (3) identification of guiding principles, (4) developing the ability to recognise situations with little or no analysis, (5) building a collection of design gambits. It is worth mentioning that Lawson points out that the end of every stage overlaps the beginning of the next one.

For an additional treatment of design expertise see Lawson (2004b) and Lawson and Dorst (2009).

6.2 The primary generator

According to Darke (1979) the designer does not usually start by defining a problem or making a complete and exhaustive list of factors to be considered, but rather seeks to reduce the variety of potential solutions to the problem at hand – which at the initial stage of the design process has not yet been completely understood – to a manageable number that can be handled from the cognitive point of view. The designer, in consequence, sets a particular goal or small group of goals that are generally self-imposed and based on assessments founded on subjectivity, more than on a logical procedure. Darke (1979) calls these initial goals *primary generators*. They propitiate a suggested concept for a solution or conjecture, which at the same time makes it possible to clarify the requirements described as the conjecture is assessed. Darke (1979, p.43) asserts:

> The greatest variety reduction or narrowing down of the range of solutions occurs early on in the process, with a conjecture or conceptualization of a possible solution. Further understanding of the problem is gained by testing this conjectured solution.

This implies that the concept for a solution or conjecture is reached even before analysis as depicted in the following model:

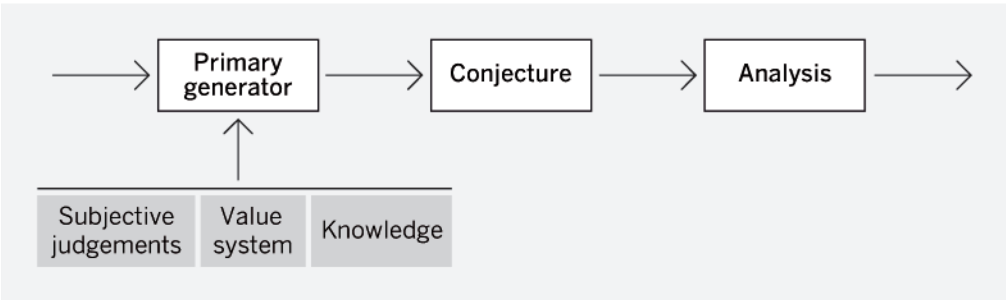

Figure 11: Primary generator model (Ariel Guersenzvaig based on Lawson, 2006)

Rowe (1987), Lawson (2004b) and Dorst (2006) are other authors who defend the primary generator model and its forms of reasoning based on non-analytical conjecture-generation strategies to direct the decision-making process.

6.3 Knowing and thinking in design

Bryan Lawson (2006) argues that problems and solutions cannot be separated from each other and should be considered two aspects of a design situation description. In design, the problem does not precede the solution. His constructivist view is illustrated in a textual model of the process based on five groups of fundamental activities: (1) *formulating*, (2) *moving*, (3) *representing*, (4) *evaluating*, and (5) *reflecting*. In the following sections, I will be mainly referencing to and paraphrasing from Lawson (2006) except when explicitly stated otherwise.

Formulating

The nature of the design activity does not obey to a rationalist sequence of analysis that precedes synthesis. The designer identifies initial problems, reformulates them and structures them, but 'in design, problems do not necessarily precede solutions in the way normally expected in conventional problem solving' (Lawson, 2006, p.297). Lawson argues that designers are often solution-focused and work by generating concepts about whole or partial solutions that may or may not be a part of the final result of the design project.

The naming and framing processes, proposed by Schön (1983) and previously mentioned in § 6.1.1, allow designers to selectively see the design situation in a particular and personal way during this stage of the process. Lawson prefers the term *identifying* instead of naming, because it reflects better the nature of the activity, in which the designer is not simply naming but also identifying aspects that need further exploration. The nature of the brief will depend on the type of the project, in the case of a project with a well-defined problem, the briefing may happen mostly at the beginning. Nevertheless, one can assume that briefing is a continuous process that may go on throughout the project and not only occur at the beginning of it (Lawson, 2004b).

Moving

Lawson gives the name *move* to the generation of solutions and distinguishes moves of three kinds: (1) *initiation*, (2) *interpretation* and (3) *development*. The first kind is related to primary generators, the second refers to the transformation of an existing idea into a new one, even if maintaining some of the original characteristics. The development moves refer to the advancement of an idea along its way to specification and performance but without important conceptual modifications. Lawson (2006, p.212) suggests that 'the development of alternative ideas by experienced designers may often be rather more sophisticated than the simple generation of a range of options'. Designers seem to be able to develop and sustain *parallel lines of thought* regarding the solution. Lawson (2006, p.212) continues: '[t]hese parallel investigations represent examinations into different aspects of the design'. The designer allows two or more of these parallel lines of thought, which are often incomplete and blurry, to take place on various aspects (i.e. about materials, forms, etcetera) of their solutions. Every line of thought responds to a specific frame that is anchored on a primary generator.

Representing

Lawson argues as well that representation (i.e. sketching, modelling, etcetera) is not only intended to generate solutions but also to explore the situation and frame the problem.

Evaluating

Lawson refers to an evaluation skill used by the designer to know when to stop in generating new alternatives. This activity is often represented in virtually every design model because this stage is the one in which solutions are tested to decide whether any of them can be seen as satisfactory or the designer should carry on and improve existing solutions or perhaps generate new ones. The designer evaluates objective and subjective aspects and is capable of making estimates based on objective metrics as well as on personal criteria and values. In case of objective criteria (e.g. the case of the electric consumption of a building or the durability of a particular material), there is a large body of scientific and technical knowledge that can be used to support evaluations as well as guidelines and standards (e.g. the WCAG 2.0 accessibility guidelines for the Web or the many ISO standards from the International Organization for Standardization). For subjective criteria designers 'may develop their own particular tools for evaluating designs against the criteria that are often important to them either because of the kind of objects they frequently design or because of the guiding principles they have developed' (Lawson, 2006, p.298). This combination of subjective and objective criteria was also mentioned by Dorst (1997) in his discussion of the rational and the reflective paradigms.

Reflecting

Lawson refers to the importance of the reflective practice proposed by Schön (1983), a subject that was considered in § 5.4 from a Schönian perspective. In Lawson's perspective there are three important aspects of reflective practice: (1) reflecting in-action and on-action, (2) developing guiding principles, and (3) collecting precedents and references. Lawson equally distinguishes reflection-in-action from reflection-on-action. On the first case, he includes the processes of formulation, moving and evaluation activities dealt with above. But on the second, refers to a reflection on the design process, not its results. In the course of time, the designer develops a set of values concerning her own work programme (i.e. a design philosophy). This set of values act as *guiding principles* facilitating a two-way interaction between the designer and the situation of each design project. The capacity for observation and registry are central to the later recovery and use of this knowledge. Designers are often heavy collectors of materials that they later use as reference for their own work. Lawson argues that professionals with experience do not start by analysing situations from scratch, but by recognising parallels between the current design situation and previous referents and precedents. They use these parallels as a starting point and this process of analogy does not only save time by simplifying or going around exhaustive analysis, but also traces connections between problem and solution.

6.4 Theory of design synthesis

Jon Kolko (2007) asserts that the design process has two interrelated stages: (1) design synthesis and (2) ideation. Design synthesis is about developing an understanding of the design opportunity that exists, ideation is about artefact creation to address those opportunities. The focus of Kolko's theory is on synthesis. Design synthesis is formed by the combination of two entities: (1) the designer, her experience, expertise and personal background, and (2) the design problem, the inherent constraints and the mental model of the problem (Kolko, 2011a). The pillars to this synthesis process are sensemaking and abductive reasoning. In his theory of design synthesis, Kolko (2010a, 2010b, 2011a) integrates many naturalistic concepts covered above, such as sensemaking, frames and the use of mental models in understanding, explaining and acting in design situations.

As designers gain experience, they seem to act intuitively. Hence, the recognition of patterns is an essential factor that allows experienced designers to identify patterns and to apply past solutions and types to new design problems (Kolko, 2011a). The designer is able to estimate the development of future events and, without analysing, discard solutions that will possibly be ineffective and also foresee external conditions such as client feedback or market conditions that will affect the decisions. Experienced designers are fast and effective in representing concepts and modelling to move forward in generating solutions without an explicit need to consider how to continue the process.

Synthesis is an abductive decision process; fundamentally, a way to apply abductive logic within the boundaries of a design problem. It allows designers to explore the hypothesis that makes the most sense given observed phenomenon and data and based on prior experience (Kolko, 2010a, 2011a). Building on Coyne (1988), Kolko (2010a) states that the constraints of a problem start to act as logical premises, and the capacity of the designer and her vital experience begins to give shape to the abduction. In practice, this abductive reasoning is shown in three types of fundamental synthesis actions: (1) prioritising, (2) judging and (3) forging connections. Thanks to these, designers can manipulate, organise and filter data in the context of a design problem. Externalisation and representation of the problems enables relationships and patterns to be found between the elements and forces the designer to take an external perspective on things (Kolko, 2011a).

Kolko (2010a, 2010b, 2011a) maintains that even though design synthesis is often presented as a fundamental part of the design process, it still has no profound discourse and there continues to appear something magical about synthesis when encountered in professional practice. According to Kolko, himself a renowned professional and educator, 'this complexity demands a more formal theoretical understanding of synthesis, and designers require a better understanding of the cognitive and social structures that are used to support the various activities involved in synthesis' (Kolko, 2010b).

In this chapter, the designer's overarching tendencies toward brief and fast goal analysis and problem formulation, opportunistic, solution-focused behaviour and her constructivist reflective process approach were made manifest. Theories and research findings regarding the non-analytical reasoning of designers based on satisficing behaviour was also displayed.

In the following chapter, I will draw parallels between these strands of design decision making and the theories and models from the NDM framework that were reviewed and discussed in previous chapters.

Part III
Towards a naturalistic outlook on design decision making

'Step one is always very hard to do.
[...]
For nearly all methods
however rational
step one is a non-rational step
and has to be done with
not only intuition
but with experience.
That is
intuition which is informed with experience.
Intuition which is not informed by experience
is a very misleading thing
very often.
Intuition which is based on the right experience
is the only really good guide we have in life.'
John Christopher Jones (1984)

CHAPTER 7

Fit between NDM and design research

Introduced by the previous part, the present chapter is about a compilation and a discussion of many parallels and correlations found between the NDM framework and the theories and models regarding design cognition and design decision making addressed in chapter 5 and chapter 6. Also a naturalistic model of design decision making is presented.

Shortly, I will draw parallels between theories and research findings from the field of design research and the NDM framework. To facilitate understanding, I shall structure the discussion around groups of activities characteristic on the linear accounts of problem solving: (1) formulation of the problem, (2) generation of solutions and (3) evaluation of solutions. At first sight, this might seem odd or even paradoxical, because, after all, this thesis *is* a critique of the paradigm of rational problem solving. It must be conceded that the components of the linear model *are* reasonable in themselves. People (i.e. designers) do formulate problems and generate and evaluate solutions. The problem is not the components but the misleading linear presentation of the process.

Nevertheless, it is a logical imperative that problem formulation precedes solution generation and so is that generation precedes evaluation. I cannot help wondering if this logical imperative might be one of the very reasons why the classical linear models are still so popular and attractive; maybe it is because of its simplicity and the logical appeal of the linear narrative. A linear presentation of the process will facilitate understanding; it would be otherwise too complex for the reader of this text to jump back and forth following the multidirectional non-linear path of naturalistic decisions. However, it must be kept in mind that the naturalistic outlook is not linear, and that the processes of defining the problem and generating and evaluating solutions do not appear independently but rather are intrinsically related and simultaneous.

7.1 Parallels in problem formulation

Nigel Cross (2007a) notes that designers do not spend much time on extensive problem analysis, but on adequate 'problem scoping', and on a focused or directed approach to gathering problem information and prioritising criteria. This satisficing behaviour, which designers manifest towards problem formulation, is consistent with the DFTS and the RPD models, in which people do not analyse and formulate the problem and then act, but analyse it as little as possible or even do not analyse at all. According to Connolly and Wagner (as cited in Orasanu and Connolly, 1993, p.19), 'instead of analysing all facets of a situation, making a decision, and then acting, it appears that in complex realistic situations people think a little, act a little, and then evaluate the outcomes and think and act some more'.

The activities of framing and naming proposed by Donald Schön (1983) are crucial and determinant for the final result of any design project. The naming initiates an interactive dialogue with the situation by determining what features of the problems will be attended to and how; the framing enables the designer to identify areas of the solution space which she chooses to explore for solutions. Naming and framing are sensemaking processes and the data/frame theory of sensemaking can account for them. The initial frame[11] is inferred from a few anchors – data or cues from the environment – in a manner that resembles the process of naming. Once an initial frame is elaborated, the person uses it to search for more data elements and consolidates it, rejects it or search for a new frame. The data is fitted into a frame, but the frame also determines what counts as data. This chain of closed loops is almost identical to the dialectic loop between naming and framing proposed by Schön (1988, p.182):

> In order to formulate a design problem to be solved, the designer must frame a problematic design situation: set its boundaries, select particular things and relations for attention, and impose on the situation a coherence that guides subsequent moves. Moreover, the work of framing is seldom done in one burst at the beginning of a design process. Designing triggers awareness of new criteria for design: problem solving triggers problem setting.

Another noteworthy aspect in relation to problem formulation is the quick jump from problem to solution. Many researchers (e.g. Cross, 2007a; Lawson, 2006) suggest that designers generate concepts for solutions or conjectures very early in the project in order to explore and define the problem-solution pair together. This solution-focused behaviour is at the core of naturalistic decision making and the RPD model. Klein (2008, p.457) describes decision making from this perspective as 'committing oneself to a course of action where plausible alternatives exist, even if the person does not identify or compare these alternatives'. This decision process also fits the notion of satisficing proposed by

[11] The concept of frame in the DFTS model has a broader meaning and is not restricted to the identification of potential solutions as in Schön's terms case.

Simon (1957) of looking for and committing to the first workable option instead of trying to maximise.

7.2 Parallels in solution generation

In the previous paragraphs it became evident that problem formulation and solution generation overlap. Paradoxically, designers generate solutions in order to explore problems and not the other way around, inasmuch as they are solution-focused. The primary generator (Darke, 1979) is a prime example of this behaviour. In this model, the generation of an initial conjecture precedes analysis. Lawson (2006, p.46) summarises the primary generator as follows:

> First decide what you think might be an important aspect of the problem, develop a crude design on this basis and then examine it to see what else you can discover about the problem.

This behaviour is acknowledged by Fawcett (2003, pp.16-17) in his hands-on, non-theoretical basic text on design issues:

> Although it may be ill-formed and far from clear, architects generally arrive at a visual image for their building soon after the design process gets under way. Such an image often merely exists in the mind's eye long before the laborious process begins of articulating such imagery via drawings and models and then testing its validity; nevertheless, this initial creative leap into form-making, this point of departure when the initial 'diagram' of the building begins tentatively to emerge is the most crucial and most difficult aspect of designing and, indeed, the most intimidating to a fledgling designer.

The RPD model predicts this kind of behaviour so far as it implies a singular evaluation approach, in which a decision maker generates a course of action and commits to it instead of generating multiple courses of action and exploring them in parallel. The generation of the course of action (i.e. an initial concept for a solution) is based on recognition (i.e. intuition) and sensemaking. From a DFTS perspective, the primary generator is thus a model of design sensemaking.

The generation of a limited number of alternatives is consistent with one of the main postulates from the NDM field: decision makers commit to a single course of action without comparing alternatives. Starting from a very limited set of goals (i.e. primary generators) the designer is able to develop rough concepts for solutions and progress successively closer to a desired result, thanks to moves of interpretation and development (Lawson, 2006). The negative side of this satisficing behaviour is illustrated by the problem of fixation and attachment to initial concepts. Nigel Cross (2007a, p.115) notes that 'generating a wide range of alternative solution concepts is another aspect of design behaviour which is recommended by theorists and educationists but appears not to be normal design practice to generate a variety of solutions precisely as a means of problem-analysis'.

Design is problem solving inasmuch as it is problem finding. Nigel Cross illustrates the nature of design as follows: 'designing involves "finding" appropriate problems, as well as "solving" them, and includes substantial activity in problem structuring and formulating, rather than merely accepting the "problem as given"' (Cross, 2007a, p.99). Lawson (2006, p.296) adheres to this view:

> In the conversational view of design we might be less inclined to make the distinction between problem and solution. Indeed we might see frames and primary generators as ways of negotiating between a problem and solution view of the situation in order to bring about some resolution between what is required and what can be made. [...] [P]roblem and solution are better seen as two aspects of a description of the design situation rather than separate entities.

In the field of NDM, the dual concept of problem and solution is unified in a naturalistic decision: it is not a question of optimising or improving the decisions to a greater or lesser extent, but rather a question of defining and structuring the alternatives at the same time. In real-world complex settings – and design is one of these – problems are often not defined beforehand and their structure needs to be constructed. Problem solving is thus a constructivist and dynamic task that involves sensemaking and simulation in order to build and define possible solutions right from the beginning, starting from initial cues. Both the courses of action and the goals are clarified and defined while a solution is developed.

Lawson (2006) points out that briefing is not concentrated only at the beginning but is rather a continuous process of revising and modifying. Richard MacCormac (as cited in Darke, 1979, p.42) notes: 'you can't start with a brief and [then] design, you have to start designing and briefing simultaneously, because the two activities are completely interrelated'. In a similar fashion, Cross (2007a, p.34) claims that 'often, the problem as set by the client's brief will be vague, and it is only by the designer suggesting possible solutions that the client's requirements and criteria become clear'. This activity of brief development and revision is consistent with several macrocognitive functions: planning, adaptation/replanning and problem detection. It may be also argued that creating a brief is in itself a sensemaking activity.

The creative strategy presented by Cross (2007a) – consisting in a broad system approach, a personal framing and the use of guiding principles to work towards solutions – matches the central hypotheses of the NDM framework, namely that experts perform sensemaking and that the process is constructivist. This means that experts do not take the problem (i.e. brief) as given. Arguably, the use of representation (e.g. drawing, sketching, prototyping or modelling) can be seen as sensemaking attempts since representation is generated as a means of exploring the situation and framing the problem as well as generating a solution. The question of the parallel lines of thought posed by Lawson can be seen as another clear example of sensemaking in action. This parallel exploration is about fitting data, originating in the *reflective conversation with the situation*, into a frame for every specific aspect of the exploration (e.g. materials, shapes, textures).

7.3 Parallels in solution evaluation

Cross (2007a, p.51) indicates that 'the designer, in constructing a design proposal, constructs a particular kind of argument, in which a final conclusion is developed and evaluated as it develops against both known goals and previously unsuspected implications'. The task of evaluating is not only a constant, but a difficult one as well, since in many cases the multiple facets of a design project will complicate assigning values even to objective metrics. Lawson (2006, p.291) posits:

> [Design] moves are regulated most obviously through the use of some kind of evaluation of them against some set of criteria however precisely or vaguely understood. There are then clearly a whole range of skills which we shall refer to as 'evaluating'.

Designers often show evaluation behaviours that can be characterised as intuitive and non-analytic (i.e. based on rapid judgement that does not seek to optimise) as they are often evaluating against a set of criteria that is ill-defined. The importance of the macrocognitive functions of problem detection and simulation during this type (i.e. the *subjective* type) of evaluation has been established earlier on. As discussed in § 4.5, the RPD model leaves plenty of room for analysis, especially during simulation.

7.4 Parallels in the reflective process

Reflection-in-action refers to the activity of deliberating on the current understanding of the design problem and the soundness of the solution while is being generated. This reflection is triggered by 'surprise, puzzlement, or confusion in a situation' (Schön, 1983, p.68). In a broad naturalistic perspective, reflection-in-action matches the third case in the RPD model: 'situations of mental simulation, evaluation and adjustment' (see p.57), in which the decision maker weighs the relevance and adequacy of a course of action and through simulation adjusts it accordingly. From a naturalistic perspective, it may be argued that besides mental simulation, at least two other macrocognitive processes are at work in reflection-in-action, namely problem detection and adaptation/replanning. The designer detects cues from the environment, becomes more alert as she searches for new cues, and when a threshold is reached, the designer stops the action and starts to adapt or replan.

The opportunistic behaviour of designers pointed out by many authors (see Cross, 2007a) in which the designer does not follow a prescriptive method accurately, can be seen as a naturalistic, cost-effective way of negotiating with ill-structured problems. This cost-effectiveness refers to cognitive costs as well as time. By being opportunistic, the designer is thereby satisficing as an expert does; she is not being sloppy. Cross (2007a, p.111) argues: 'so it may be that we should not equate "opportunistic" with "unprincipled" behaviour in design, but rather that we should regard "opportunism" as characteristic of expert design behaviour'. As it has been already shown in this thesis, the non-compliance with normative-prescriptive models of decision making and problem solving exhibited by experts, is at the core of the NDM framework. The ability that experts have to identify leverage points in order to find promising opportunities and turn them into courses of actions, may account for opportunistic design behaviour. The designer is looking for a leverage point, and when she finds one, she needs to readjust her initial plan.

Also the use of just-in-time mental models can be related to this behaviour. Since design problems are often unique and ill-defined, the designer creates an *ad hoc* mental model that is based on partial understanding of what the problem is. The mental model is the frame from which the designer examines the problem; when adapting and improving her mental model as the comprehension of the problem-solution pair advances, the initial plan needs to be revisited and modified as well; this may give the wrong impression of inconstant or capricious behaviour.

Designers recast their activity through rapid modal shifts, alternating between different tasks (i.e. drawing, examining, gathering information, etcetera) (Cross, 2007a). From a naturalistic perspective, it may be argued that these shifts are motivated by the intrinsic difficulties of trying to solve ill-defined or wicked problems. The designer cannot move in linear fashion from problem to solution because these entities co-evolve; the modal shifts obey to the logic of the constructivist task of co-defining problem and solution.

Many authors (e.g. Cross, 2007a; Dorst, 2006; Lawson, 2004b, 2006) agree that design strategy and behaviour are determined by the designer's experience and expertise. They also agree that there is a kind of experience ladder in which designers become less attached to general rules and move towards the recognitional realm. Lawson (2004b, p.118) describes the last stage of expertise acquisition as follows:

> [The] stage of developing the ability to recognize situations with little or no analysis and the final stage of building a 'repertoire of tricks' or design gambits which are integrated into the schemata used to recognize problem situations surely mark designers out as being 'masters'.

The similitudes between this description and the NDM hypothesis regarding expert decision making are manifest. As an example of these similitudes, it may be argued that the 'ability to recognise situations with little or no analysis' is at the core of the RPD model and that the schemata and design gambits, cited in the previous quote, are congruent to the concepts of frame, action script and mental model. Designers make extensive use of reference material and experienced designers seem to recognise parallels between the project they are currently working on and precedents from their own previous work and others. Lawson (2006, p.301) reflects on the usefulness of this behaviour:

> This process has the double advantage of massively speeding up thinking by side-stepping much lengthy analytical thought, and by making links between problems and solutions. Clearly a very important ability then for designers is to be able to recognise features of situations that make connections with apparently remote sets of ideas.

The recognitional feature of the design ability is at the very core of the RPD model. The pattern matching that occurs in the first type of situations described by the model – situations recognisable as prototypical – is accountable for the first intuitive reaction a designer experiences when recognising parallels between precedents and the current project. Of course, it is rarely the case that a designer simply applies the previous solution and settles with it. Then, it can be argued that the designer, having framed the situation in a particular way through this initial recognition, would move to the second type of situation described by the RPD model, a diagnosis of the situation and sensemaking.

To end this overview, Kolko's theory of synthesis should be included. This theory, however, will not be covered further as the many parallels with the NDM framework were explored already in §6.4.

7.5 Overview of parallels between research in design and NDM

To summarise these findings, I include four tables that serve as an overview of the detected parallels.

In the tables, the following key is used to identify the authors:
Nigel Cross (NC)
Donald Schön (DS)
Bryan Lawson (BL)
Jane Darke (JD)
Jon Kolko (JK)

Parallels in problem formulation	
Design Research	**NDM Framework**
Fast goal analysis and problem formulation (NC)	RPD model Satisficing
Framing and naming (NC, BL, JD)	Data/frame model of sensemaking Cue detection
Focus on the solution (NC, BL)	RPD model

Table 1: Parallels in problem formulation

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Parallels in solution generation	
Design Research	**NDM Framework**
Primary generator (NC, BL, JD)	RPD model Singular evaluation approach Intuition
Limited number of alternatives (NC, BL, JD) Fixation (NC)	Single course of action Sensemaking Satisficing Singular evaluation approach
Co-evolution of problem and solution (NC) Variable order of appearance of solutions and problems (BL)	Central hypothesis of the frame NDM RPD model Non-linear problem solving
Briefing as a continuous process (NC, BL)	Macrocognition (adaptation and replanning, problem detection) Data/frame model of sensemaking
Creative strategies (NC)	Use of experience to perform sensemaking Constructive process
Use of representation elements (NC, BL)	Data/frame model of sensemaking Mental simulation
Parallel lines of thought (BL)	Data/frame model of sensemaking Mental simulation

Table 2: Parallels in solution generation

Parallels in solution evaluation	
Design Research	**NDM Framework**
Evaluation (BL)	Singular evaluation approach Analytical methods Satisficing

Table 3: Parallels in evaluation

Parallels in the reflective process	
Design Research	**NDM Framework**
Reflection-in-action (BL, DS)	RPD model Problem detection Adaptation/replanning Mental simulation
Opportunism (NC)	NDM framework RPD model Just-in-time mental models Identification of leverage points
Modal changes (NC)	Non-linear problem solving
Strategies determined by experience (NC)	Characteristics of the experts: use of mental models, perceptive capacities, sense of tipicality, routines, and declarative knowledge. Larger repertoire of frames, action scripts and mental models.
Application of guiding principles (BL)	Mental model Action scripts
Use of precedents and referents (BL)	RPD model Cue detection Pattern recognition Use of action scripts
Theory of Synthesis (JK)	Data/frame model of sensemaking Framing Mental models Simulation

Table 4: Parallels in reflective process

7.6 A naturalistic model of design decision making

In this section, I present a graphic model (Figure 12) that combines three main NDM processes and the model of co-evolution of problem and solution proposed by Cross (see Figure 9) that was treated in § 5.1.3. This model contextualises the problem-solution pairing; the way concepts for a solution are generated and transferred iteratively into and from the problem space.

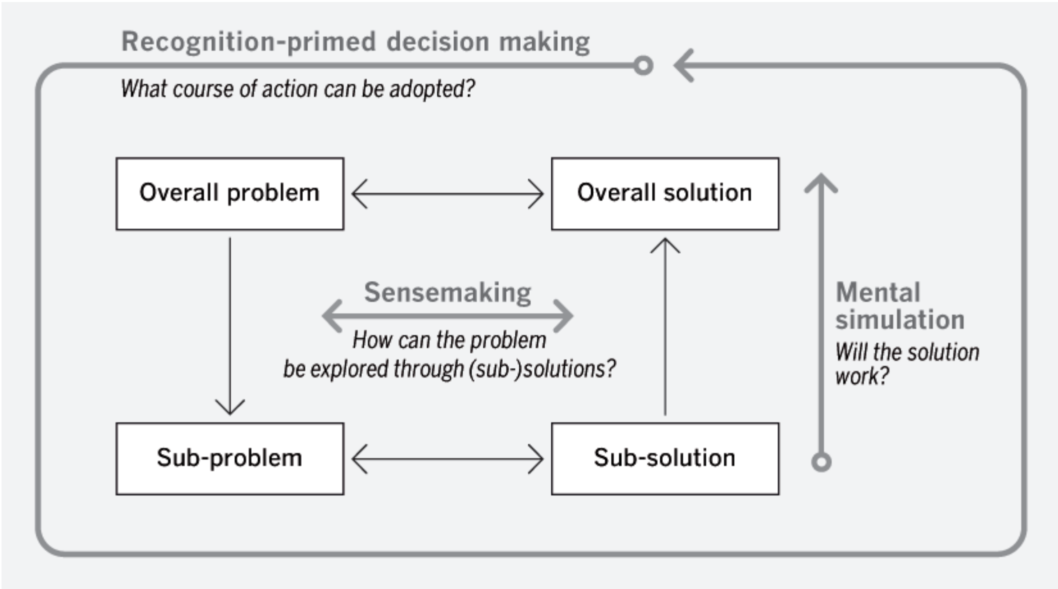


Figure 12: A naturalistic model of design decision making (Ariel Guersenzvaig based on Cross, 2008)

These three processes are:

1. Recognition-primed decision making: describes how designers make decisions while dealing with ill-defined problems in dynamic situations with unstable goals. To fix an initial problem-solution pair, an emergent course of action is needed in order to work as a primary generator. The RPD model describes how this solution emerges through pattern recognition, pattern-matching and the implementation of action scripts, as seen in § 4.2.
2. Sensemaking: the DFTS model describes how framing, problem exploration and structuring occur. Sensemaking is about fitting data into a frame and matching a frame to the available data. This can be also regarded as defining the problem space (the left side), while exploring the solution space (the right side), which is the constructive tasks of finding a matching problem-solution pair.
3. Mental simulation: this process describes how solutions and sub-solutions are assessed and evaluated intuitively and analytically. Mental simulation goes from the simulation of loose, partial sub-solution to the simulation of integrated and complete solutions.

In this chapter, I have drawn a great number of parallels between the NDM framework and theories and models from the field of design research. A strong theoretical link was established and a graphical model of naturalistic design decision making was put forward. This model is an extension of Cross' integrative model of co-evolution of problem and solution.

In the next chapter, drawing upon my own professional experience, I will analyse three design cases from a naturalistic perspective in order to show the adequacy of the NDM framework to describe and explain design activity.

CHAPTER 8

A proposal for a naturalistic outlook of design decision making

In this chapter three different design cases are used to test and show the naturalistic model's relevance. To structure the discussion several macrocognitive functions are used as guidance.

I will draw upon my own professional experience in order to examine three design cases to see how they measure up against a naturalistic outlook. Although this topic was already approached from a theoretical perspective in chapter 7, in this chapter I will approach it from a practical one. Different design situations will be explored and described with the help of naturalistic models. The relevance and adequacy of a naturalistic outlook on design situations will as a consequence fall into place and seem less abstract in discussion. To structure this discussion, I have used three strands of thinking as discerned by Klein (2009): (1) decision making, (2) sensemaking and (3) adapting. These three macrocognitive functions – treated in § 4.1.1, § 4.2 and § 4.3 respectively – are related to one another: making decisions depends on how the situation is assessed and sized up, adapting to the course of event rests on how those events are understood and framed.

Some of these cases might be somewhat dated regarding their visual appeal or degree of interactivity[12]; I consider this not to be a problem whatsoever since what is under attention is not the quality of the formal, graphic dimension or its interactive aspects. The function of these examples is to act as *paradigmatic* cases to establish the possibility of an analysis guided by the NDM framework. In this type of information-oriented selection cases are chosen on the basis of expectations about their information content (Flyvberg, 2001). Flyvberg (2001) mentions a well-known example of paradigmatic case: Michel Foucault's use of the *Panopticon*. The Panopticon, a type of institutional building designed in the late 18th century by English philosopher and social theorist Jeremy Bentham was used by Foucault (1995) as metaphor to describe freedom-restrictive modern societies and their inclination to control and normalise. To avoid confusion, it must be noted that the Panopticon as used by Foucault is not a real historical

[12] Most of my personal work as a designer is commissioned work for large companies in the field of financial, investment and insurance services. A great deal of my recent work is still under non-disclosure agreements (NDA) I am not able to freely discuss them or reveal their existence. Having to cope with this difficulty I have chosen relevant cases that are already public or are not under an NDA.

event, as it was not built at the time, while on the contrary the design cases I examine are real.

The treatment of each case is structured around a design technique or a group of related design techniques. I concentrate on the technique, as it is what enables the designer to move from one step of the process to the other by executing a particular task (Spool, 2010). Having introduced the technique, the case is presented and finally a naturalistic reading of the case is provided.

8.1 A case in decision making

In this section a case is presented an analysed in relation to decision making.

8.1.1 The techniques

Many techniques were used during the development of the project described in the first case. I will cover only four of them as they are the most important ones and support the claims that are made in the discussion. The first part of this case concerns two techniques: *sketching* and *wireframing*. In the second part other two techniques will be considered: *site mapping* and *flowcharting*. All these techniques will be examined before proceeding with the case.

Sketching

A sketch is a quick rough drawing or outline by hand in simple strokes. Its purpose is to give an idea of something and its focus is not on capturing the precise details of the thing depicted, but on schematically recording its essential (formal) features (Kurz, 2008). Sketches are widely used in all areas of design. Designerly tools such as sketching are used as a means of exploring design intentions and ill-defined problems at the initial stages of a project while design activity remains divergent, iterative and uncommitted (Self, 2012). Many authors (Cross, 2001, 2007a; Cross, Christiaans and Dorst, 1996; Lawson, 2004b, 2006; Lawson and Dorst, 2009; Visser, 2006) have discerned exploratory sketching as being a way to cope with uncertainty in design activity.

As an example, below I include sketches created by the Spanish interaction designer Javier Cañada[13] and by myself.

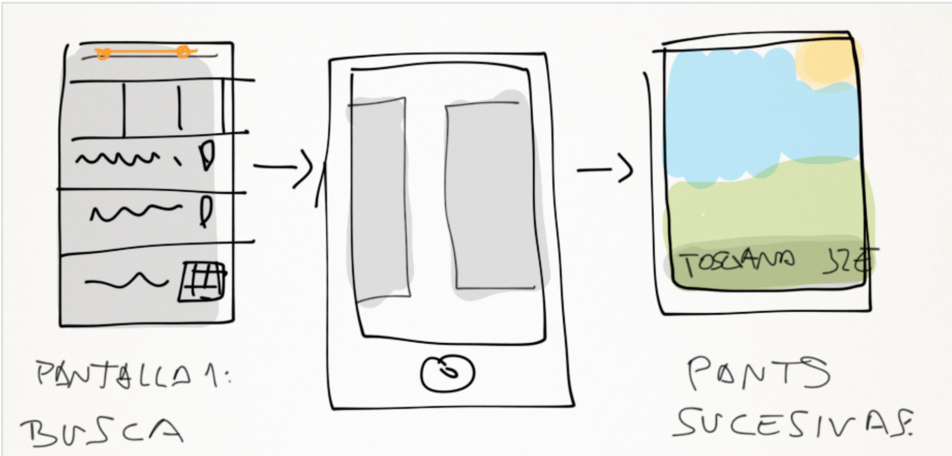


Figure 13: Annotated sketch by Spanish interaction designer Javier Cañada

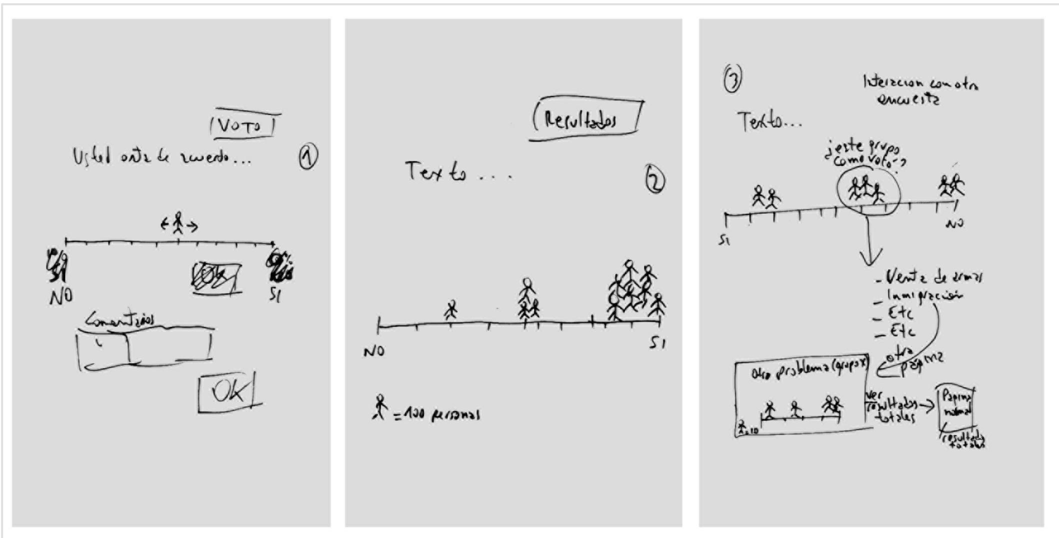


Figure 14: Sketches for slider controls (Ariel Guersenzvaig)

Wireframing

Brown (2007, p.265) defines wireframes as ‘rough illustrations that show, to a greater or lesser extent, the contents of each screen’. The author refers to screens used in interactive devices such as websites, mobile telephones, tablets, etcetera. The wireframe used in interaction design borrows its name from the wire-frame models or drawings traditionally used in architecture or product design to represent a three dimensional physical object or space. In interaction design, wireframes are typically rendered with simple lines and represent a skeletal visual

[13] http://www.vostokstudio.com/

structure; they are at the intersection of visualising structure, they show how one kind of information relates to another, and help to display how to represent information on the screen (Brown, 2007).

Brown (2007) characterises wireframes as follows: (1) the purpose of a wireframe is to communicate initial design ideas, (2) the scope of a wireframe is content and structure, (3) the wireframe conveys what content the user expects to see. Each wireframe includes: (1) key page elements and their location, such as header, footer, navigation, content objects, branding elements, (2) grouping of elements, such as side bars, navigation bars, content areas, (3) labelling, page title, navigation links, headings to content objects, and (4) place holders, content text and images (Webopedia, 2013).

Wireframes can be produced by hand in simple strokes (i.e. through sketching) or they can be developed with the aid of specific software tools (e.g. Adobe Fireworks). Sometimes annotations are included in the wireframes as well. Below, I include an example of sketched wireframe and a wireframe created with a software tool, Figure 15 and Figure 16 respectively.

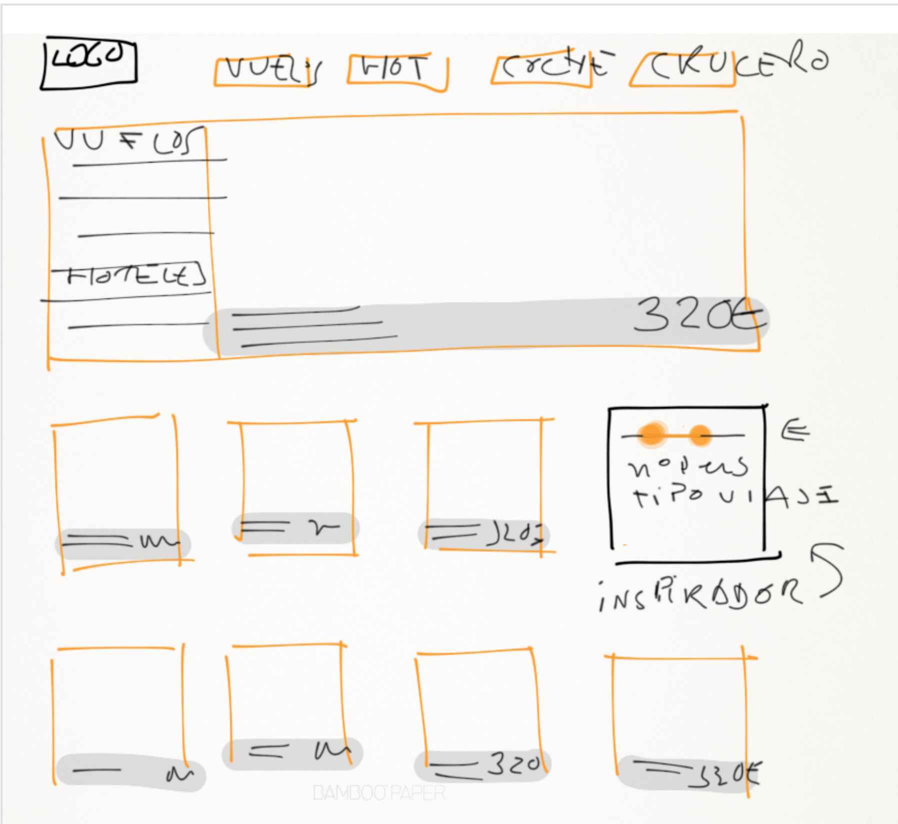


Figure 15: Sketched wireframe (Javier Cañada)

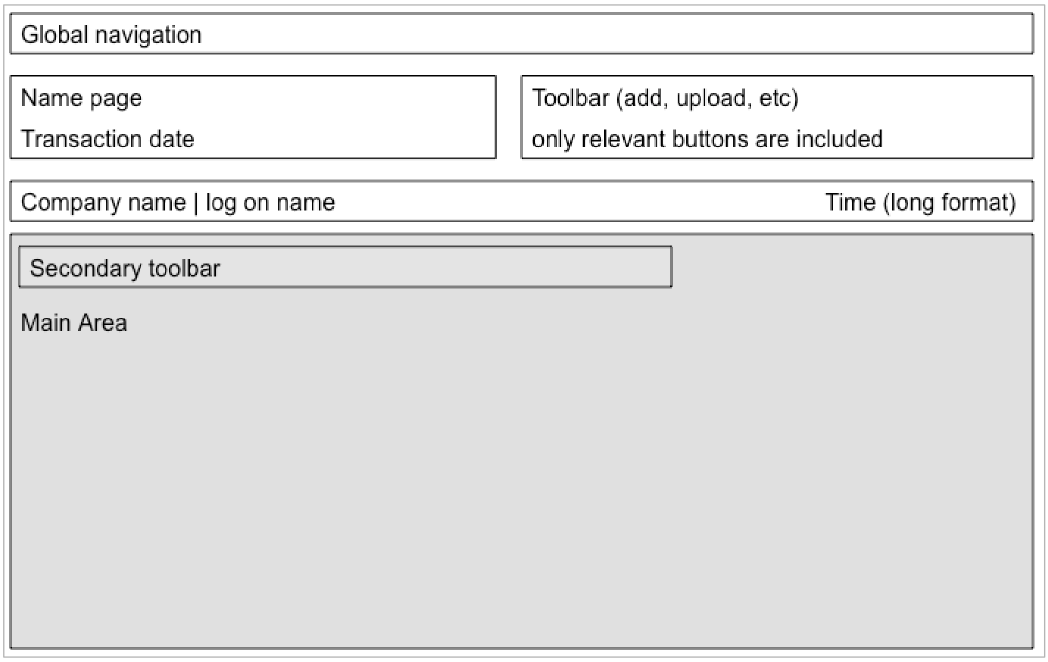


Figure 16: Generic wireframe created with a software tool (Ariel Guersenzvaig)

Site mapping

Site maps represent the structure of information on a web site and generally illustrate relationships between pages or sections (Brown, 2007). Site maps crafted for static web sites are hierarchical and the structure matches the steps a user will need to take to get through the site; for these types of maps, a tree diagram is often used. The site map consists of a system of boxes representing pages, which are connected by lines representing links.

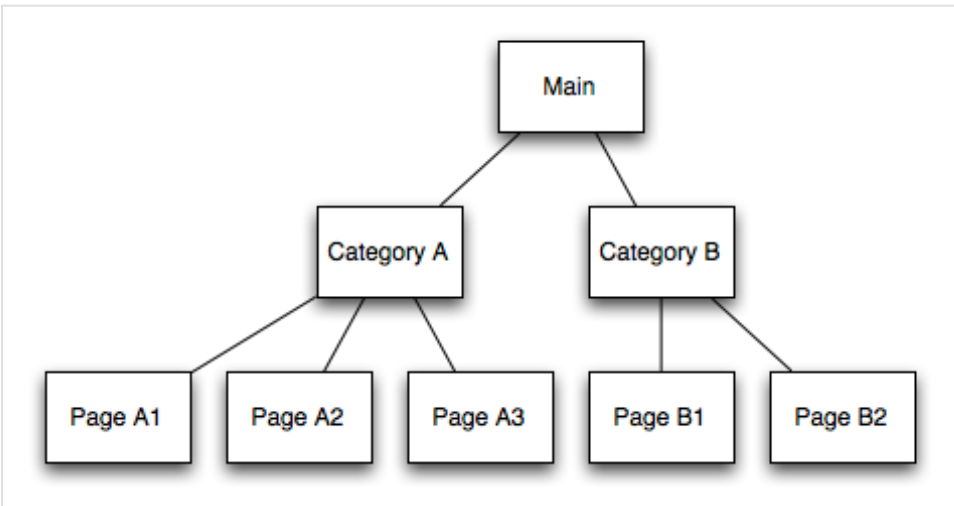


Figure 17: Generic site map for a static website (Ariel Guersenzvaig)

Site maps crafted for dynamic database-driven websites – such as an online newspaper – are less hierarchical and more abstract as the interaction they represent is of a greater degree than in the case of static maps. In this case, links across the hierarchy, loops and stack of pages, among other things, are represented.

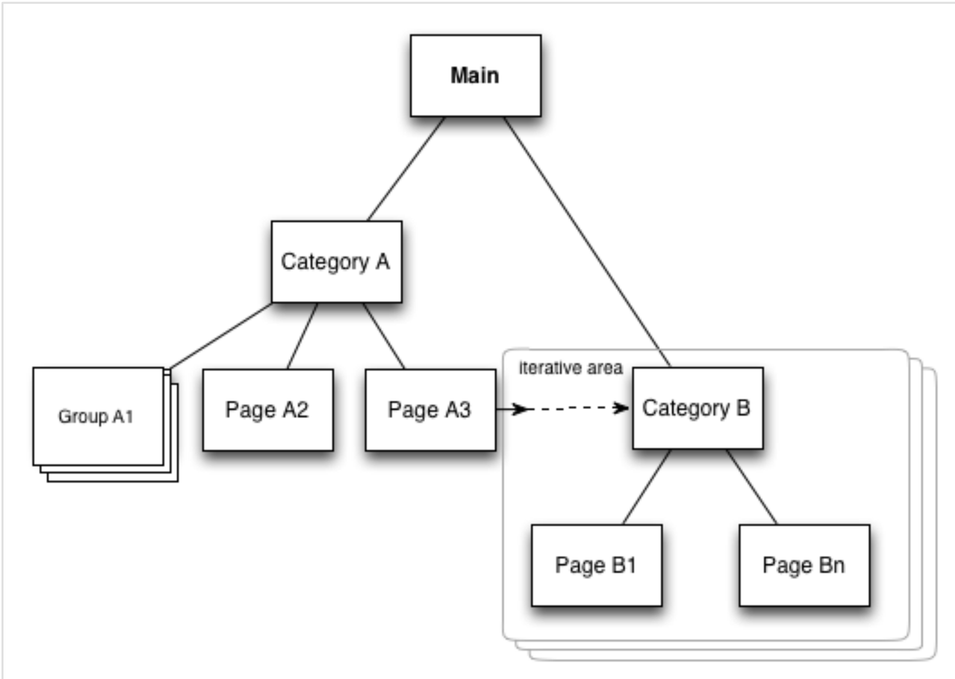


Figure 18: Generic site map for a dynamic website (Ariel Guersenzvaig)

Flowcharting

Flow charts are visualisations of flows of interactive tasks. For web-based processes, flow charts often represent a series of screens that collect and display information to the users (Brown, 2007). Besides boxes and arrows, several other shapes are used to indicate conditional or parallel processes. Figure 19 illustrates a simple flowchart.

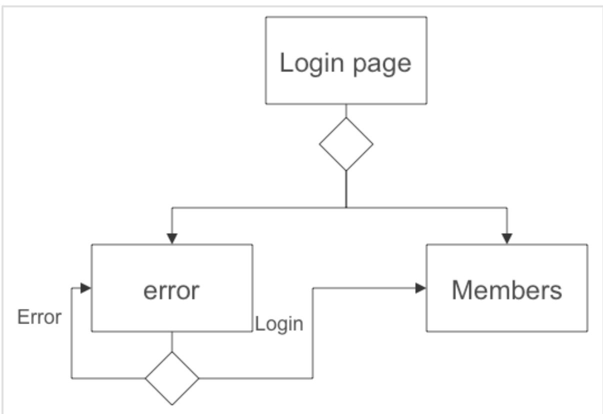


Figure 19: Simple flowchart representing a log-in process (Ariel Guersenzvaig)

Even a static website is interactive in most cases, in the sense that the user determines the order in which she navigates. In such case, a flow-chart might not be needed, as the flow of tasks is congruent with the site map and the user flow can be inferred from the lines connecting the boxes. Figure 17 depicts such a site map that contains an implicit flow-chart (i.e. the lines represent the user flows). What separates a flow chart from a site map is that in the former, time is the defining factor, since the relationships between the steps are sequential, not structural or hierarchical (Brown, 2007).

8.1.2 The case

For The Van Gogh Museum in Amsterdam I participated in the design and development of their online shop and an online experience about an exhibition of the work of Vincent Van Gogh and Paul Gauguin in 2002.

The first approaches to the interaction design of the shop were rough wireframe sketches such as the one included below.

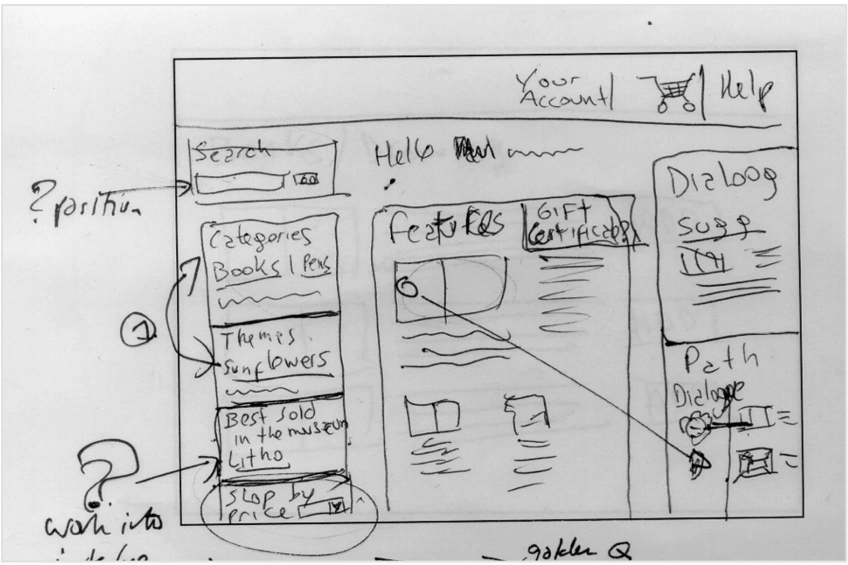


Figure 20: Early wireframe sketch (Ariel Guersenzvaig)

The sketches were iterated into wireframes designed with the aid of a computer.

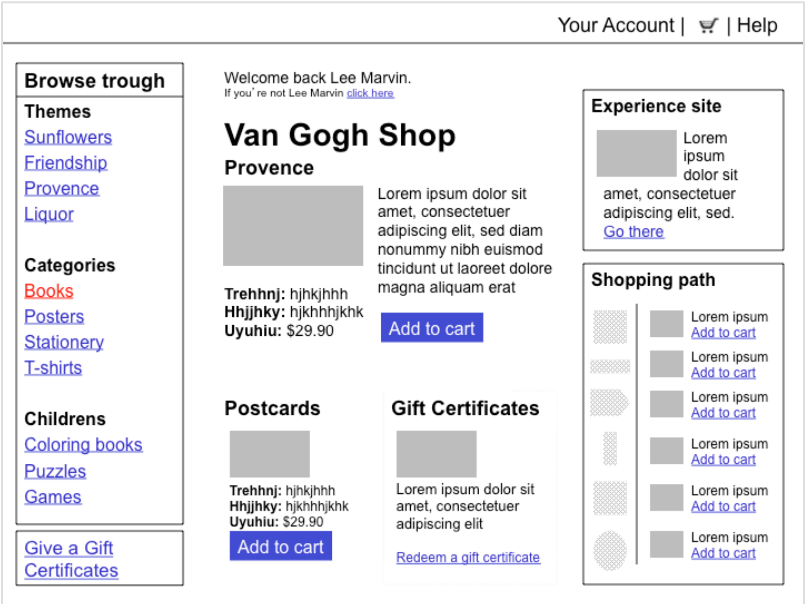
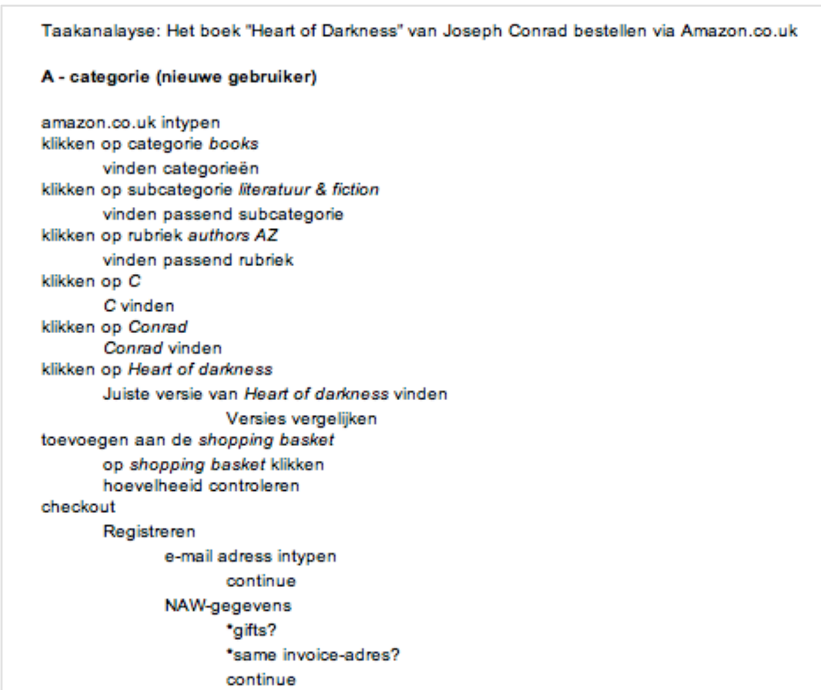


Figure 21: Wireframe for the Van Gogh online shop [1st iteration] (Ariel Guersenzvaig)

As discussed in Guersenzvaig (2002), at this stage user research was conducted in order to gain insight for the definition of the shop's content and functionality. Several analytic techniques were performed such as a task analysis of the required steps to buy an item in an online shop from other museums or online competitors (e.g. Amazon.co.uk).


Taakanalayse: Het boek "Heart of Darkness" van Joseph Conrad bestellen via Amazon.co.uk

A - categorie (nieuwe gebruiker)

amazon.co.uk intypen
klikken op categorie *books*
    vinden categorieën
klikken op subcategorie *literatuur & fiction*
    vinden passend subcategorie
klikken op rubriek *authors AZ*
    vinden passend rubriek
klikken op *C*
    C vinden
klikken op *Conrad*
    Conrad vinden
klikken op *Heart of darkness*
    Juiste versie van *Heart of darkness* vinden
        Versies vergelijken
toevoegen aan de *shopping basket*
    op *shopping basket* klikken
    hoevelheeid controleren
checkout
    Registreren
        e-mail adress intypen
            continue
        NAW-gegevens
            *gifts?
            *same invoice-adres?
            continue

Figure 22: Task analysis of shopping steps (Ariel Guersenzvaig)

A complex variety of interfaces showing different interaction states were created. The next example illustrates this aspect.

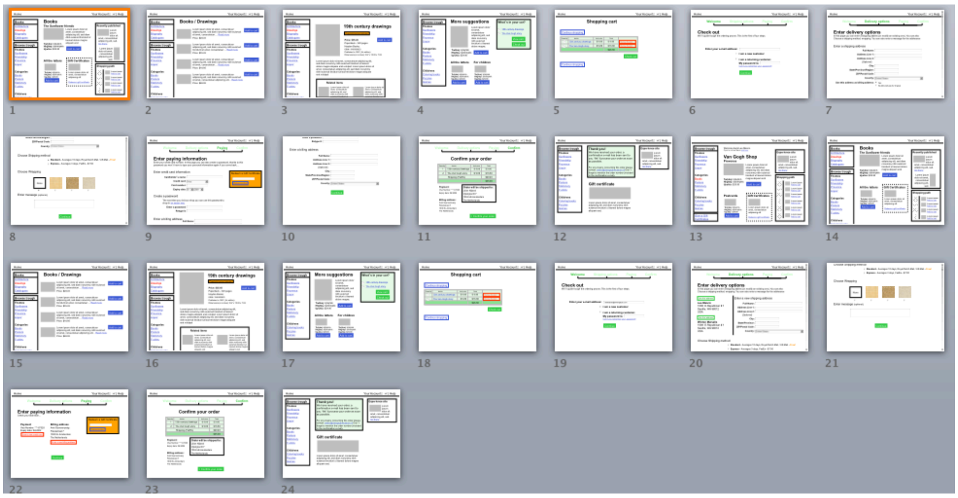


Figure 23: Wireframe *comps* for several interfaces and states (Ariel Guersenzvaig)

These wireframes were iterated further by an interface designer and developed into graphical user interfaces.

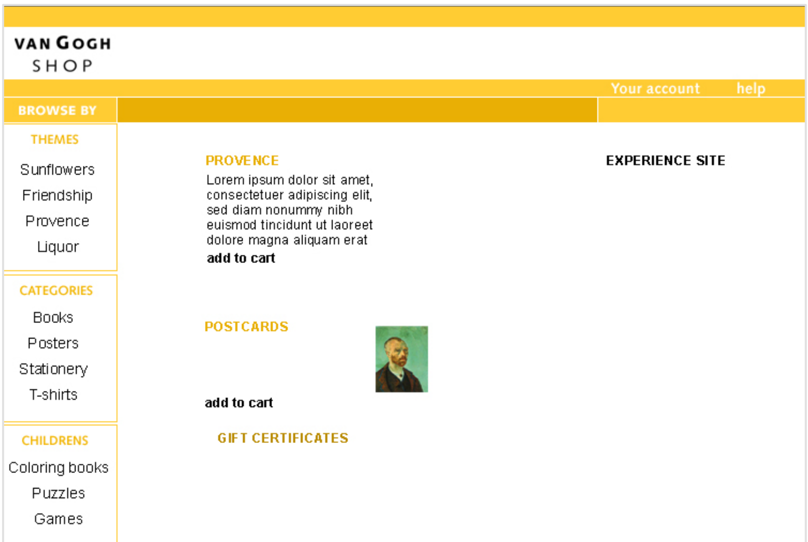


Figure 24: Graphical user interface [1st iteration] (Lilian Nijland/SQR)

At this point, negative feedback from the potential users and the client sent me in a different direction in which I explored a less cluttered interface. This involved having to go back to a more abstract stage of the process in order to reframe the problem. I will explain the motivations behind the changes in the discussion part of the case. Figure 25 (next page) depicts the new design direction.

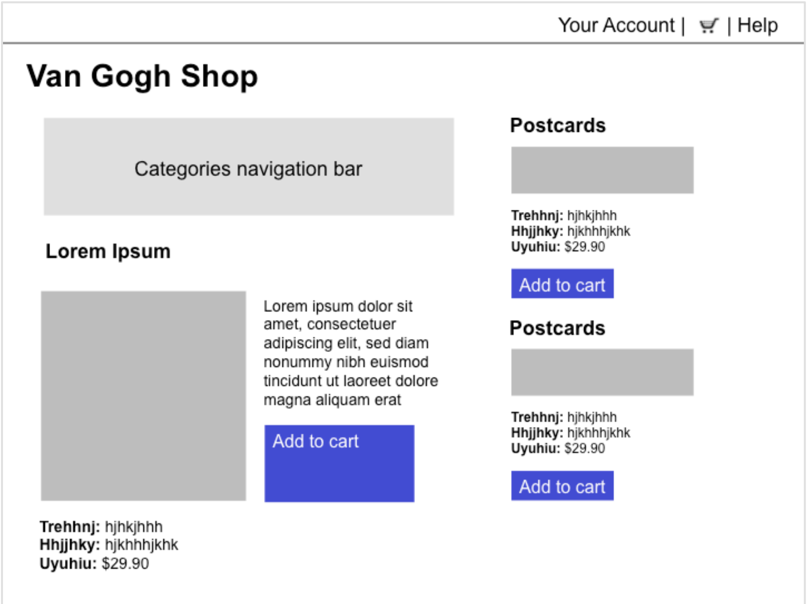


Figure 25: Wireframe showing a less cluttered interface [2nd iteration] (Ariel Guersenzvaig)

The interface displayed in the wireframe above was the final scheme chosen and a graphical interface designer further developed it. The final graphical interface can be seen below in Figure 26 and Figure 27 (next page).

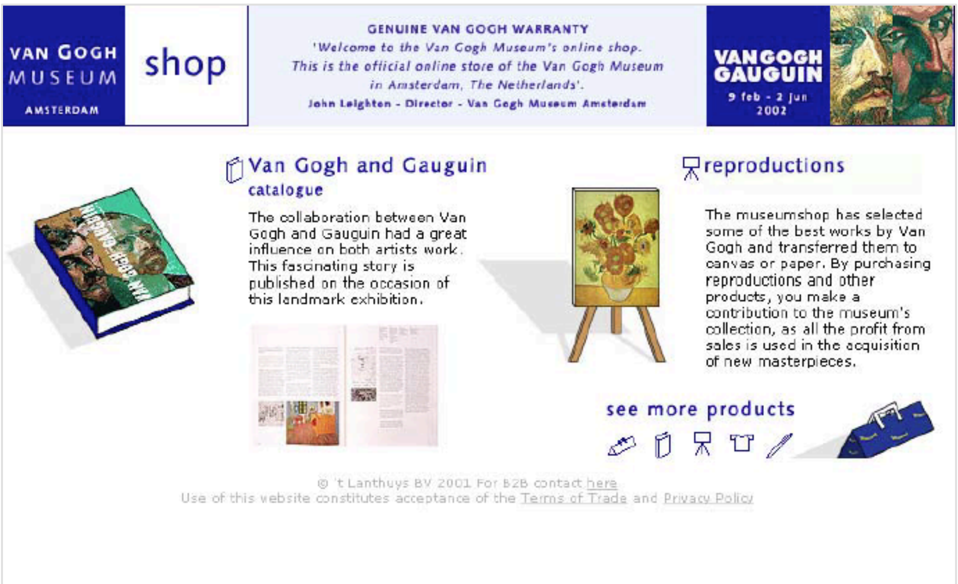


Figure 26: Final graphical user interface for the home page [2nd iteration] (Lilian Nijland/SQR)

Figure 27: Final interface for a product page [2nd iteration] (Lilian Nijland/SQR)

While working on the wireframes, I was also busy defining the interaction layer and the user flows. Below, I include an example of an early flow chart.

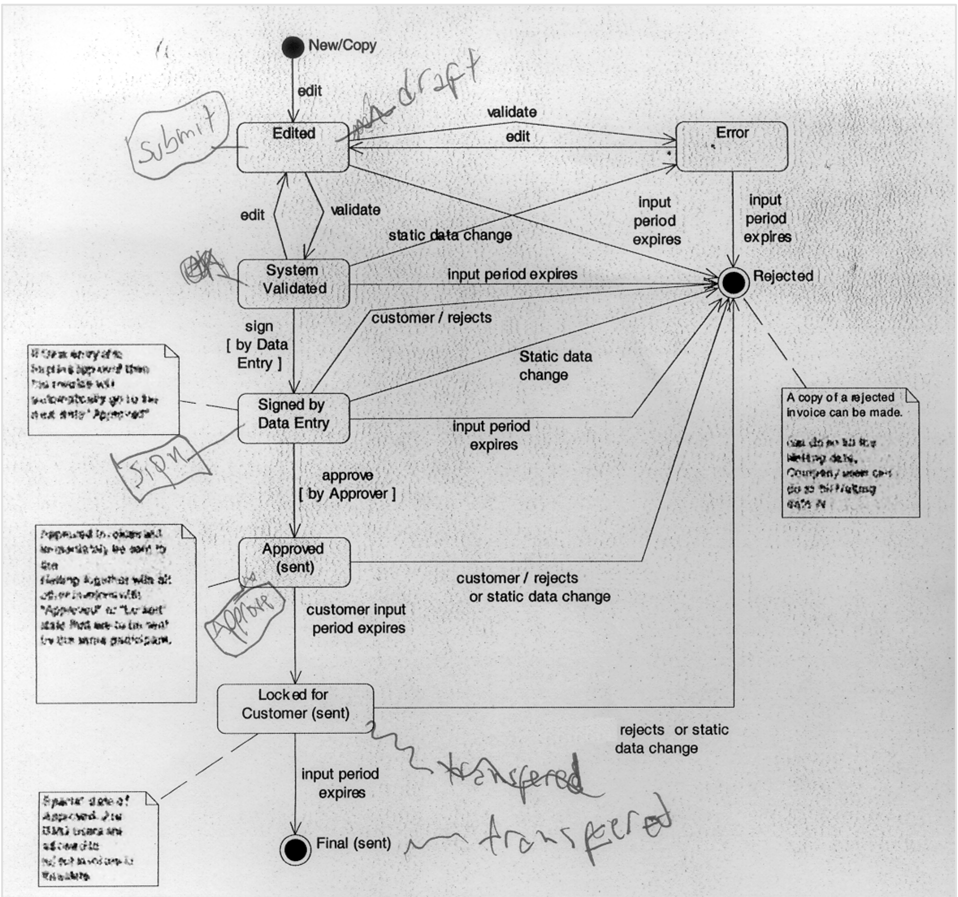


Figure 28: Flow chart from the Van Gogh online shop (Ariel Guersenzvaig)

At a later stage these flowcharts were integrated into the site maps.

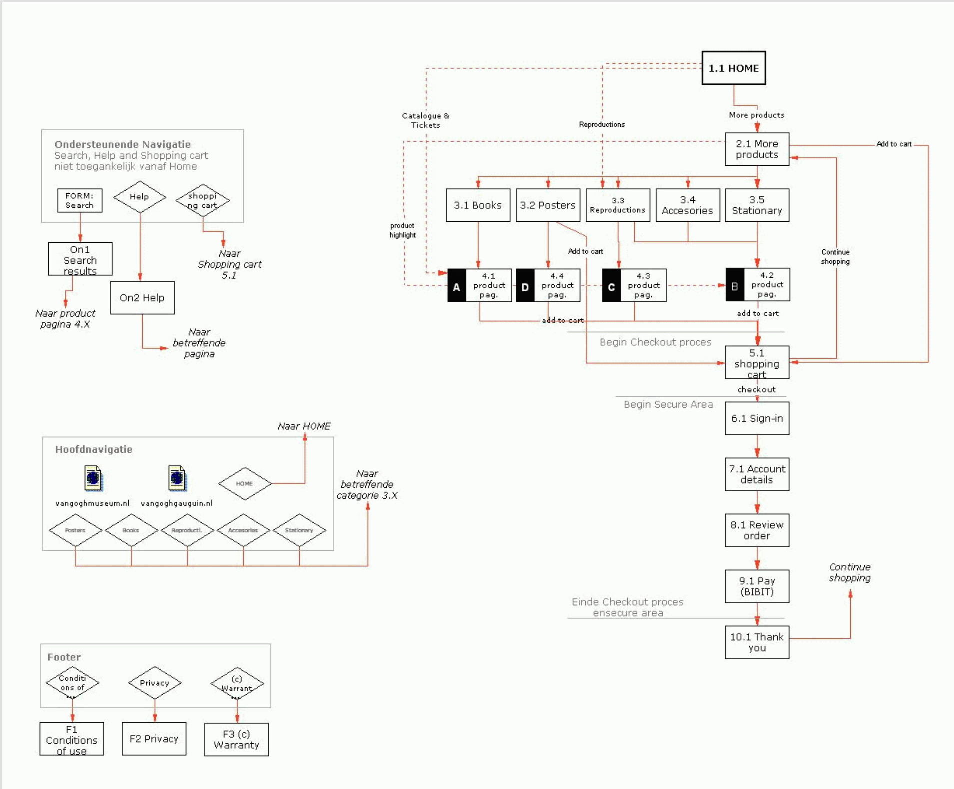


Figure 29: Site map including flow representations (Ariel Guersenzvaig)

Once the design for the graphical interface was well advanced, I kept iterating directly on it and no longer using wireframes for making corrections that affected the implicit flows of interaction and the graphic layer.

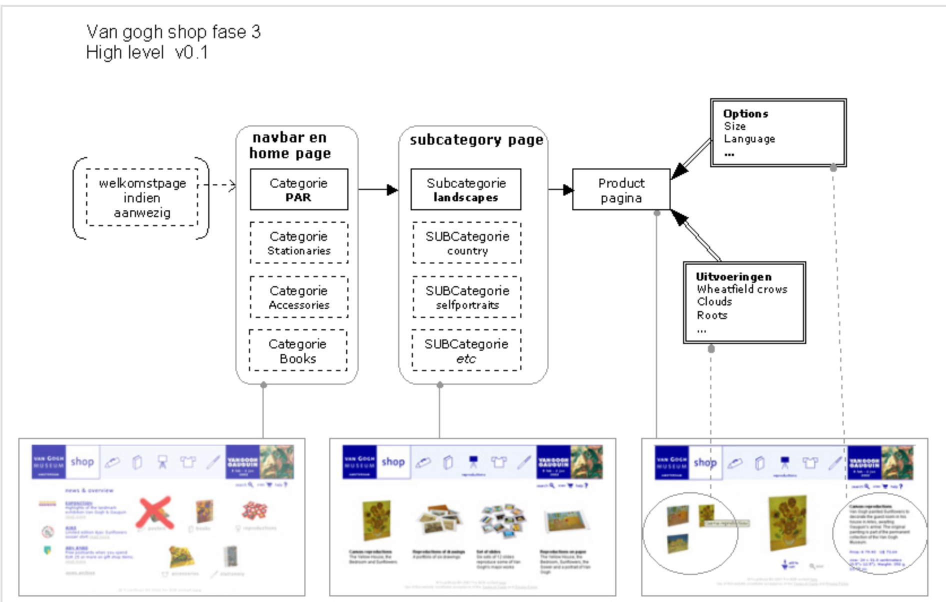


Figure 30: Iterations on graphical user interface and interaction flows (Ariel Guersenzvaig)

A naturalistic reading

A number of reflections can be made after this case.

The first one is related to several aspects of the RPD model, specifically making decisions based on pattern recognition, detecting anomalies and developing mental models. Having designed online shops in the past, I approached the project as a classical online shop. The three-column structure depicted in the sketch from Figure 20 resembles the classical pattern of online shops at that time, such as the popular online shop Amazon.com.

Figure 31: Amazon.com in 2002 (Kindermann, 2010)

The behaviour of generating a solution from a referent through pattern matching fits the RPD model. The generation of the course of action (i.e. the initial concept for a solution) is based on recognition (i.e. intuition) and sensemaking. In interaction design and software design, the use of patterns is a well-established practice (Van Duyne, Landay and Hong, 2003). Many researchers mention the extensive use of patterns and precedents during solution generation in all areas of design (e.g. Cross, 2007a; Lawson, 2004a; Lawson, 2004b). For the sensemaking process, a frame based on a traditional model of an online shop was applied. In practice, this meant generating a solution that provided many ways to find products in order to make the shopping experience as usable and convenient as possible.

However, during the research at the initial stages, it was discovered that buying products at the Museum shop was a substantial part of the whole experience of going to the Museum. This shop was not just a simple online shop, it had to be part of the experience, and a common online shop with lists of traditionally categorised items did not fit the user expectations. A first step in the experiential direction was including *thematic* categories such as 'sunflowers', 'friendship' or 'Provence', to evoke subjective sensations, along classic product-based categories: 'books', 'posters', etcetera. Despite the efforts, this was not sufficient. After a graphical interface, a designer integrated the graphic layer but the designs were still seen as dull by the whole team, the client and several potential users. The client, however, did not have a clear set of goals that may be used as guidance. There were many unacknowledged assumptions about what the design should be and it became necessary to create an explicit common starting point. A workshop with other team members and the client was organised in order to define a general statement for the shop. A statement indicates an explicit direction that does not dictate a specific solution. After this workshop, several statements (i.e. goals) were defined, most notably that it was necessary 'to deepen the product to create meaning'.

The mental model I was using was one of an online supermarket, but this online shop was different, because it was part of an art museum, and an art exhibition would be a better analogy. I used the statement regarding the necessity 'to deepen the product to create meaning' as anchor from which to develop a new mental model. From this model, having identified an opportunity, I tried to explore it by means of simulations of the future user experience that were guided by the wireframes and the flow charts. From here, a different design approach – the online shop as an exhibition instead of the online shop as a supermarket – was taken, and evaluated against itself in a singular evaluation approach as predicted by the RPD model. The wireframes were less cluttered with product information and the product presentation became the most important aspect. Bigger pictures were used and experience, not convenience, was the most important goal. On a graphic level the issue was addressed by combining photographs and line art.

The second reflection relates to the non-linear aspects of problem solving that occur in naturalistic situations where the differences between problem solving and decision making become blurry. This aspect is illustrated with the parallel development of the wireframes and the flow of interactivity. While sketching is about exploring and framing the situation, flowcharting is about finding and consolidating answers. The rapid sketching activities are essentially abductive, and are a way of exploring what it could be. Every new sketch provides new questions, new constraints and new opportunities; the proposed solution generates a new list of issues to consider, either through sensemaking, simulation or rational analysis.

In the field of NDM the dual concept of problem and solution evolves in a naturalistic decision: it is a question of defining and structuring the problem while the concept for a solution is being generated. From this case it can be seen that problem solving is a constructivist and dynamic task that involves mental simulation – imagining the interaction – in order to build and define possible solutions by developing the wireframes. Sub-solutions are explored in parallel, clarified and defined while the understanding of the problem is developed, which in this case meant seeing the shop as an exhibition.

Simulation is sometimes carried out *ad hoc* (i.e. just imagining the future course of events), but a guided framework for simulation and analysis can be used such as the *who-how-what-why-when-where* framework: *How* does this feature solve a particular problem? or *Who* might have trouble with this feature?. The simulation can also be guided by the use of personas and scenarios – both concepts already referred to previously – created to represent different user types and foreseeable interactions between a persona and the system (Guersenzvaig, 2004a, 2004b).

The insights from simulation and analysis served in the case to further iterate the wireframes and the flow charts. Alongside intuitive and/or rapid evaluation, objective criteria were also used to assess the quality of the designs. Here, *guiding principles* were used, such as the degree of learnability, efficiency, elegance, usability, etcetera. It was through the formulation of conjectures (i.e. wireframes and flow charts) that the problem was defined and solutions were developed.

Figure 32 (next page) contains a timeline of the evolution of the design deliverables examined in this case and the different frames, referents and goals that were defined.

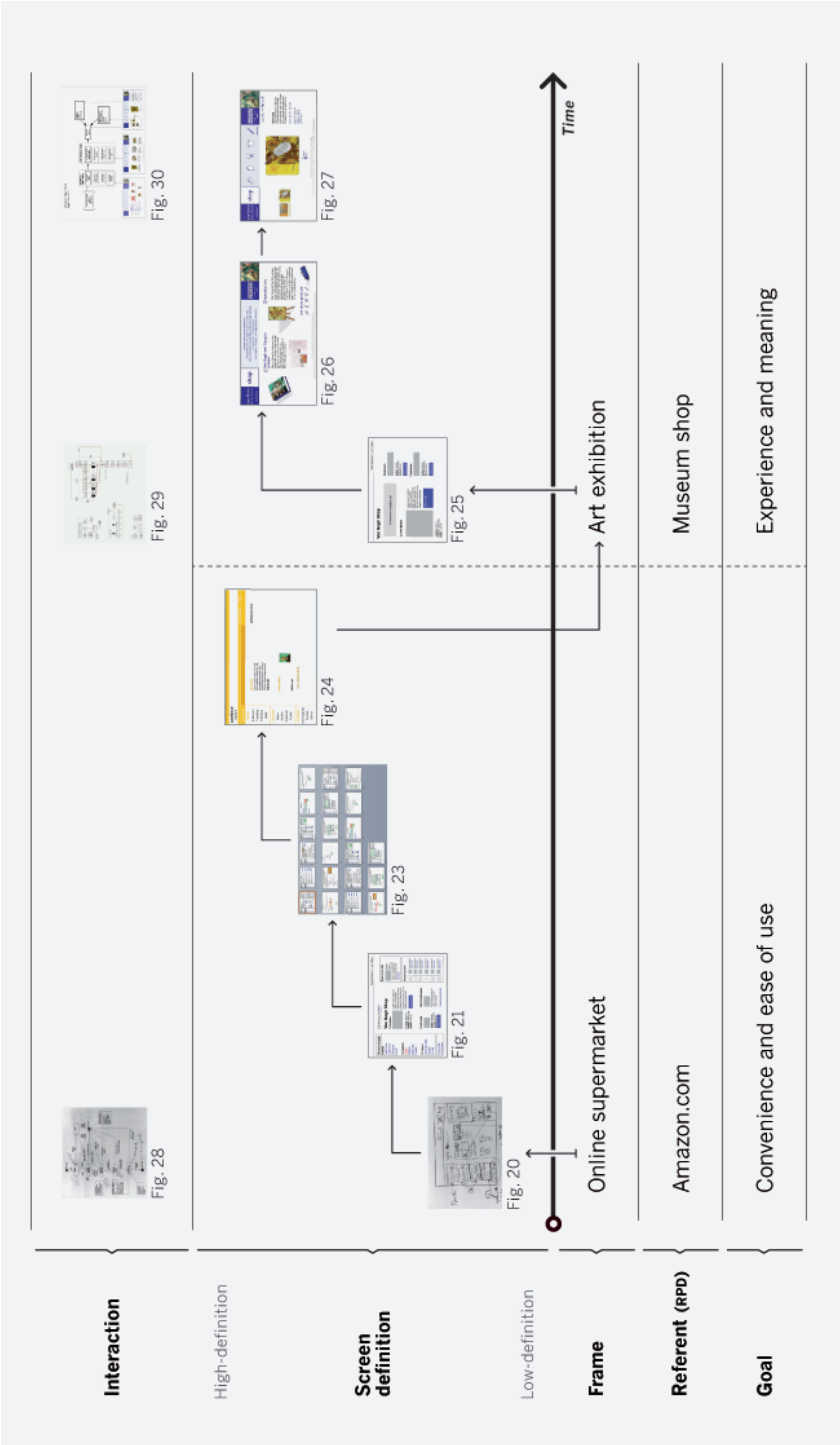


Figure 32: Timeline of the design deliverables for the Van Gogh online shop (Ariel Guersenzvaig)

8.2 A case in sensemaking

In this section a case related to sensemaking is discussed.

8.2.1 The technique

This case revolves around a *card sorting* exercise that was used in the definition of the information architecture of a website. Information architecture can be defined as 'the art and science of organizing and labelling websites, intranets, online communities and software to support usability' (The Information Architecture Institute, 2007). Card sorting is a user-centred design method for increasing the ease with which information contained on a website can be found.

The process involves sorting a series of cards, each one labelled with a piece of content or functionality, into groups that make sense to users or participants (Spencer and Warfel, 2004). Spencer (2009, pp.6-7) explains the technique as follows:

> You give people a set of cards (often paper index cards) that have example content written on them. You ask people to sort the cards into piles according to what's similar and describe the groups they make (this is called an open card sort as illustrated in Figure 33). Or you can give people a set of content cards plus a set of categories and ask them to sort the cards into the predetermined categories (this is called a closed card sort, as illustrated in Figure 34). Either way, you record the results, analyze them, and apply what you learned to your project.

The following figures visualise the steps of an open and a closed card sort exercise.

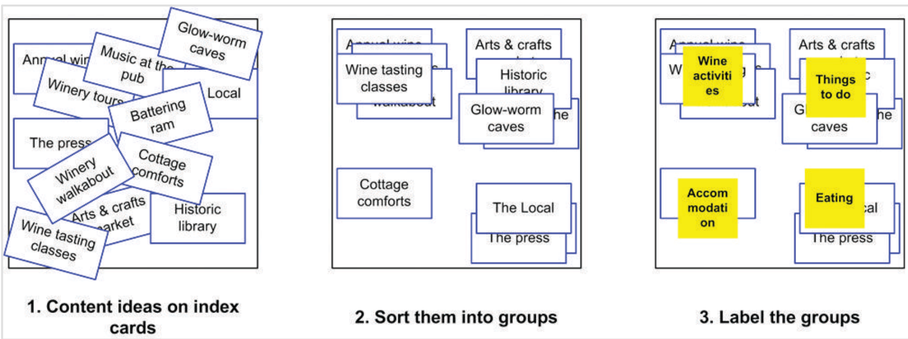


Figure 33: Open card sort (Spencer, 2009)

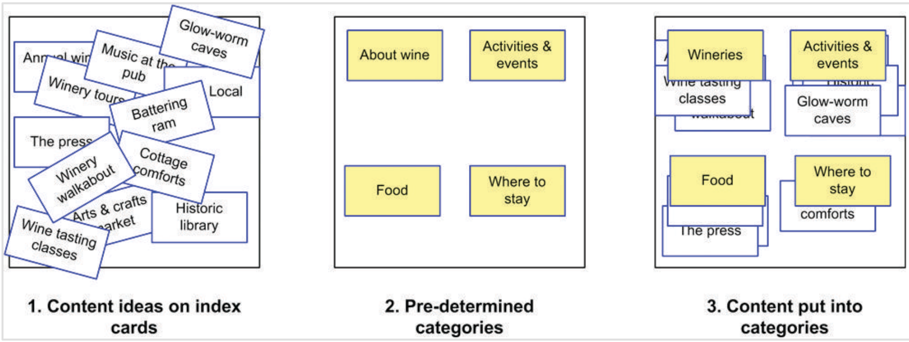


Figure 34: Closed card sort (Spencer, 2009)

The exercise is conducted with as little as 5-6 participants, usually running only a small number of card sorts – even with this amount of participants – yield good results and helpful insights (Spencer, 2009). The arrangement from every participant is entered into a software tool – at the time I used IBM's EZSort/EZCalc – in order to analyse the results. The software aggregates the results from every participant and generates a *dendrogram*, which is a tree diagram that represents relationships of similarity among a group of entities produced by hierarchical clustering. A generic dendrogram is depicted below in Figure 35.

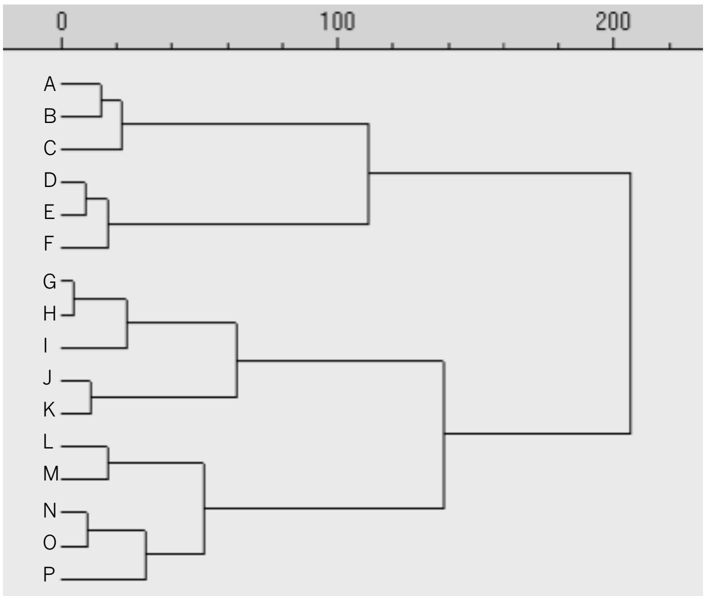


Figure 35: Generic dendrogram

The basics of dendrogram reading will be discussed now; for a comprehensive tutorial of dendrogram reading see Drout and Smith (2012). The dendrograms indicate the strength of the perceived relationships between items or pairs of items by the relative distance from the origin (0) to the nearest vertical line that connects the item's associated horizontal lines. The closer to zero this connecting vertical line appears in relation to another item, the stronger the relationship and thus the similarity between them. The distance between the connecting points of the branches indicate how similar or different they are from each other: the bigger the distance, the greater the difference. Shortly, in the discussion of the case, some more specific aspects related to dendrograms will be discussed.

8.2.2 The case

In 2004, I conducted a project for "la Caixa" – the third-largest financial group in Spain and the leader among Spanish and European Savings banks ("la Caixa", 2013). The client commissioned the design of the Intranet's Employee website.

An Intranet is a local or restricted communications network, especially a private network created using World Wide Web software (Oxford Dictionary of English, 2010). The Intranet hosted multiple private websites and was accessed by more than 20 thousand employees. The Employee website contained vast amounts of information that needed to be made available in a usable manner to all employees.

In the first stage of this project the strategic needs of the client and other stakeholders were researched. The initial brief from the client included a proto-classification that was discussed in order to understand the motivations behind it. Once the client's strategic goals were understood I performed several card sorting exercises in order to discover the mental models that employees had regarding the information contained on the website. The proto-classification from the initial brief was not taken as given, but used as a source for the card sorting exercise. The goal of performing these exercises was to gain insights on which to base the classification of information and the design of the website's navigation.

Every item in the proto-classification was written on a card. Two types of content cards were created: (1) 'webs', which referred to web sites belonging to the main employee website, and (2) 'links to articles', which were shortcuts to stand-alone articles that belonged to a particular web or to the main employee website. A total of 9 employees (end-users) participated in this exercise. Every participant performed two open card sort exercises, one for 'webs' and one for 'articles'. Every participant generated, thus, two arrangements for the card sort. Figure 36 illustrates a finished exercise.

Figure 36: Finished card sort exercise (Ariel Guersenzvaig)

After compiling the results from every user and entering the data into the software tool a dendrogram was generated (Figure 37) showing the aggregate data.

Differentiated line colours, shading, and spatial separation indicate the group membership of the cards; I will explain this briefly. The alternating blue and red text and line colours in Figure 37 indicate low-level groupings (pairs of cards or groups of cards). The orange and blue background colours indicate that the cards belong to a high-level grouping (i.e. a group of related cards).

Two thresholds, indicated by the green and pink vertical lines, define the pairing for high-level grouping (green line) or low-level grouping (pink line). By dragging these lines to the right or to the left, I was able to directly adjust the thresholds. Changing the thresholds affects the groups, which changed as the lines were moved. The software tool provided dynamic visual feedback, which I used as a guide in defining the most appropriate quantity of groups. The more high-level groups, the less populated each group is, fewer high-level groups result in more crowded groups.

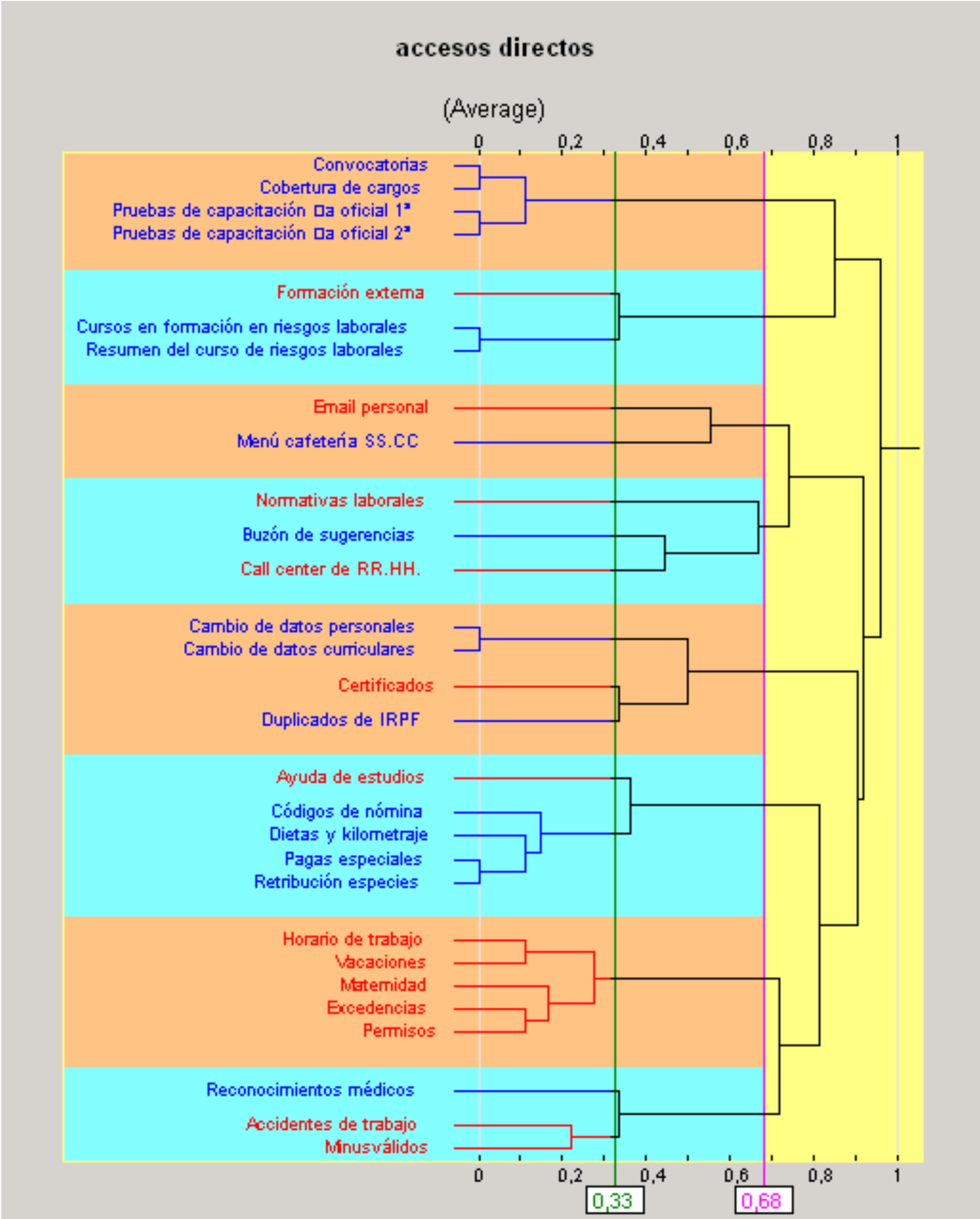


Figure 37: Dendrogram showing aggregated results for the link to articles exercise (Ariel Guersenzvaig)

In the dendrogram can be detected that the relationship between some particular items is very strong across participants. This is shown in Figure 38.

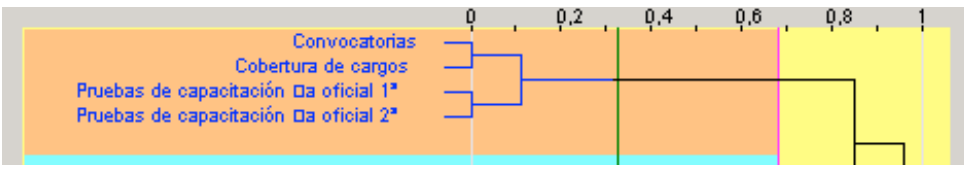


Figure 38: Strong relationship between cards and groups of cards (Ariel Guersenzvaig)

On the contrary, the relationship between other items was very weak. This is shown in Figure 39.

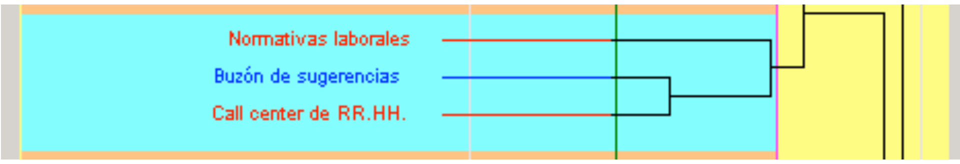


Figure 39: Weak relationship between cards and groups of cards (Ariel Guersenzvaig)

This exercise provided great insight into the mental models of the users of the Employee website and the inconsistencies that existed in the proto-classification and it also enabled the discovery of several patterns and common aspects regarding the expected labelling of information and its classification (Guersenzvaig and Atxondo, 2004).

A naturalistic reading

From previous case, common issues can be identified and several conclusions can be drawn.

The first aspect to be considered is the fact that the brief and its proto-classification were not taken as given and it was necessary to take it back to a more abstract form. After an initial review of the brief, it became evident that the taxonomy defined by the client was not aligned with the client's own strategic goals. The original taxonomy was created using a thematic classification scheme when a hybrid of a task based and a thematic scheme would have been more usable.

To reflect on this case the data/frame theory of sensemaking treated in § 4.3 will be used. The DFTS theory postulates that data elements are explained when they are fitted into a structure (frame) that links them to other elements (Klein et al., 2007). Sensemaking occurs when a person needs to actively fit data into a frame and match a frame to the available data. One of the sensemaking processes is that of *frame questioning* – depicted in Figure 40 – in which the decision maker after detecting inconsistencies and gauging data quality, judges the plausibility of the frame. Questioning begins when detecting that the data are inconsistent with the frame we are using.

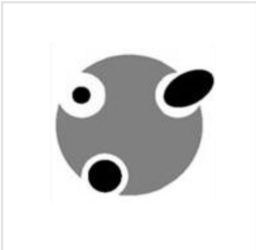


Figure 40: Frame questioning (Klein et al., 2007)

Based on a rapid assessment of the proto-classification, I ***knew*** that the proto-classification created by the client had to be carefully assessed and should not taken as given. Having designed many Intranets in the past and drawing from the then-current literature defining what a good, usable, classification was (e.g. Rosenfeld and Morville, 2002), I sensed that the proto-classification was not going to be usable. Lawson (2004a) mentions that expert designers have the ability to categorise and recognise situations with a little or no analysis at all; this ability is at the core of the RPD model and is congruent to the concepts of frame, action script and mental model proposed in the DFTS model. At this moment of the sensemaking process, I did not know for sure whether the frame used – based on my mental model of intranet users – was correct or incorrect, or if the inconsistencies I detected in the data were real or not. At this point, I just realised that some of the data did not match my frame, but I could be wrong. Weick (1995) asserts that sensemaking is often initiated by a surprise. In this case, the surprise was caused by the original proto-classification's apparent lack of usability. Klein et al. (2007) speak of a 'moment of untruth', that knocks people out of their existing beliefs. In this case, people may deliberately try to find a frame when confronted with data that makes no sense, or when a frame is questioned for being obviously inadequate.

I rejected the initial frame (i.e. the proto-classification) but I did not have a new frame yet. Sometimes, one frame can be replaced by another, but other times it is necessary to find or construct a frame. The card sorting exercise was an attempt at seeking and finding a new frame. The frame needed to be constructed, as there was no ready-made frame. Also, in order to convince the client that their proto-classification was wrong, I needed more information than just a hunch or my implicit knowledge. The data obtained was objective in the sense that it was measurable and it could be quantified. There was no guarantee that the card sort exercise could be replicated as the sample was small and may even be biased. Card sorting is not meant to achieve validity but to assist and guide the attempts to organise, label and present information into a coherent and cohesive information architecture.

The analysis of the results and the findings of the card sorting exercise were highly subjective, but the ability to replicate findings was not a relevant part of the design process. The goal was not to generate a theory but a workable solution to address an ill-defined problem. By manipulating the threshold lines in the software tool – in order to balance the number of items per group and the number of overall groups –, I synthesised and manipulated the gathered data in a personal way and achieved a certain result. Another capable designer might have synthesised the same data with different results.

Nonetheless, the card sort exercise did indeed provide objective data to convince the client that the initial frame was not adequate for achieving usability. It also provided a good argument to defend the new frame as it could be explained as being inferred from the findings. The exercise also helped create new groups of information by adjusting the threshold levels until an acceptable number of high-level and low-level groups resulted. In this manner, I was able to understand the user's mental model of the information space and adopt it as new frame, while achieving a balance between several conflicting elements (e.g. the number of resulting groups, a certain element belonging to an specific group or to another, the strength of the relationship between elements, etcetera).

8.3 A case in planning and adapting

In this section a case regarding planning and adapting a plan is presented.

8.3.1 The technique

In this case, I will examine several aspects related to planning and specifically the creation of a Gantt chart, a common charting technique related to planning.

Planning is about devising and maintaining a workable scheme to accomplish the need that the project was undertaken to address (Project Management Institute, 2003). Planning a project is on one side about considering *what* needs to be done: the overall goals, requirements or the design brief; and on the other, side about defining *how* it can be done, a planning of activities. There are several types of processes regarding planning activities (i.e. tasks) (Lessard and Lessard, 2007):

1. *Definition*: involves understanding the tasks that need to be performed and developing a work breakdown structure.
2. *Sequencing*: involves reviewing activities and determining the type of internal dependencies.
3. *Duration estimating*: involves defining a duration time for each activity.
4. *Schedule development*: involves defining start and end dates of the project and its activities.

5. *Schedule control*: involves ensuring that the schedule is met, or, on the contrary, rescheduling tasks or taking corrective action if the initial schedule is not met.

The Gantt chart is a graphic display of schedule-related information used as a tool for carrying out the processes regarding planning seen above. Gantt charts have a role of providing a readily useful interface allowing users to define problems, and better understanding and acceptance of solutions (Wilson, 2003). In a Gantt chart (see Figure 41 for a generic example), activities or other project elements are listed down on the left side of the chart, dates are shown across the top, and activity durations are shown as date-placed horizontal bars (Project Management Institute, 2003). The horizontal bars denote tasks and the lines that connect the bars show dependencies between the tasks related to their start or finish date.

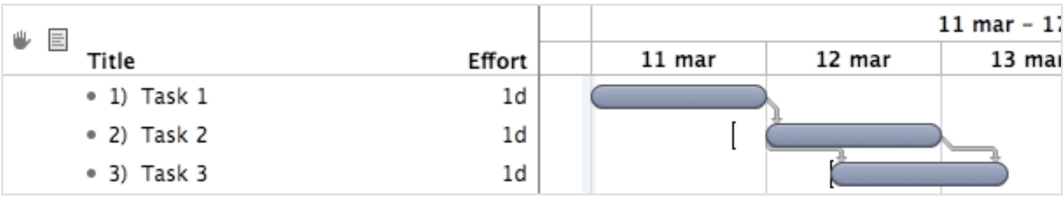


Figure 41: A generic Gantt chart (Ariel Guersenzvaig)

Often the goals or the design brief are unclear, and as it was shown in other chapters, designers do not wait to have a perfectly clear understanding of the goals or requirements before starting. The planning of tasks often includes the definition of tasks whose objective is to determine goals and more specific requirements and specifications.

8.3.2 The case

I led several projects as a senior interaction designer for Iberia. Iberia is Spain's largest air transport group and, after its merger with British Airways, the third-largest in Europe and the sixth one in the world in terms of revenues (Iberia, 2013). One of those projects was the redesign of the Bookings and Special Deals section of their website in 2006 and 2007. In this section, I will discuss the planning of this project and the use of its associated Gantt chart to convey a work breakdown structure of design tasks related to planning and replanning.

A Gantt chart was defined according to theory: tasks were defined in a work breakdown structure, then sequenced and its internal dependencies stated. Also an estimate was given for the duration of every task. This Gantt chart is included below (Figure 42).

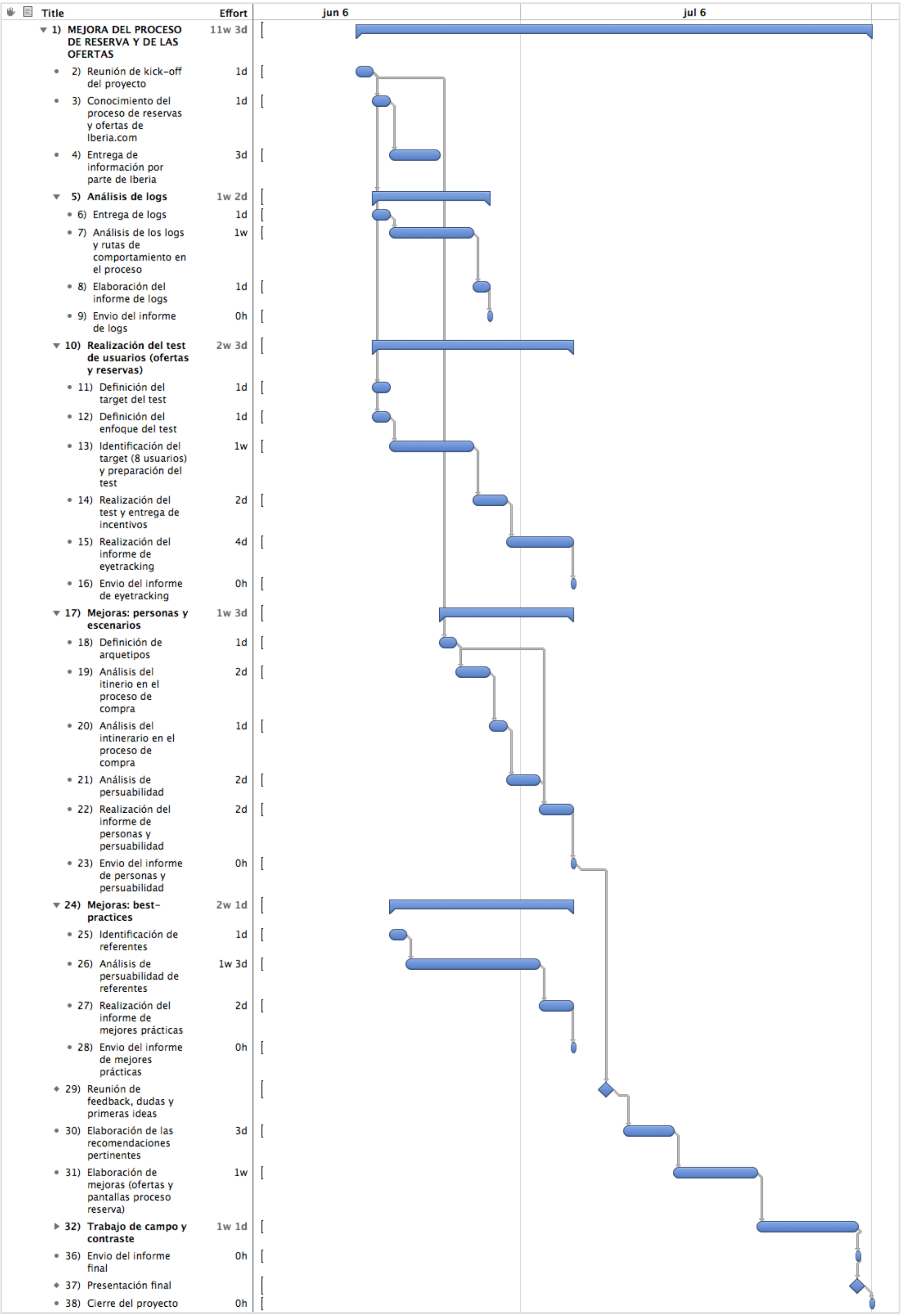


Figure 42: Gantt chart for Bookings & Special Deals project (Ariel Guersenzvaig)

The goals in this particular design project could not be completely formulated at the start of the project. That is why many tasks and groups of tasks were planned in order to clarify uncertain goals and requirements. The inclusion of these tasks is what makes this case noteworthy. Some of these tasks were:

- Task 3: analysis of the then-current booking process.
- Task 5: analysis of the then-current web server logs[14].
- Task 10: usability testing and analysis.
- Task 24: identifying the sector's best practices.

Once the project was underway, some of the tasks had to be rescheduled, while others were created because of the results of previous tasks that were meant to discover goals and requirements. The Gantt chart was sometimes, but not always, amended, but after it started it never perfectly reflected the real development of the project. There were always mismatches between the Gantt chart and the activities that were conducted. These differences involved the duration of the tasks, their dependencies or their time scheduling.

A naturalistic reading

A Gantt chart is a plan, and as such, it makes many people feel ready for the future. Many sources regarding planning (Berkun, 2008; Lessard and Lessard, 2007; Luckey and Philips, 2006; Project Management Institute, 2003) insist in the importance of defining requirements before committing to the development of any project. Lessard and Lessard (2007, p.4) write:

> One of the most important aspects in product development and engineering design is to adequately define the scope of the problem. Often, the problem is stated initially in terms of vague project requirements.

Luckey and Philips (2006, p.61) assert:

> When you and the stakeholders have a clear vision of where the project's going, you need a clearly defined set of requirements. Early on in the project, you and the key stakeholders define what must be in the project and what would be nice to have in software. While ideally everything the project will create is defined at the beginning of the project, chances are you, the project team, and the project customer will have inspirations for other deliverables that can be folded into the software as the project

[14] A web server log is a log file that includes a history of pages served by that web server to the web users.

> moves along. Changes to the software scope can be dangerous because they can eat into time and the budget.

This standard advice follows the linear model of problem solving: from problem definition to option generation, and evaluation; but if the vision of design problems as wicked problems is accepted, the advice is a sure fail. The first step of defining clear goals and a set of requirements can, by definition, never be accomplished if the problem is wicked or ill-defined, and that means that the designer cannot move forward and she is trapped at the first step.

The Gantt chart can give the impression that everything is under control, and this might be true under well-ordered conditions, but wicked problems often prevent goal clarification at the outset. It may be argued that a Gantt chart is above all, a written transcript of a mental simulation of a course of action. The Gantt chart represents future events and in order to craft it and evaluate it, it becomes necessary to perform a mental simulation of all tasks and their dependencies. Planning can be seen as working backwards from the goal. This is an analytical activity, indeed, but one should not conclude that by tracing this path backwards from goal state to present state the whole design process becomes a logical activity. The goal state has been defined by intuitive and abductional reasoning of exploring what it might be. Planning is therefore a sensemaking effort. Since sensemaking ceases when the frame and the data have fitted congruently and sufficiently, there seems to be no use in amending a chart to reflect the changes that took already place. Modifying a Gantt chart afterwards seems to be a waste of time as long as there is no formal requirement to do so (e.g. a client requiring an updated Gantt chart to be included in a report).

The Gantt chart is a snapshot of a plan at a particular time but it is not the whole plan. Beyond that concrete Gantt chart there is something far broader and fluid; Hill and Lineback (2011) speak of the *unwritten plan*:

> Your unwritten plan exists in your mind as a living, evolving understanding of what you do, where you're going, why you're going there, and how you're going to get there — all based on your current understanding of how the future will unfold and how you can shape and influence it.
>
> [...]
>
> Don't assume unwritten plans take shape automatically. They require that you actively cast your eyes to the horizon, proactively gather information,

consciously suggest and discuss possibilities with your people and those in your networks, and systematically reflect on what you learn.

The Gantt chart case exemplifies the naturalistic behaviour of (re)defining goals as one tries to reach them; the macrocognitive processes of planning, adapting and replanning can account for these behaviours. Design strategy is determined by the designer's experience and expertise (Cross, 2007a; Dorst, 2006; Lawson, 2004b, 2006) and one of the defining features of planning and adapting (i.e. defining a design strategy) is that it requires goal negotiation (Crandall et al., 2006; Klein et al., 2003). If goals are not defined at the start, it is not a sign of bad planning, but an adaptive way of dealing with wicked problem, uncertainty and dynamic situations.

8.4 Conclusions

From the explanations in the previous design cases, it becomes self-evident that the NDM framework and its internal models serve to describe and explain several features of design activity. Below I include a summary of conclusions. The following keys are used to indicate in which cases the features regarding reasoning and deciding appear:
Van Gogh Museum online shop case: (VG)
Card sorting case: (CS)
Gant chart case: (GC)

The NDM framework was useful to describe and explain:

1. The possibility of solving the problem (GC).
2. The viability of the goals and their attributes (VG, GC).
3. The factors constituting a cue or an opportunity that is worth investigating (VG, CS).
4. Which analogies fit in with the situation and can be applied to it (VG).
5. The handling and solving of anomalies (VG, GC).

The following phenomena were discerned:

1. Sensemaking (CS, GC).
2. Non-comparative decision strategies and single course of action (VG, CS).
3. Satisficing behaviour (GC).
4. Decision in situations of uncertainty (VG, CS, GC).
5. No difference between problem solving and decision making (VG, GC).

To finish this chapter, I offer a summary focused on design decision making. It can be concluded that the NDM framework served to describe the following design situations:

- *Detection, formulation and reformulation of the problem and sub-problems*: often, the designer will start with a project brief as the initial goal; in other cases, as in the card sort case, the brief can be questioned right from the start; in other, activities might be planned in order to complement or redefine the brief, as in the Gantt chart case. The work of detecting and/or (re)formulating problems or sub-problems arises in the process of simulating a course of future action, although this aspect appeared in all cases.
- *Generation of courses of action*: sometimes the path to be taken seems obvious, as in the case of the Van Gogh Museum online shop. However, in other situations it is necessary to assess the situation in order to make sense of it and to seek cues on which to build possible solutions, as in the case of the card sort exercise.
- *Evaluation of courses of actions*: by means of simulation, the decision maker evaluates the course of action and revises it, if necessary, to generate a new course of action or a new representation of the problem, such as when the goals are changed, as in the cases of the Van Gogh Museum online shop and the Gantt chart.
- *Representation of the problem*: the designer assesses the possibility of solving the problem before beginning to generate or evaluate possible solutions, as in the Gantt chart case. Goal definition is also part of the representation of the problem, and in poorly structured problems, frequent goal modification can be expected, as in the case of Van Gogh Museum online shop.

In this chapter, the NDM framework was used to explore and analyse three design cases. The naturalistic outlook was put to the test and emerged as relevant and adequate to describe and explain many features of design activity.

In the final chapter, I will make some theoretical and philosophical considerations to tie the conclusions together and to reflect on the relevance of this thesis. To finish, I will offer some suggestions for future research.

CHAPTER 9

Conclusion

This final chapter closes the work by arguing the need to overcome certain wariness expressed by important authors towards interdisciplinarity. I will take the opportunity of presenting my stance in relation to analytical rationality in design and I will discuss the validity, generalisability and relevance of this research in various domains to at last, formulate some future lines of research. As a closure there will be a general conclusion.

9.1 Stance on overcoming wariness on interdisciplinarity

In § 1.5 a criticism of the classical cognitive approach to the study of design activity was presented. Now, it is time to argue the need to revise certain reserves on the *interdisciplinary* work on the fields of psychology and cognitive science. But first, the critical arguments will be presented and discussed in more detail.

Lawson (2006, pp.136-137) is one of those who show scepticism with regard to the contribution that can be made by other disciplines to design research:

> The cognitive science approach is strongest when dealing with well-ordered problem solving situations rather than the ill-defined 'wicked' problems, which are so characteristic of design.

Cross (2007a, p.99), is more belligerent in his rejection of cognitive science:

> In analysing design cognition, it has been normal until relatively recently to use language and concepts from cognitive science studies of problem solving behaviour. However, it has become clear that designing is not normal 'problem solving'. We therefore need to establish appropriate concepts for the analysis and discussion of design cognition.

Cross (2007a, pp.126-127) also alerts to the danger regarding the potential hazards of hybridisation for design research:

> One of the dangers in this new field of design research is that researchers from other, non-design disciplines, will import methods and approaches that are inappropriate to developing the understanding of design. Researchers from psychology or computer science, for example, have tended to assume that there is 'nothing special' about design as an activity for investigation, that is just another form of 'problem solving' or 'information processing'.

In his reference to 'normal problem solving' and 'just another form of problem solving', Cross seems to refer to the well-structured problems – e.g. cryptoarithmetic problems – traditionally used in experimental psychology. He argues that psychologists have approached design and have tried to study it for their concern with well-structured problems. Cross makes an allusion to what is special in design as a human activity – specifically the way in which designers work and think –, the manner in which they deal with ill-structured problems, which Cross calls designerly ways of knowing. It could be argued from the fragments mentioned above, that Cross and Lawson seem to suggest that psychologists or cognitive scientists only deal with well-structured problems. I have shown elsewhere in this document that there are several currents and researchers within cognitive science and psychology who challenge the relevance and external validity of experiments carried out on well-structured problems, and that they are aligned with the critique posed by Lawson and Cross. The NDM framework shares their critique of traditional cognitive psychology and this view is at the core of the movement.

With respect to design education, Cross (2007a, p.46) is open to other scientific disciplines:

> We need to base design education on tested theories from education, psychology and cognitive science, and from design research, and we need a much stronger experimental base for educational innovation.

However, regarding design research, Cross (2007a, p.124) insists on the preservation of design's own identity in interdisciplinarity:

> The challenge for a broad and catholic approach to design research is to construct a way of conversing about design that is at the same time both interdisciplinary and disciplined.
>
> Many researchers in the design world have been realising that design practice does indeed have its own strong and appropriate intellectual culture, and that we must avoid swamping our design research with different cultures imported either from the sciences or the arts. This does not mean that we completely ignore these other cultures. On the contrary, they have much stronger histories of enquiry, scholarship and research than we have in design. We need to draw upon those histories and traditions where appropriate, whilst building our own intellectual culture, acceptable and defensible in the world on its own terms. We have to be able to demonstrate that standards of rigour in our intellectual culture at least match those of the others.

In this context of preserving identity, the interdisciplinarity referred to by Cross does not seem to be a 'cross-pollination' with other scientific disciplines, but rather interdisciplinarity within design. The distinction between the design research carried out from inside and outside design is stated eloquently by Cross (2007a, p.124) in the following fragment by:

> Developments in artificial intelligence and other computer modelling in design have perhaps served mainly to demonstrate just how high-level and complex is the cognitive ability of designers, and how much more research is needed to understand it. Better progress seems to be made by designer-researchers, and for this reason the recent growth of conferences, workshops and symposia, featuring a new generation of designer-researchers, is proving extremely useful in developing the methodology of design research. As design grows as a discipline with its own research base, so we can hope that there will be a growth in the number of emerging designer-researchers.

Cross seeks to systematically define the field of design research by saying that it can learn from other scientific disciplines and research cultures, but that it must do so on its own terms. It is not clear why must we, as design researchers, close the door on other currents of enquiry rich in researchers and with suitable theoretical models, especially when these researchers share values and approaches. Reading Cross' recommendations with the history of design methodology in mind, it may seem to be assumed that we should close in from what the field has learnt from the errors committed, above all, in the first decade of the design method movement when this search to turn design into a science – to structure it and exteriorise it – managed to define a logical, rational framework for design, but at the expense of divorcing it from practice. Christopher Alexander, another pioneer in the Design Methods movement, reflected about the state of design methodology in a famous interview in 1971, rejecting the design methods movement completely:

> I've disassociated myself from the field.., there is so little in what is called 'design methods' that has anything useful to say about how to design buildings that I never even read the literature anymore... I would say forget it, forget the whole thing (as cited in Cross, 1981, p.3).

Today's cognitive science is very different from what it was in the late 1960's, when Simon published the first edition of *The Sciences of the Artificial* and it consolidated the paradigm of design as problem solving. The design method movement was *regenerated* thanks to the generation game proposed by Rittel in the early 1970's. Almost forty years have passed since then and twenty-five years have passed since Schön's welcomed reaction against Herbert Simon's technical rationality. It is true that at that time, cognitive research was little more than research on well-formed problems that were indeed very far from real design problems. However, many things have changed since then, the normative decision-making models have been questioned and new movements have appeared in the cognitive sciences, offering new ways of understanding human rationality.

9.2 Stance on overcoming analytical rationality

In previous chapters, it was established that problem solving and decision making are intrinsically present in the design process models; it was established as well that the concept of rationality is transversal to design methodology. And to some extent, it was argued that in the design models of the early years of design methodology methods were sought to bring scientific procedures onto the design process in order to make rational decisions. The intention behind it was to overcome the artistic or intuitive methods that characterised the beginning of design in order to embrace a logical and rationalist ideal but the initial methods of design were not adequate (Alexander, 1964; Jones, 1992; Maldonado, 1977; Rittel and Webber, 1973). This rationalist view reached its peak with the publication of *Notes on the Synthesis of Form* by Christopher Alexander in 1964, a very influential source that sets the principles of logical deduction and mathematical optimisation techniques to reach 'form' (Alexander, 1964). The rationalistic focus precipitated an important crisis within the movement in the early 1970's and, as it was mentioned before, it did not take long for the pioneers in design methodology to start doubting the success of these kinds of methods. In 1970, Jones (1970, p.27) wrote that 'there is not much evidence that they have been used with success, even by their inventors'. Since the failure of the rationalistic approach is extensively documented (e.g. Cross, 1981, 1984; Cross, 2007b; Jones, 1984, 1992; Lawson, 2006), I will not elaborate on this issue any further.

The dichotomy between intuition and rationality is well extended and mentioned in many sources (Cross, 2007a; Jones, 1970, 1984, 1992; Lawson, 2006). It can be argued that in this case 'rationality' is being equated with 'logical analysis'. This conception of rationality as a synonym of analysis was widespread in the cognitive sciences at the late 1950's and early 1960's, but towards the end of the 1960's, new conceptions of non-analytical – instrumental – rationality emerged.

I challenge the very grounds for the existence of this dichotomy and the use of the term rationality in this fashion. Intuition is an expression of human rationality; thus rationality cannot be opposed to intuition.

The limited capacity of human analysis, the slow speed of conscious thought and the enormous number of design alternatives that can be generated in a design process is well recognised and explained by Jones (1992), in his view of the designer as a self-organising system. This view proposes methods of control and meta-control of the process that enable designers to overcome the impossible task of evaluating every existing alternative analytically, as it was suggested by the view of the designer as computer, but without having to go back to traditional design methods. The view of the designer as a self-organising system is a way out of the analytical, and it still is, forty years after its formulation, an interesting path to get around the complexity of design problems. It is even modern from a cognitive point of view, as it implies a dynamic space for solving problems. Complex problems cannot be dealt with using the analysis → synthesis → evaluation model considered in the glass box methods; they can be solved or re-solved only in an iterative process where the synthesis of activity generates new requirements to be analysed that, by definition, cannot be considered in the analysis that precedes the very synthesis that generated them. Also in Dorst (1997) the dilemma between rational paradigm and reflective paradigm is discerned. The use of the term rational requires again a terminological remark: the rational methods are rather the analytical methods characteristic of the Simonian technical rationality criticised by Schön (1983); in other words, the application of general principles and standard scientific knowledge to specific problems.

In § 4.1.3 the Dreyfus model that describes a qualitative leap from novice to expert was introduced. According to the Dreyfus model, analytical rationality and analysis are indeed important, but it does not follow that calculative, analytical rationality should be the ultimate goal. Flyvberg (2001) reflects on the significance of this leap:

> [It] implies an abandonment of rule-based thinking as the most important basis for action, and its replacement by context and intuition. Logically based action is replaced by experientially based action.

Dreyfus defends a kind of deliberative rationality, which does not seek to analyse the situation into context-free elements but to test and improve whole intuitions. Intuition, I restate, does not mean guesswork, divine inspiration or irrational hunches. Intuition, as it was considered in § 4.4, is a feature of the mind that enables experts to act without consciously thinking things out, and it includes tacit and explicit knowledge and the capacity of assessing situations rapidly through pattern recognition and matching.

I assert that analytical decision making can indeed be the goal of any particular method or technique, but should not be the sole target of any design process, as the analytical mode of thinking is only a part of the total spectrum of human decision making. I do not claim that rational analysis is not an important aspect of design decision making. It *is*. I simply assert that it should not be raised into the best way of making decisions and solving problems. Allowing rational analysis to be the ultimate design goal, and allowing it to dominate our view of design decision making is adopting a model of decision making that has been proved to be inadequate to explain the total spectrum of human decision making and expertise. The paradigm of design as a reflective practice needs a methodology that puts rational analysis and intuition in their proper context, not favouring analysis over intuition, nor considering intuition less valuable than rational analysis, but allowing a useful coexistence of analysis and intuition.

I do not claim either that we should go back to *traditional*, artistic methods. By embracing a properly understood notion of intuition in the paradigm of the reflective practice we are not adopting the view of the designer as a magician whose reasons remain unknown even for the designer herself. While designing, professionals manage large quantities of – often contradicting – information, and they deal with unclear or shifting goals, trying to solve ill-defined problems. The expert assesses and discriminates situations and associates with these a course of action that is implemented through both intuitive and analytical decision-making processes. A novice as much as a competent performer can definitely make decisions analytically, but only an expert can make effective intuitive decisions. Experts explore these aspects in parallel and they detect, name and frame relationships and solution directions that not always can be explained solely by analytical rationality.

In this thesis, intuition was associated with expertise and expert decision making; intuition is more than merely recalling and knowing what to do, it also includes the building of a repertoire of action scripts, frames and schemata that will support intuition. Without these, intuition is hollow and it is nothing else than a hunch or a guess.

To summarise, design methodology needs to accept and acknowledge that in order to make good design decisions intuition is as necessary as systematic analysis. The more ill-defined and dynamic the decision is, the less useful traditional analytical methods are.

9.3 Generalisability and validity of findings

I consider this research and the problem identified to be of sufficient scope and originality to be worthy of investigation. I reckon that the final result of this research is of enough theoretical interest to constitute a genuine contribution to the scientific enquiry on design decision making. Following the advice posed by Cross (2007a) I tried to be methodical, disciplined and inquisitive seeking to acquire new knowledge while being aware of previous, related research.

To develop its arguments, this thesis has relied upon a great deal of research performed by others. In terms of generalisability and validity, this works has a transitive relation with the theories and models from the NDM framework and the field of design research. These domains use a wide range of methods for data gathering and analysis. In § 4.1.4 a set of gathering and analysis naturalistic techniques was discussed and pointers to methods were included. The design field uses several research strategies and qualitative and quantitative techniques to pinpoint the cognitive mechanisms behind design cognition; some of these are: interviews, observations, experimental situations, protocol analysis, content analysis and simulation. See appendix 1 for a short overview of the above-mentioned methods.

In this way, I did not test hypotheses or compare experimental groups with control groups for this work, nor was I controlling variables as in classical formal science. In other words, my research approach was very different to that of experimental cognitive psychology or the natural sciences. I have relied heavily on theories and empiric models from the NDM framework and the design research community. In these areas of studies, researchers share the same values that we find in controlled experimentation: *objectiveness*, *repeatability*, *falsability*, *generalisability*, *observability*, *scepticism* and the search for *causal explanations*. See Crandall et al. (2006) or Klein (1998) for reflections around validity coming from the NDM field or see Lawson (2006) and Cross (2007a, 2007b) for a reflection from the design research field.

Since I have not conducted controlled experiments, the results of this enquiry are not generalisable in an empirical-statistical way, as I have not relied on the logic of representative sampling. The wider relevance of my enquiry relies on theoretical or analytical generalisations. In analytical generalisations, the criterion used to select cases – from which one will generalise – is not their representativeness but the extent to which they contribute to supporting and refuting the argument or explanation being developed by the enquirer (Schwandt, 2007). Triangulation of findings through the use of multiple theoretical sources was carried out as a means of assuring and checking the integrity of the arguments made. Triangulation is a way to ensure validity, and validity in this context means that the findings are true, in the sense that they are backed up by evidence and that they accurately represent the phenomena to which they refer, and that there are no good grounds for doubting the findings, or the evidence for the findings in question, is stronger than the evidence for alternative findings (Schwandt, 2007).

The claims of this work are based from, on one side, the many theoretical similitudes between the NDM field and the field of design research that were explored in chapter 7; and, on the other, on the use of the NDM framework to explain the processes presented in the practice-based cases from chapter 8. Harry Eckstein (as mentioned in Flyvberg, 2001) argues that the study of cases is valuable at all stages of the theory-building process, but that it is more valuable at testing hypotheses than at producing them. The value of these cases is related to the claim that I placed on its study, namely to show that the NDM framework and its main hypotheses can indeed serve to explain expert design decision making. No other generalisations regarding design decision making can be drawn from these cases.

9.4 Relevance

In this section, I will consider the relevance of this thesis for three areas of design: methodology, practice and education.

9.4.1 Relevance for design methodology

The paradigm of design as rational problem solving is grounded on rationalist or analytical decision-making models (Dorst, 1997). In spite of being inadequate, the paradigm of design as rational problem solving has its theoretical framework: the normative-prescriptive models seen in § 3.3.2. The insufficiency or unsuitability of these rationalist models to explain the whole of design activity has been discussed by many authors (Cross, 2007a; Dorst, 1997; Lawson, 2004b; Simon, 1996). On the contrary, the paradigm of design as reflective practice does not yet have an overarching theoretical framework that enables methodologists to describe, understand and explain design decision making from a broad theoretical perspective. A suitable broad theoretical decision-making framework has thus yet to be found and applied to examine decision-making activity.

I have presented promising signs that NDM framework might provide such models that may enrich design research. The NDM framework is broad, in the sense that it addresses common patterns in expert human decision making without being too general for use in a practical teleological endeavour like design methodology. Dorst (1997) called for a greater connection between the paradigms of design as rational problem solving and the paradigm of design as reflective practice in order to achieve a more precise description and a deeper understanding of design activity. This work is an attempt in that direction.

The NDM framework can offer tools to model the elusive *subjective* mode of design, which is determined by, among other things, a personal framing, the context and the designer's expertise. Design decision making cannot be properly studied and understood without including the designer's personal – and even idiosyncratic – constructed world-view and the situations in which design decision making occurs.

The linking between the field of design research and the NDM framework that was presented in chapters 8 and 9, and the graphical model depicted in Figure 12 is meant to offer a model with promising descriptive qualities. It also aims to feed the discussion within design methodology on the use of naturalistic or ecological theories to explain design cognition, a discussion that has indeed gained momentum in recent years.

9.4.2 Relevance for design practice

In spite of the focus on concrete cases, this work does not exclude analytical generalisations. However, it may be argued that it will be very difficult to make generalisations that go beyond those already made by NDM researchers and those made by researchers from the design field, regarding expert decision making and the designerly ways of knowing respectively. Nonetheless, there are some very significant analytical generalisations that can be made on theoretical grounds.

First, if the wicked problems view of design is adopted, any design method that, as a whole, favours analysis and rule-based deliberations over intuition and experience-based behaviour is likely to fail.

Second, the view of clearly separated problem-definition and problem-solution stages must be abandoned and shall no longer serve as a norm. A designer that stipulates that she will not proceed to the solution stage before defining the definitive design problem is sure to remain at the problem definition stage until she runs out of time. Sometimes, solutions can be reached through rational analysis, but often solutions are reached intuitively. Formulating an initial solution, even when there are no logical grounds to justify it, is a way of framing the problem. The designer has lots of tools at her disposal to speculate in order to reach a pairing of problem and solution that makes sense (i.e. sketching, modelling, prototyping, etcetera).

Third, acknowledging that expert users usually stick to a singular-evaluation approach and that there exists a tendency to remain fixated on previous or initial solutions can help the designer to better reflect on her own work, through analysis, mental simulation and sense making.

Fourth, and as I have argued before, expert design praxis, and expert praxis in general, is contingent on context-dependant judgement. Designers make sense of data through a constructive task of fitting these data into frames, but the reverse also happens: the frame determines what counts as data.

I summarise these generalisations in a generic recommendation for dealing with fuzzy design problems:

> If you intuitively recognise parallels between the current problem and previous design cases in which you were (i.e. your own work) or were not directly involved (i.e. someone else's work), do explore these parallels.
>
> If it seems, after or even before an initial consideration, that these parallels will yield – automatically or not – hypothesis and conjectures for a (sub-)solution, then explore these through mental simulation and analysis in order to learn more about the solution before committing to it.
>
> Exploring the conjectures for a (sub-)solution and committing to the generation of (sub-)solutions will yield new knowledge about the problem at hand allowing the problem-solution pair to co-evolve in parallel.

9.4.3 Relevance for design education

Design education is not a central topic of this thesis and has not been addressed specifically earlier in this work[15]. Having acknowledged this, I am convinced that there are several aspects that arise from this thesis that might be beneficial to the design educator. Especially if these educators aim to teach a kind of design that in essence resembles design as it is practiced outside academia. I carefully choose the verb 'to resemble' as the academic environment is not likely to offer a realistic imitation of many facets of a real projects (e.g. complex timescales, budgets, product-life cycle constraints, market needs, etcetera).

The Dreyfus model introduced in § 4.1.3 signals that the learning of rules and the acquisition of context-independent knowledge is a precondition for the qualitative leap to the stages of the intuitive expertise. A similar argument is posed by the naturalistic researchers, who favour a view of tacit expert skill to explain decision making. The design educator should keep in mind that training students in context-independent rules is only the first step of the learning process. After the basic rules have been internalised, the design educator should help the student gain expertise in situations that mimic real practice. This is already occurring across the world as many design schools adopted the studio class as one of the main teaching environments. By being aware of the basic macrocognitive processes that intervene in decision making (i.e. RPD, sensemaking and mental simulation), the design educator could address the journey of gaining expertise in a more systematic and explicit fashion.

As an educator, I have often been confronted with the inability of students to explain and motivate their decisions during a design studio class. This inability may indeed be a sign of messy or random work ethos, but it may also mean that the student is precisely gaining expertise and moving to an intuitive realm in which the knowledge she has at her disposal is still tacit. An important part of the design practice is communicating with clients and presenting and explaining work (Shaughnessy, 2005), but this might be easier said than done. Hubert Dreyfus asserts that 'nobody really can justify what their intuition is. So you have to make up reasons, but it won't be the real reasons' (cited in Flyvberg, 2001, p.80). This *post hoc* rationalisation for the process is also mentioned by Lawson (2006, pp.288-289). But whether the designer is telling the real reasons or just making up reasons that are generally valid and collectively acceptable in order to

[15] The subject of knowledge and expertise acquisition by students has been approached before by many authors: e.g. EASTMAN, C. M., MCCRACKEN, W. M. & NEWSTETTER, W. C. (eds.) (2001) *Design Knowing and Learning: Cognition in Design Education*, Amsterdam: Elsevier Science and LAWSON, B. & DORST, K. (2009) *Design expertise*, Oxford: Architectural Press).

show a logical progression, knowing how to make tacit knowledge explicit is a very important part of design as reflective practice. Hence it should be a part of design education and fortunately is already so in many design institutions: the design critique and the reflection on one's own work is also a central part of the studio class. However, one may argue that a student that is producing good work but is not able to produce a good explanation might be simply advancing slower in the domain of persuasive argumentation. Then, it might be argued that in order to gain expertise in the domain of explaining and presenting argumentations, general rules and context-independent knowledge on this domain are also needed and must be addressed in the curriculum.

9.5 Future research

From this study, maybe more questions than answers have emerged. Based on the findings, I would like to suggest a number of future research directions.

The first and most obvious direction for future work may be directed at validating or rejecting the naturalistic model of design decision making proposed in § 7.6. This may be a step into integrating a broad theoretical model of decision making into design research other than rational choice theory. As for now, the model is preliminary, it needs further research and I reckon that it may be developed much further considering that an improved naturalistic model of design decision making may become a very valuable tool for design research.

I have argued in this thesis for an embracement and acceptance of experience-based intuition as a valid form of reasoning for design. An interesting line of research may be an axiological exploration into this matter. The consequences of accepting a qualitative leap from rule-based behaviour to experience-based behaviour may be very profound since it affects the very core of Western – rationalist – thought. Are designers prepared to admit that rational analysis is not a final goal in itself? An initial exploration in this area may be directed at understanding what designers' stance and values are in relation to rational analysis and intuition. Martin (2009) proposes the notions of *reliability* and *validity*, whose goal is to produce consistent, predictable outcomes as well as to produce outcomes that meet a desire objective, respectively. This line of research into designers' stance regarding rational analysis may be further explored to include these notions to examine whether a correlation between rationalist attitudes and a bias towards reliability exists or not.

Another area of research may be the further study of design methods and techniques in order to map them according to their usefulness for different naturalistic decision-making strands. Kolko (2011a) already goes in this direction, but the number of examined techniques is rather limited. Another initial – and also limited – attempt to this, was undertaken in chapter 8 of this thesis. Mapping these techniques may help understand the complex landscape of design techniques and eventually point out the lack of techniques to support specific decision-making processes. This teleological endeavour may benefit many areas of design: design practice, education and methodology.
Other important area of research is design decision making in groups. Design is often a social activity when carried out professionally, involving designers, clients and other stakeholders. Further research is needed to better understand how teams deal with problem solving and decision making. Several notable efforts on this area have been undertaken in this direction from the field of ethnography (Bucciarelli, 1994; Vinck, 2003) and most recently by Stompff (2012) from a pragmatic, *Deweyan* perspective. A naturalistic approach to the research of macrocognitive functions and processes in design teams can yield valuable results as the NDM framework has proven successful at describing many professional domains where expert decision making occurs (for several papers about expert decision making in teams see Mosier and Fischer, 2011)

I will end this section with a series of recommendations for future research in the area of education. Extensive work is being conducted on the cognitive and learning styles of students and their progression (e.g. Demirbas and Demirkan, 2003; Demirkan and Osman Demirbaş, 2008; Kvan and Jia, 2005; Roberts, 2006). This research may benefit from the use of the NDM framework, its internal models and its associated research techniques, specially Cognitive Task Analysis. Two themes worth exploring through naturalistic methods are sensemaking and students' mental simulation processes. A better understanding of these processes may be translated into improving tutoring and evaluation techniques.

During design school, students invest a great amount of time analysing precedents and referents and learning from them (Lawson, 2006). The RPD model – as it predicts the use of previous examples to anchor a new solution – may be used as a theoretical guide for researching the extent to which these previous cases influence or determine a new design solution. This research may complement and revisit research done in the area of fixation and analogy (Casakin, Goldschmidt and Planning, 1999; Hassard, 2011; Jaarsveld and Van Leeuwen, 2005; Jansson and Smith, 1991; Youmans, 2011).

A different subject related to design education worth exploring is how gaining expertise affects every student's own learning styles and design strategies. This type of research may start when a student is a *fresher* and continues until she is a fourth-year student or even be carried on after design school, when the student starts working as a professional designer.

These future directions are all worth investigation and capable of leveraging valuable results for both design research and practice.

9.6 General conclusion

This work is an attempt to leave behind the idea of human rationality as an unlimited capacity or as a purely analytical function when considering design decision making. In this thesis, I have reviewed non-analytical ways of decision making and problem solving and I have compiled a series of parallels between postulates of the NDM framework and many aspects of descriptive models of design. I have shown that naturalistic models can offer a theoretical framework that enrich and complement existing descriptive design models. Since NDM is a descriptive framework, it is therefore plausible to foresee that the incorporation of NDM theories in interpreting research on design decision making might enrich the analysis by providing it with a fruitful theoretical framework. In its focus on the situation in which decisions are made, NDM may give us conceptual tools to try to begin to model the design process in accordance to the paradigm of design as a reflective practice, something which has been very difficult up to now (Dorst, 1997).

The postulates of NDM are consistent with the constructionist view expressed by Donald Schön (1987, p.78) in his criticism of technical rationality and the analytical dichotomies that do not occur in practice:

> Means and ends are framed interdependently in the problem setting. And [the subject's] inquiry is a transaction with the situation in which knowing and doing are inseparable.

We need to move forward in defining descriptive models from the basis of research into real design practice, which involves research on both the analytical, rule-based, context-independent processes and the intuitive, situated design processes.

To finish, allow me to introduce a quote[16] from an essay by Martin Heidegger (2003) in which he refers to *Holzwege* (woodpaths). In German, to be on a *Holzweg* is to be lost. This quote perfectly summarises the nature of expertise and reflective practice:

> *Holz* [wood] is an old name for forest. In the forest there are *wege* [paths} which often being overrun with bushes, suddenly break off in an impenetrable thicket. They are called *Holzwege*.
> Each of these goes off on its way, but in the same forest. Often it seems as though they are identical to one another. Yet it only seems so.
> Woodcutters and foresters know them well. They know what it means to find oneself on a path that goes astray.

For Heidegger, striking out on *woodpaths*, even if it means getting lost in a dead end and finding oneself in an unexpected place, is the only way to know the woods.

In design, expert knowledge is subjective, biased – since framed in a personal way –, context-based and dependable. Going from ruled-based to systemic and context-dependent knowledge might be noisy and failure-prone. This metaphoric 'finding oneself in a *Holzweg*' does not necessarily entail reckoning one is lost at all. Being on a *Holzweg* is about developing practical rationality, the best tool we have, as designers, to deal with the complex task of making design decisions.

[16] I have translated the quote from the German edition.

APPENDIX I

Short overview of methods in design research

Authors such as Cross (2007a, 2007b) or Craig (2001) argue that design is a distinct type of behaviour and that it must be studied within its own theoretical frameworks. In a survey of literature of methods for studying the nature of design cognition and behaviour (Craig, 2001; Cross, 2007a, 2007b; Lawson, 2004b) the following research strategies and techniques are included as a means to pinpoint the cognitive mechanisms behind design cognition:

- *Interview*: often, but not always, these are open or 'semistructured' interviews with designers, who are often recognised in their area. The interviews seek to let the subjects to reflect on the general or specific processes and procedures of a certain project. Lawson (2004b) mentions that designers are used to persuading and convincing their customers, and therefore – often involuntarily – they offer twisted descriptions of the activity, where the decisions seem much more logical and well-based than they actually have been.
- *Observation*: these are studies focused on studying a particular design project. Using this method, one or more observers record the project's progress and development, and later they produce hypotheses and assess the data obtained according to a framework of interpretation. The observation may be participative – the observer interacts actively –; or non-participative – the observer tries to minimise their interaction and simply observes. Lawson (2004b) argues that the naturalistic observations offer greater realism than experimental situations, but the data of the cognitive processes are difficult to obtain because what is truly interesting is hidden within the designers' minds. Methods such as ethnography and action research fall into this category.
- *Study of experimental situations*: there are different kinds of experimental situations. One method is to produce an artificial project and observe the designer in this controlled situation. The main problem is the situations' lack of realism, both regarding the briefing in itself and its relationship to the context where the project occurs and the designers' behaviour.
- *Protocol analysis*: this is a formal experimental method used in design and very often in cognitive psychology (see Ericsson & Simon, 1993). In the think-aloud protocol, the participants perform a series of tasks and the research lies on recording the actions and verbal statements associated with these tasks, which are then analysed. In order to code and analyse –

quantitatively or qualitatively – the results of the reports, a theoretical framework is needed for telling us what to pay attention to and what to encode as part of a representation (Craig, 2001). The protocol studies have been criticised for not having a control condition and for interfering in the very process that is studied (Christensen, 2005). Chai and Xiao (2012) conclude from a bibliometric study that protocol analysis is starting to emerge as a popular research method.

- *Content analysis*: this is a method that seeks to explain mental representations and internal conceptual structures. Like think-aloud protocols, content analysis may involve asking subjects to say what they are thinking while solving a problem. However, since the aim of content analysis is to uncover internal representations, some probing on the part of the experimenter is usually admitted (Craig, 2001). One goal of verbal analysis is to understand how representations change through reflection; hence instigating change may lead to valuable insights (Craig, 2001). Like protocol analysis, content analysis requires a theoretical framework for the coding of reports.
- *Simulation*: researchers seek to simulate the design process using programs of artificial intelligence.

Cross (2007a, p.126) formulates – borrowing from Bruce Archer – a series of aspects, normal features of good research in any discipline that characterise good design research. Design research must be:

- *Purposive*: based on identification of an issue or problem worthy and capable of investigation
- *Inquisitive*: seeking to acquire new knowledge
- *Informed*: conducted from an awareness of previous, related research
- *Methodical*: planned and carried out in a disciplined manner
- *Communicable*: generating and reporting results which are testable and accessible by others

Many authors have treated design research from an historical perspective (e.g. Bayazit, 2004; Cross, 2007b). There are many comprehensive surveys of work on design cognition and the methods used to investigate problem solving, creativity, analogy, mental modelling, simulation, conceptual combination, conceptual blending, 2d and 3d mental representation (Craig, 2001; Eastman, 2001; Wright, 1997). See Chai and Xiao (2012) for a bibliometric analysis of the core themes of design research cited in the journal *Design Studies*. See Dorst (2008) for a still timely reflection on the future of design research.

GLOSSARY

Abductive reasoning: a type of reasoning different from both induction and deduction, it is the process of facing an unexpected fact, applying a rule – already known or created *ad hoc* – and, as a result, proposing or hypothesising a case that may be.

Action script: a routine for responding when facing a typical or familiar situation.

Cognitive bias: a deviation from the norm or a mental error in judgement caused by heuristic reasoning (see definition below).

Cues: a feature of something perceived that is used by the decision maker as an initial data element provided by the situation. Cues allow decision makers to recognise patterns.

Data/frame theory of sensemaking: a naturalistic theory that explains sensemaking (see definition below) based on two main entities: data and frames.

Decision making: in a classical sense, the process of choosing a preferred option or course of action among a set of alternatives.

Design process: all action taking place during a design project, regardless of specific methods and techniques.

Descriptive models of decision making: empirically derived models that account for how people decide in real-world settings.

Designerly: a term proposed by Nigel Cross regarding 'the deep, underlying patterns of how designers think and act'.

Expectancy: a sense of what is going to happen in a situation. When a decision maker reads a situation correctly, the expectancies should match the events.

Expertise: the skilled execution of highly practiced sequences of procedures.

Flow chart: an interaction design technique for visualising flows of interactive tasks.

Framing: a key process of reflective practice in design indicated by Schön (1983) in which the designer determines what aspects of the problems will be explored and how. Not to be confused with the framing-effect, a well-known cognitive bias, in which question wording significantly affects how people respond.

Frame: a data-structure for representing the characteristic of a stereotyped situation.

Gantt chart: a graphic display of schedule-related information used as a tool for carrying out processes regarding planning.

Heuristic reasoning: the use of general rules of thumb in order to reduce the time and effort required to make a judgement or a decision.

Intuition: a performance that is speedy and of which the expert is unable to initially describe in detail the reasoning that produced the answer. Intuition works thanks to the application of heuristics and pattern-recognition.

Macrocognition: it comprises the mental activities that must be successfully accomplished to perform a task or achieve a goal (e.g. decision making, planning, sensemaking, etcetera). Macrocognition contrasts with the traditional study of the basic cognitive processes (e.g. memory, perception).

Mental model: mental representations that correspond in structure to the situations that they represent.

Mental simulation: the generation of hypotheses about possible future scenarios in order to explore alternatives or how a situation can evolve.

Naturalistic decision making: how experienced people make decisions in dynamic, uncertain, and often fast-paced environments.

Normative models of decision making: models that serve as the norm for decision making and establish what is to decide properly.

Prescriptive models of decision making: models that define and estipulate how people should decide in order to decide properly.

Primary generators: early ideas or organising principles that define the boundaries of the problem and suggest the nature of its possible solution.

Problem: a representation of a question to be solved.

Problem solving: transforming a given situation into a desired situation or goal.

Recognition-primed decision making: a naturalistic model that describes how people use their experience in order to make good decisions without comparing alternatives. It integrates two key processes: sensemaking and mental simulation.

Satisficing: an adaptive behaviour that seeks to choose the first option that is minimally acceptable and adequate and which satisfies a goal or criterion.

Sensemaking: the deliberate effort to understand events; it is commonly initiated by the detection of anomalies or surprising changes in the maybe expected course of events.

Singular evaluation approach: In a singular evaluation approach a decision maker generates a course of action and commits to it instead of generating multiple courses of action and exploring them in parallel.

Site map: a visual representation of the structure of information on a web site.

Wicked problem: an elusive type of problem that is difficult or impossible to solve because of its intractableness.

Wireframe: a rough illustration that shows the contents of an interactive screen.

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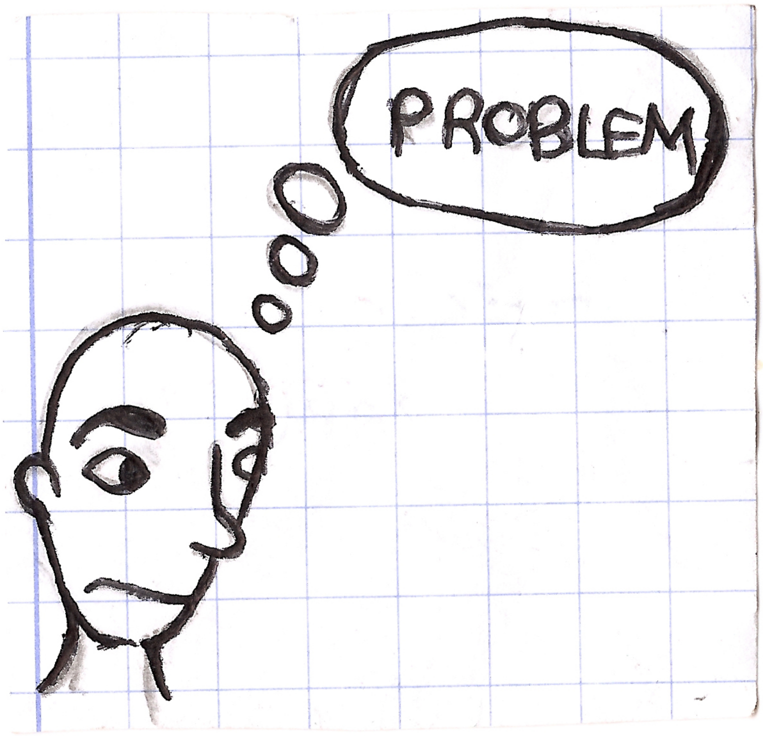

Designer thinking about a problem.
Drawn by my daughter Eloisa while I was working on this thesis.