Method Usage in Design

How methods function as mental tools for designers

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Voor mijn liefste dames, Francien & Fenna

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Introduction

Capuchin monkeys take years to learn how to carefully select and use tools to crack the boisterous palm nut and benefit from the rich, oily substance inside it. Scientists studying the Capuchins' nut cracking behavior have uncovered an underlying, systematic process. The process for cracking palm nuts consists of a number of stages that require preparation (e.g. the nuts need to be laid to dry for more than a week), careful timing, testing and evaluating the readiness of nuts, tool selection and highly developed dexterity.[1] *The skill of nut cracking is transferred between individual monkeys. In fact, capuchin monkeys and many other primates have been shown to exhibit social learning - learning from others - as well as learning through culture (Brosnan & de Waal, 2004), i.e. learning through traditions that exist in groups. You might think: why is this relevant for the introduction to a thesis in design methodology? Surely, capuchin monkeys do not use methods? As far as we know, they do not. At least not in terms of using externalized and abstracted descriptions of their nut cracking process. Rather, they learn directly from what other monkeys are doing. And surely, design processes are far more complex than the process of nut cracking displayed by capuchin monkeys? Indeed they are. Yet the story is relevant for at least two reasons. First, the story points to the fundamental purpose of methods: they mediate advanced social learning. Methods are 'intermediates' that allow us to learn from others across space and time. That is, what one person has learned at some place in the world at some point in time can be shared with another person at another place and at another time through the use of a method. Methods are crucial means that we use to transfer procedural knowledge between individuals. A good method allows an individual to learn or perform a certain activity and reach goals more efficiently and effectively than without it. The story also*

1 For a beautiful coverage of the process of cracking palm nuts as well as the learning process that is associated with it, see the episode on 'Primates' from BBC's documentary series 'Life'.

points to the fact that social learning does not necessarily need methods as it can happen for example through a direct master-apprentice-like learning process, which is the case for the capuchin monkey and which has been predominant in design (see e.g. Alexander, 1964; Jones, 1972) and in many cases still is. Social learning, either with or without methods, is bound to a specific context, involving certain individuals and social settings, resources and infrastructure. Both points are central to this thesis and will be theoretically and empirically investigated in the following chapters.

Young Capuchin monkeys observe an adult cracking a nut (photo courtesy of Barth Wright)

§ 1.1 *Methods in design*

Many different types of methods exist, and one way to distinguish them is by the purpose they help to serve. For example, research methods are supposed to help scientists construct theories of the world, supported by empirical evidence and with an emphasis on the reliability and validity of their results. Artistic methods are supposed to help artists create beauty, with a strong emphasis on the expressive and aesthetic qualities of their outcomes. What purpose do design methods serve? According to Simon, designing is a human activity aimed at changing existing situations into preferred ones (Simon, 1996). This is a broadly accepted definition of design that is applicable to the design of artifacts in general (e.g. products, services, policies, laws, medical treatments, artwork, theories). Specific design disciplines typically focus on the design of a specific class of artifacts (e.g. graphic design, product design, service design). In the light of Simon's definition, methods are means to help designers achieve desired change as efficiently and effectively as possible. Methods can be used to do so in the context of learning - to help teach students how to design on a professional level. Methods can also be used in the context of performance - to help professional designers be better at what they already do (well). Methods do so by influencing a designer's thinking patterns and mental model and should be seen as mental tools, as I will argue in chapter 2. If we accept that me-thods function via a designer's mind, we can see that method usage is a human activity in which the designer is the central actor. This seems to be an obvious fact to be aware of for a discipline that is characterized by its focus on the user of the products and services they design (amongst many other see e.g. Hertzum, 2010; Jordan, 1998; Norman, 2002; Norman, 2005; Rubin, Dana Chisnell, & Spool, 2008).

Yet quite remarkably, many design researchers have paid little attention to the users of their products: the designers who are expected to use their methods. Instead, most design research is aimed at 'directly' improving the design process through methods often ignoring differences between designers, design contexts and design objects (Dorst, 2008). In this way, many method makers bypass the role of the designer as central actor in method usage. When they do so, they seem to assume that designers will – and will want, and be able to – follow their method almost "like a road that can be followed" (Jensen & Andreasen, 2010, p. 3). This seems to have caused a discrepancy between what method-makers expect from their methods and what designers actually do with them. Many scholars have not been satisfied with the use of methods in design, as the overall uptake of methods in industry has been disappointingly low (Albers, Sadowski, & Marxen, 2011; Andreasen, 1991, 2011; Araujo, Benedetto-Neto, Campello, Segre, & Wright, 1996; Birkhofer, Kloberdanz, Sauer, & Berber, 2002; Cross, 1993; Hein, 1994; Jänsch & Birkhofer, 2007; Wallace, 2011) and even the use of methods in design education has been far from satisfactory (Andreasen, 2011; Dorst, 2008). As an exception rather than a rule, some scholars have pointed to the designer-dependent nature of method usage by for example highlighting the necessity of a proper mindset as prerequisite for proper method usage (Andreasen, 2003) and the method-maker's responsibility towards the user of methods (Badke-Schaub, Daalhuizen, & Roozenburg, 2011; Dorst, 2008; Stappers, 2009). In this thesis, I depart from that position and argue that an important reason for the current state of design methodology is our marginal understanding of the phenomenon of method usage. I also argue that to study method usage, we have to start with studying the method user: the designer.

The size of the problem is significant. The engineering and product design research communities have produced an abundance of methods as it builds on a tradition of method development (Blessing & Chakrabarti, 2009). Within that tradition, design researchers typically develop a method as a product of their research. And with an increasing number of researchers in the field, an increasing amount of research funding is being spent on method development. Of course, there is no doubt that some methods are very useful in the hands of designers, design educators and researchers, and this has been acknowledged as well (Andreasen, 2011; Cross, 2006; Dorst, 2008). Yet in general, method uptake and method usage is disappointingly low. How can we explain this situation? As a first step, we shall analyze the design methodology along historical lines. Method development has long been related to the 'rationalization' of the design profession as was for example advocated by Hubka (1982). As many method developers aimed to develop object- and context-independent procedures, they produced methods that were expected to be followed systematically and lead to certain results irrespective of the designer and situation at hand. The role of the designer and the design situation was often implicitly put 'between brackets' (Dorst, 2008, p. 5). As a consequence, design methodology has long been dominated by ideals to systematize design along with aims to develop design into a science (see e.g. Cross, 1993 for an analysis).[1] Many method developers have investigated how the use of scientific knowledge in the design process could facilitate rational decision making in design (Bayazit, 2004). The emphasis was

1 Another reason for the tendency to portray methods as systematic procedures was the need to justify the position of design in university settings. Models and methods that emphasized the rational and the systematic nature of design have been used to support claims about the scientific nature of the design discipline (see e.g. Simon, 1996).

often on methods' systematic nature (Jensen & Andreasen, 2010) rather than the situated nature of their use in which methods are optional and flexible means to help achieve goals. A telling example is Hubka's definition of the term design method:
"Any system of methodical rules and directives that aim to determine the designer's manner of proceeding to perform a particular design activity and regulate the collaboration with available technical means, assuming a 'normal' engineering designer, 'normal' technical knowledge, and certain 'normal' environment conditions" (Hubka, 1983, p. 17).

Hubka's definition emphasized methods as a way to determine the way designers act, with little regard for individual differences, availability of knowledge and differences in the context of design. He aimed to rationalize the engineering design profession and to promote design work on a knowledge-based level (Rasmussen, 1974):
"The main reason for advocating conscious thought modes is to avoid the common error of 'jumping to conclusions', without thoroughly investigating the problem. The author advises against relying on intuitive thought for present-day usage, even though this was the almost exclusive thought mode in the past" (Hubka, 1982, p. 28).

In doing so he largely dismissed the important role of intuition in design. He also largely excluded individual differences between designers and the context of design, a choice that can still be felt in design methodology today (Dorst, 2008). The same development was observed and criticized during the early years of design methodology in product- and architectural design (Alexander, 1971; Jones, 1977). Formalization of methods was reinforced by the efforts in industry which typically focus on the organization's need to formalize best practices (Araujo, 2001). Such efforts are typically undertaken in order to impose best practices to the organization at large (Eris & Leifer, 2003) with little attention being paid to the designer's need for and use of methods.

In sum, the emphasis of many method developers and design methodologists has been on methods' systematic nature (Jensen & Andreasen, 2010) rather than the situated nature of their use. As a consequence, it is often assumed that there is a strong (direct) link between method usage and quality of design outcomes (Jensen & Andreasen, 2010). Yet little empirical evidence exists to support this assumption (Blessing & Chakrabarti, 2009; Finger & Dixon, 1989). Methods in design are typically portrayed as sets of instructions that should be systematically *followed* to reach certain results. But is that a valid portrayal? In spite of having received more than fifty years of considerable academic attention, and in spite of the substantial progress that has been made, we might ask whether design methodology has reached the status of an established field with a strong and acknowledged contribution to industry. It seems that design methodology has not reached that point yet, and that there is still little agreement on how to improve the situation.

§ 1.2 State of design methodology

A key question for design methodology[2] is: why are methods needed in design? Several answers to this question have been articulated. For example, it has been

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2 Design methodology refers to both the study of methods as a specific scientific discipline – a discipline that also has a tradition of developing methods (Blessing & Chakrabarti, 2009) - and to a coherent set of methods (Roozenburg & Eekels, 1995). In the context of this thesis design methodology refers to design methodology as a field of study unless otherwise indicated.

argued that methods support designers in dealing with the increasing complexity of design challenges (see e.g. Alexander, 1964; Jones, 1972 for early work on this topic). Methods were expected to avoid that designers jump to conclusions (Hubka, 1982), to increase their perceptual span (Jones, 1972) and to avoid arbitrary (intuitive) problem decomposition (see e.g. Alexander, 1964). In general, methods were aimed to aid to the professionalization of the design discipline (Archer, 1979).

As we pointed out before, the uptake of methods in industry has disappointed many scholars in design. To make matters worse, the utilization of methods in design education is not always perceived to be successful either (Dorst, 2008; Andreasen, 2011). Over the years, many problems, causes and culprits have been pointed out in the design methodology literature (amongst many others see e.g Alexander, 1971; Andreasen, 1991; Andreasen, 2011; Araujo, 2001; Dorst, 1997; Eder, 1998; Frost, 1999; Jensen & Andreasen, 2010; Stetter & Lindemann, 2005). Potential explanations for this situation have been put forward. On an organizational level, explanations for the lack of fit between methods and their context of application have been found in a survey of the UK industry by Araujo et al. (1996). Their results showed for example that poor acceptance of methods in industry is sometimes due to poor results associated with newly introduced methods. They found that methods in general are often met with skepticism after designers have had bad experiences with a method that was applied in a poor way, with poor timing, with an improper mindset, with a lack of support from top-management, with a lack of support from bottom-up, with a lack of skills/qualifications and/or with unrealistic expectations about the method's benefits.

On the level of the individual designer, explanations for the lack of fit between methods and method user point to their complexity and difficulty in use (Araujo, 2001; Birkhofer et al., 2002; Cantamessa, 1999). Moreover, assessing the impact of new tools is problematic (Araujo, 2001). In addition, many methods require data that are difficult and expensive to assess (Frost, 1999). Regarding the representation of methods, the form that many design methods take is typically derived from the technical context of engineering causing them to have a non-appealing form (Araujo et al., 1996). Furthermore, the abstract language that is used to describe the methods is not appropriate for use in practice. Most methods do not fit designers' focus on challenges rather than limitations and do not fit the thinking patterns and vocabulary of practitioners (Frost, 1999). Methods are too complicated (Subrahmanian et al., 1997), too theoretical and therefore are hard to remember (Jorden, 1983). Reluctance in accepting methods is also due to the largely absent evaluation of their quality and effect on performance (Blessing & Chakrabarti, 2009). Limitations of methods are usually not defined (Müller, 1985).

To summarize, methods are typically poorly accepted in practice because they are not described with the user in mind (Jänsch, Sauer, Walter, & Birkhofer, 2003). Most design methods still do not take into account the cognitive abilities and limitations of their users. And in addition, one of the problems of design methodology is that even if design methods mediate knowing about some aspect of designing, they typically do not mediate knowledge and experiences that are needed to apply the method itself in specific contexts.

Based on the many problems that have been identified, we might conclude that design methodology, as a field of study and as a primary producer of methods, finds itself in troubled waters. Yet, paradoxically, design methods seem to be alive and kicking at the

same time. Statements about the importance of methods are pervasive in design, both in practice and education. For example, a look at the website of well-known design firm IDEO reveals an emphasis on methodology:
"Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success" (IDEO, 2013)

Similarly, Philips Design regularly publishes papers on their innovation approach in which they describe "the mindset, methods and tools" as important parts of their approach to design (Parameswaran & Raijmakers, 2010, p. 1).

A look at the visions, missions and beliefs articulated by institutes for design education reveals the same emphasis:
"Our mission is to contribute to the knowledge, skills, methods and professional attitudes in the field of integrated product development" (Delft University of Technology, 2013).

"We welcome our students with a methodology for innovation that combines creative and analytical approaches, and requires collaboration across disciplines. This process – which has been called design thinking – draws on methods from engineering and design, and combines them with ideas from the arts, tools from the social sciences, and insights from the business world." (Stanford University Institute of Design, 2013).

“Design problem solving methods are taught to develop the ability to understand the structure of design problems and solve them creatively” (Kaist, 2013).

In addition, quite a number of publications have emerged over the years that provide collections of methods. Seminal works in this area are the books by Jones (1972), Andreasen and Hein (1987), Pahl and Beitz (2007), Ulrich and Eppinger (1999), Cross (2008) and Roozenburg and Eekels (1995). In recent years, still quite a lot of method collections have been published, albeit typically in a way that is more focused on accessibility and usability of the methods. For example, IDEO (2009) published a freely downloadable document called ‘Human-Centered Design toolkit’ that contains a set of methods. Delft University of Technology published the ‘Delft Design Guide’, a collection of methods that are used in their design programs (van Boeijen, Daalhuizen, Zijlstra, & van der Schoor, 2013). Hanington and Martin (2012) published a collection of 100 methods for design. The Design and Emotion Society maintains a collection of tools and methods on their website (2013). Sanders and Stappers (2013) published a book on generative tools for design. Methods also aid in giving meaning and content to the abstract concept of ‘design thinking’. In recent years, that concept has been adopted outside of the field of design (See e.g. Brown, 2009; Martin, 2009; Verganti, 2009) increasing the potential impact of the design profession, but also increasing the importance of building a strong body of knowledge and methods in design that is linked to the concept of design thinking in an unambiguous manner.

The image of method in design as it emerges from this introduction so far seems to be paradoxical. On the one hand, the uptake and use of methods in product- and engineering design disappoints most scholars in design, and certainly does not match the efforts and investments made to develop them. On the other hand, methods are still claimed to be crucial to professional design practice and education and many methods have been published in recent years. How to explain this paradoxical situation? And, more importantly, how to resolve it?

§ 1.3 Aim & structure of the thesis

In this thesis, I argue that methods can be powerful means to assist designers in dealing with many of the challenges they face but that the simplistic view of methods 'as instructions that can be followed to reach certain results' is standing in our way to exploit method's full potential in design. Unfortunately, the 'methods as instructions' view seems to be pervasive in the design (research) community. I argue that an important reason for the current state of design methodology is our marginal understanding of the phenomenon of method usage. I also argue that to study method usage, we have to start with studying the method user: the designer. I propose that method usage deserves to be a topic of study in its own right to be studied theoretically and empirically. The following questions guided the research:

- What does it mean to use a method?
- When does a designer's need for methods arise?
- How do methods function when they are used?
- What specific roles can methods play for designers when they are used?
- What kinds of situations give rise to a need for methods?
- How does expertise relate to method usage in design?
- What are prerequisites for proper method usage?
- How do individual differences influence method usage?

The next chapter 'Method Usage in Design' elaborates on the theoretical underpinnings of method usage with the purpose of providing a detailed analysis of method usage in design. It starts out with describing method usage as a situated activity and articulates methods as resources for designers to deal with non-routine situations. It goes on to describe methods as mental tools, by explaining how methods function by facilitating certain perceptions of situations and certain ways of reasoning about possible actions, offering a reconceptualization of methods in design. The third chapter, 'Dealing with Uncertainty in Design Practice' describes an interview study with design practitioners investigating their perception of non-routine situations in design. The chapter goes on to describe the ways in which practitioners respond to these situations and how they characterize them in terms of influencing factors. The fourth chapter, 'Method Usage and Expertise' describes a quasi-experiment investigating method usage of advanced beginner and expert designers and the effect on their performance for a design project planning task. It goes on to describe the difference in method usage between designers of different level of expertise and its relation to performance. The fifth chapter, 'Individual Differences in Method Usage' describes a large-scale experiment with students investigating how different types of methods and individual differences influence method usage for a concept design task. The last chapter discusses the results of the theoretical and empirical inquiries into method usage in design.

•2
Method usage in design
a theoretical inquiry

In this chapter, I set out to elaborate on the theoretical underpinnings of method usage with the purpose of providing a detailed analysis of method usage in design. The analysis will serve to provide a conceptual basis for the three empirical studies that are presented in the three subsequent chapters and for thinking about method usage in general. The argument takes time to develop with the analysis being structured as follows. The first section, Method Usage as a Situated Activity, brings methods into context with their users, the users' goals and the situations in which they are used. It distinguishes routine and non-routine situations in design, indicating how a designer's need for a method can arise from the subjective feeling of uncertainty. The second section, Design Methods as Mental Tools, explains how methods function by facilitating certain perceptions of situations and certain ways of reasoning about possible actions, offering a reconceptualization of methods in design. The section goes on to describe method usage in relation to deliberate and intuitive thought, opening up an avenue to link it to expertise, a topic that has received much attention in the design literature in the past one and a half decade. The third section, Method Mindset, discusses the individual prerequisites that are necessary for proper method usage which encompass a designer's method mindset. Conclusions are drawn about situated method usage in design pointing to the different roles that methods can play for designers.

§ 2.1 Method usage as a situated activity

Designing is often described as a situated phenomenon, characterized as "a conversation with the materials of a situation" (Schön, 1983, p. 78) with the aim to change less desirable situations into "preferred ones" (Simon, 1996, p. 111). Situatedness in design refers to the idea that the interaction between designer and environment determines the course of designing to a great extend (Dorst, 1997; Gero & Kannengiesser, 2004;

Schön, 1983). This means that along with a designer's idiosyncratic characteristics like experience and attitude, what they perceive and how they interpret that is determined by what they are doing and the results of what they have done. And what they do next is determined to a large extend by how they perceive and interpret a situation. The concept of situatedness is central to reflective practice and is for example elegantly captured by Leifer's (2011) metaphor: 'dancing with ambiguity'. Designing is like dancing with an unpredictable (creative) dancing partner. One has to take a step, see how one's dancing partner reacts and then, in turn, react to that by making another move that is appropriate. At the same time, most forms of dance have underlying patterns that can help partners to predict to some extent how to move. The act of designing is typically very complex and so are the possible patterns that a designer can use to bring some structure to his or her activities. As designing is influenced by a practically infinite number of interrelated factors, and can entail many different types of possible actions, designers are bound to encounter unexpected consequences of their actions. In those cases a designer can "take account of the unintended changes he has made in the situation by forming new appreciations and understandings and by making new moves" (Schön, 1983, p. 79). The impact of a 'situated view' on design has been discussed quite extensively (amongst many others see for example Adams, Turns, & Atman, 2003a; Badke-Schaub & Frankenberger, 1999a; Bucciarelli, 1984; Dorst, 1997; Gero & Kannengiesser, 2004; Schön, 1987; Soo Meng, 2009; Valkenburg & Dorst, 1998) and is grounded in a number of empirical studies. For example, Busby and Payne (1998) studied the influence of circumstances on how designers predict activity duration. In the context of cooperation in engineering design, Boujut and Laureillard (2002) revealed how practitioners negotiate and redefine design goals in relation to a changing context. Similarly, Badke-Schaub and Frankenberger (1999b) studied the impact of influencing factors on 'critical situations' in engineering design. Baton and Dorst (2011) studied the reframing activities of expert graphic designers and revealed its situated nature. In summary, effective method usage is tied up with a complex set of factors influencing most design situations and many different situations will be encountered in practice. Being the central actor perceiving and responding to those situations, the designer is pivotal in enacting design practices and – if deemed necessary – in choosing and adapting methods for specific circumstances. How to characterize the type of situation in which the need for a method typically arises?

Non-routine situations in design

Designers are known to continuously work at the boundary of their current knowledge (Ball & Christensen, 2009) often giving rise to high levels of uncertainty. In order to be successful, designers need to face uncertainty, as designing is characterized by innoductive reasoning or 'innovative abduction' (Roozenburg, 1993). That is, a designer has to reason 'backwards' from the intended purpose of the product towards the innovative design (the 'form') and its actuation (its use and the technological means and natural laws utilized to enable the use) in such a way that the product will fulfill the intended purpose. The form, the actuation and the reasoning that connects them to their purpose "are unbreakably tied together." (1993, p. 14) and in the case of innovative design, neither one can be known beforehand. In practice, this means that many combinations of the aforementioned 'elements' are possible, and that a designer's reasoning requires creative leaps – which in turn give rise to uncertainty. For the designer uncertainty is inescapable: in order to engage in innovative design and develop innovative designs, a designer will have to embrace uncertainty, rather than to try to mitigate or ignore it.

What types of uncertainty might a designer experience? Uncertainty can be both internal and external to the designer. This distinction was originally made by Kahneman and Tversky (1981) in order to move away from an inaccurate, singular concept of uncertainty in human decision making. Internal uncertainty can be attributed to our own state of knowledge. External uncertainty can be attributed to the external world (see figure 2.1). Going one level deeper, Kahneman and Tversky distinguished four prototypical variants of uncertainty. Internal uncertainty can relate to the scrutinizing and assessing of evidence and arguments (e.g. should we change our approach to the project? The client does not seem to be very committed so we might need to alter our approach to engage the client more. But on the other hand, our approach usually works well). Or internal uncertainty can relate to a feeling of confidence that is based on our personal experience (I feel that something is wrong with our current approach, we should adapt it). External uncertainty can either relate to a singular case. For example, one might be uncertain about a design project at hand in terms of its own properties (what should we do in this specific project? what might turn out to be crucial issues?) or about a class of similar cases (what does one do in this kind of project? What kinds of issues turn out to be crucial in this kind of project?). In reality, any subjective experience of uncertainty will be a mix of different variants of uncertainty, but for the purpose of our analysis, the distinction made by Kahneman and Tversky will prove to be useful by showing that uncertainty may emerge from a designer's own ignorance and from uncertainty that is inherent to the external world.

Non-routine situations are directly related to designers' perception of uncertainty and can be defined as situations associated with levels of uncertainty in which the designer does not obviously know how to proceed. In words that might reflect better a designer's experience: in a non-routine situation, a designer experiences uncertainty because no sensible interpretation of a situation or option for appropriate action 'pops up' in mind intuitively or because of low confidence in the ability to deal with the situation successfully. Such situations can have a diverse character. For example, a non-routine situation might arise because of a lack of confidence in one's own ability or knowledge.

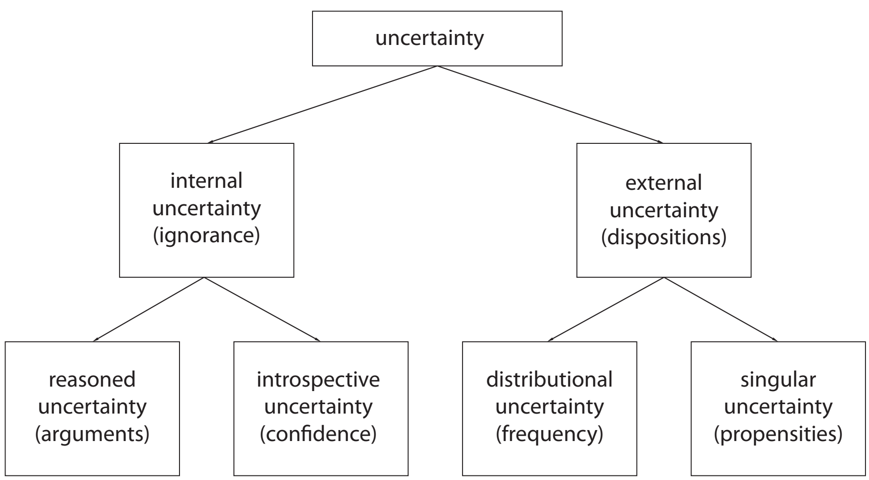

Figure 2.1 Variants of uncertainty (adopted from Kahneman & Tversky, 1981).

Alternatively, a non-routine situation might arise because a situation is unpredictable or because insufficient knowledge is available. In general, a non-routine situation occurs when intuition fails to provide (1) a sensible interpretation of a situation or (2) a way to proceed or (3) when a designer doubts a current way of working (e.g. in the light of high risk or cost of failure or retrospectively, when there was surprise). Non-routine situations are characterized by a feeling of uncertainty which can persuade a designer to switch to a deliberate mode of thinking to analyze the peculiarities of the specific situation at hand more carefully and to generate and evaluate possible actions and their consequences. In doing so, the designer can prepare deliberately for a situation by developing a better understanding of the situation and/or a new approach to respond to it. At this point, a designer might consider the use of a method to bring structure to his or her thinking about that situation, or about possible future activities – i.e. planning – that could lead to a desirable situation more efficiently and/or effectively. That is, a method can help a designer to enhance the ability to design.

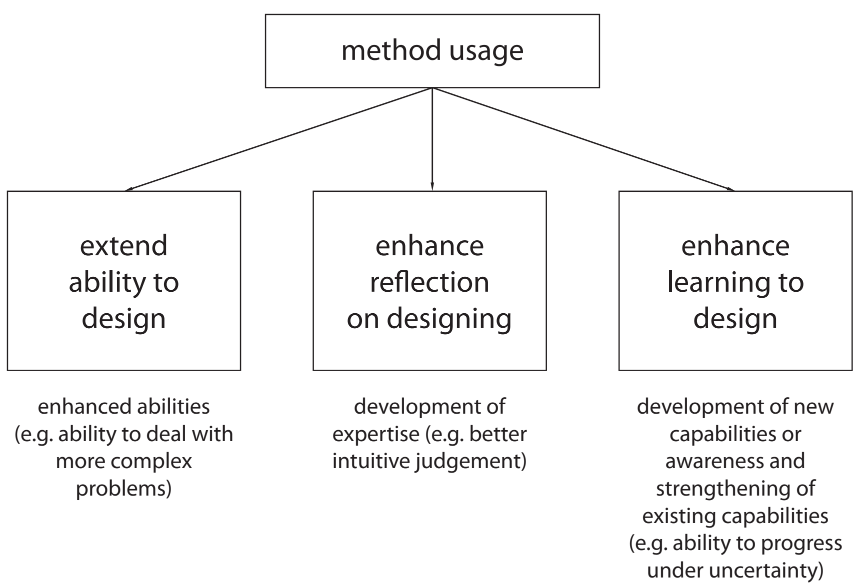

Figure 2.2 Fundamental dimensions of method usage in design.

Along similar lines, but still qualitatively different in terms of the designer's experience, a method can be used to teach designing. In those cases, a method can be used to help develop new capabilities and mindset or to become aware and strengthen existing capabilities . That is, a method can help to learn how to design. Alternatively, a designer might use a method to help reflect on activities as they unfold or on past activities to make sense of, and learn from, unexpected outcomes. In this sense, a method can become part of a designer's 'reinforced practice' (Kahneman & Klein, 2009) to develop and sharpen intuitive expertise. Intuitive expertise "is learned from prolonged experience with good feedback on mistakes" (Kahneman, 2011b) and methods can be means to structure reflection and feedback on mistakes, either through a designer's own reflections, or with the help of a teacher. It is important to point out here that in practice, and particularly for experienced designers, much design behavior will be driven by designer's intuition and methods typically only have a role to play in the relatively short episodes of deliberation that happen when intuition fails to provide an answer or when there was surprise after an event and uncertainty rises.

Uncertainty in design

In general, a balance must be found between preparing (planning) for "situations that are most likely to occur and a general flexibility to respond appropriately when things turn out different than expected" (Kahneman & Tversky, 1981, p. 151). This is particularly important for designers as designing happens with leaps and bounds according to the pattern of innovative abduction. This means that it is important for a designer to prepare and plan for a task or project while maintaining a certain flexibility to adapt to the circumstances at hand, a phenomenon in which methods (can) play an important role, and which has been empirically supported in the context of engineering design (Bender & Blessing, 2004; Fricke, 1999). It should be noted that not all non-routine situations invoke deliberate reasoning. For example, one might ignore the feelings of uncertainty and continue on a path that was prompted by intuition, an 'escape-hatch' strategy (Stanovich & West, 2000) that is often induced by a lack of confidence in the ability to consciously deal with a problem (Ball & Quayle, 2000).

What do we know about uncertainty in design? Some scholars have empirically studied the role of certain strategies under conditions of uncertainty. For example, Ball and Christensen (2009) studied analogical reasoning and mental simulation and concluded that the two strategies are deployed to resolve epistemic uncertainty in design. Epistemic uncertainty is the subjective feeling of uncertainty caused by a situation in which a designer has insufficient knowledge – or cannot easily retrieve appropriate knowledge from memory – to be able to recognize a situation and act appropriately. In their work, Ball and his colleagues have linked the fluctuation of epistemic uncertainty to certain cognitive strategies in design (Ball & Ormerod, 1995; Ball, Evans, Dennis, & Ormerod, 1997; Ball, Onarheim, & Christensen, 2010). First, designer's perception of uncertainty was linked to situations in which designers switch between breadth-first and depth-first modes of progressing in design. Second, designers' perception of uncertainty has been linked to employing satisficing behavior in a strategic manner; to avoid the cognitive effort needed to deal with multiple concepts in parallel. Third, designers' perception of uncertainty has been linked to switches in sketching behavior between structural and functional modes of representation (Kavakli, Scrivener, & Ball, 1998; Scrivener, Ball, & Tseng, 2000). Similarly, Gerber and Carrol (2012) have revealed in a longitudinal study of a team developing digital products how the practice of low-fidelity prototyping can help individual designers to cope with uncertainty in design. Alternatively, some scholars have modeled uncertainty in design processes to determine the effect of uncertainty on time span and effort (Suss, Grebici, & Thomson, 2010; Suss & Thomson, 2012). What these studies show is that a link exists between the experience of subjective uncertainty and specific cognitive strategies and design practices. This leads us to ask the question: how does the need for methods emerge from situations involving a high level of uncertainty?

In order to productively deal with a non-routine situation, a designer needs to focus attention on the situation to develop an understanding of it and to develop an appropriate course of actions. Based on the frequent occurrence of non-routine situations in design processes – as well as their significant impact on success (Badke-Schaub & Frankenberger, 1999a) – it might be expected that designers often feel the need to change to conscious thought mode, and perhaps even to use methodological support. In fact, in the previous section we have linked uncertainty to specific design practices that can help designers to deal with uncertainty in non-routine situations. Those practices and strategies could be evoked by method teaching or method usage: the strategies and practices described above are part of some of the methods in design. Yet those methods are often expected to be used 'from start to finish' rather than in a situated manner. That is, design methods rarely cater to designers' 'situated' need for methodological support. They often fail to help designers with answering the question that should be at a method's core: "If I am a designer with the following capabilities, and I am confronted with a design task with these characteristics, and I am working in this situation, and I have progressed to this point in the design process, then what should I do now?" (Dorst, 1997, p. 21). Dorst' question implies that the need for structure, and potentially for methodological support arises in a situation in which a designer is typically not in complete control, yet has to act in order to succeed, a phenomenon known as "thrownness" (Heidegger, 1962). The need for structure that emerges from being in a problematic (non-routine) situation is driven by the situation's characteristics and by a designer's knowledge and abilities. It is important to note here that methods are not the only option available in those situations. For example, designers often ask an experienced colleague for advice. In contrast, designers sometimes simply substitute a complex problem for a different, simpler problem, for which he or she does have an appropriate answer available from memory.[1]

§ 2.2 *Methods as flexible resources*

In spite of the fact that designers have other resources available – intuition being the most prominent one – many method makers seem to expect that designers use a method in most situations and that their method will be followed 'like a road', leading to certain results (Jensen & Andreasen, 2010) – as opposed to being used as optional resources. We note that some authors have articulated a more detailed view on methods in design, and

1 Substitution of complex problems for simpler ones might seem like an unlikely – and unproduc tive - strategy, but it is very common. For example, when confronted with the task to design a product that should include people with a disability, it is not uncommon that a designer mainly relies on his own experiences as a user instead and fails to empathize sufficiently with the needs and peculiarities of part of the target group (sometimes referred to as ego-design). Alexander (1964) already observed this phenomenon early on with the emergence of the design methods movement, and put it forward as an argument for the development of methods in design. The substitution of complex problems for different, simpler ones is found to be a general phenomenon in human behavior (Kahneman, 2011b).

some have done so for a long time. For example, when pointing to the heuristic nature of methods Roozenburg and Eekels (1995) stressed that methods in design rarely guarantee results, and need to be used with care and sufficient knowledge. A method's heuristic nature implies that the use of a method can at best enhance the chances of developing successful design solutions, not guarantee them. Others have stressed that methods are not needed because "we know the way", but are needed "because the solution is rarely right the first time" (Olesen, 1992, p. 40) and without systematic methods "the number of mistakes increases and the probability of major disasters rises" (Hales & Wallace, 1991, p. 108). Furthermore, Andreasen suggested that "we have to understand carefully why and when they [methods] function in practice instead of seeing them as elegant, logical and indispensable deliverables which industry should not neglect" (Andreasen, 2011, pp. 322). Empirical studies have revealed a complex network of factors that influence the design process, including factors related to the individual, the social environment, other external conditions and the task (Badke-Schaub & Frankenberger, 1999a). As method usage ties into this network of factors, their role and impact is not a matter of applying formal mechanisms leading to predictable effects (Cantamessa, 1999). In support of this claim, Badke-Schaub and Frankenberger (1999a) uncovered a broad set of interrelated factors that influence both the process and outcome of design activities within the domain of cooperative design processes in engineering design. In doing so, they found that the use of design methods does not guarantee successful results but that factors such as conflict handling often are equally – and sometimes more – important in determining the outcome of a project. Therefore, they conclude that designers should be trained to adapt methods that are inadequate and strengthening successful ones (Badke-

Schaub & Frankenberger, 1999a).

The added value of method usage rather depends heavily on how well a method fits – and is fitted to – a designer's situation at hand, and the goal to be achieved. In support of this claim, Fricke (1999) found that flexible method usage leads to better performance than either strictly following methodological guidelines, or 'muddling through' (proceeding haphazardly without observable structure). This and similar conclusions were confirmed in a study by Bender and Blessing (2004) with a larger sample size, allowing generalizable conclusions. The authors confirmed that in the case of early embodiment design, design practice is indeed characterized by 'opportunistic procedures' – involving a mixture of intuitive activity and deliberate, methodical action – rather than by 'strict hierarchical top-down procedures'. In going beyond that observation, they concluded that not only are these opportunistic procedures more common (at least for embodiment design), they also lead to superior performance.

In response to these and similar studies, Bender et al. (2001) have proposed a re-interpretation of design methodology as 'a flexible and optional heuristic' expecting to achieve better support for individual designers' performance and higher method-user satisfaction. In re-conceptualizing methods as flexible and optional heuristics, Bender and Blessing implicitly bring a method's user and context of use to the foreground. That is, seen as optional resources which are used only when needed, and are adapted to the situation at hand, method usage should include 'fitting' and 'adapting' a method's structure to the peculiarities of the situation at hand. This is typically done by the method user, of course in the light of a certain goal to be achieved. Moreover, the choice for a certain method, and the way it is adapted should also fit the individual designer's

capabilities, limitations and 'method mindset'. Additionally, a method's use should also include its abandonment as soon as it ceases to serve a designer's purpose.
Arguably, effective method usage is tied up with the complex set of factors influencing most design situations. As design is a complex activity, many different situations will be encountered in practice. Being the central actor perceiving and responding to those situations, the designer is pivotal in choosing and adapting methods for specific circumstances. From a designer's perspective, methods are resources that can be used to deal with non-routine situations.

§ 2.3 *Design methods as mental tools*

The foregoing discussion on methods as flexible resources leaves us with an important question: if not as a set of instructions that can be followed like a road but as flexible resources, how does a method function when a designer uses it? I will start to answer that question by envisioning a designer in a non-routine situation. That designer experiences the situation as non-routine because he or she is uncertain about either how to interpret it – how to make sense out of it – or is uncertain about how to act appropriately in that situation to reach a certain goal.[2] A non-routine situation might also be perceived as such when a designer doubts a current way of working (e.g. in the light of high risk of failure or retrospectively, when there was surprise). In other words, the designer does not recognize the situation clearly or does not intuitively come up with a way to act with which he or she is satisfied. One might say that the designer has insufficient knowledge – or cannot easily retrieve appropriate knowledge from memory

2 Note: The activity of goal finding itself is a design activity and can also lead to non-routine situa tions.

– to be able to recognize the situation and act appropriately. The subjective feeling of uncertainty that can be caused by this phenomenon is labeled 'epistemic uncertainty' (see e.g. Ball et al., 2010). Or, an unexpected outcome might have surprised the designer, causing doubt about the interpretation of a past situation, or about past actions; the designer has realized retrospectively that he or she had insufficient knowledge to interpret the situation or act appropriately. How might a method come into play in this kind of event? In case a designer reaches out for a method, he or she will typically do so because of its information content. From a designer's perspective, the method is used as resource that provides structured information about a design process – concerning either a design object or design activity. If a method fits the situation at hand, it can assist the designer to open his or her mind to relevant elements and relationships between elements of the phenomenon. It can help to do this at a given point in time, but also over the course of time. In the latter case, methods can help to see relationships between actions and their potential consequences over time: the method presents a diachronic structure of a design activity.[3]

Because methods typically represent abstracted models of specific design activities or processes, their use will make salient certain features of those activities or processes while ignoring others. In short, a method can help a designer to think about a problematic situation and possible actions and to prioritize and structure them; a method should be seen as a mental tool. Similarly, in a social context, methods can be used to help a designer to open other people's minds to certain elements and relationships between elements of a design phenomenon, facilitating for example the

3 For a detailed discussion of the concept of diachronic structure in relation to methods see Eekels (1982).

coordination of a design process in a team, or justification of a design project to a client. Appropriate usage of a method will help a designer to bring clarity to the interpretation of situations and support the generation of appropriate actions. It can empower a designer to make relevant aspects of design salient – and to some extend – bring them under control. Moreover, it gives direction to the designer's thinking by highlighting some aspects and ignoring others. 'Appropriate usage' refers to the importance of a good fit between method, goal, designer and context of use. This means that the aspects that are made salient by the method's use should make sense in the light of a designer's mindset and goal, and the features of the situation in which he or she is working. Conceptualizing methods in design as mental tools implies that they have a number of characteristics.

First, for a method to be used, it needs to go 'through' a designer's mind. That is, it needs to be interpreted and its content brought into context with the designer's experiences and mental model. Therefore, a method's influence is 'soft' in the sense that it does not directly lead to certain outcomes.

Second, a method consists of information – describing the structure of certain design phenomena – which needs to be taken in and be transformed by its user in order to be effective; a process that is called learning (Kolb, Boyatzis, & Mainemelis, 2001).This transformation process happens in an idiosyncratic way, being influenced by a designer's personality, background, mindset, motivation, circumstances, etc. It is therefore not accurate to still speak of method usage after a method has been learned: it will have been transformed to become part of a person's idiosyncratic and tightly compiled knowledge base or it will have provided the designer with scaffolding for reinforced practice. That is, after having learned a method, a designer's skilled behavior might show certain features that remind of a method's description superficially, but the behavior will be too intricate and idiosyncratic – and too much intertwined with other knowledge to be still compared to the method that might have helped in developing the skill. In other words, skill is not an 'echo' of method usage but methods should rather be seen as catalysts for its development.

Third, methods, by their nature, refer to the regularities that can be found in design activities or design situations. Only those activities or situations that are sufficiently predictable and occur regularly are candidates for method development. This does not mean that the results of such activities should be predictable, but that there is some regularity in the activity that the method refers to, and that it is possible to predict chances of success when a method is being used properly. At the very least, a good method helps a designer to be more efficient or effective than without it, or when using another method. Put differently, developing a method for a single, unique situation would not be efficient, nor would it be to develop one for situations which are too unpredictable. For example, a creativity method typically helps designers to generate innovative ideas by building upon the human capacity to associate on other people's ideas. It should be applicable in diffe-rent situations and by different people (given some preconditions like proper training, mindset, conditions, etc.). This does not mean that a method should predict the outcome of an activity. Although methods can be seen as attempts to make designers' private thinking public (Jones, 1972), such an attempt only makes sense when it concerns activities or situations that have underlying processes that are organized and universal and systematically increase chances of success.

Fourth, the use of a method requires conscious attention from its user. That is, the information that a method contains needs to be interpreted and transformed through reasoning (by 'paying' attention).

The concept of method in design

We now come to the point where a definition of the concept of method can be provided and where we can elaborate on in the context of design. In conceptualizing methods as mental tools that can help a designer to bring structure to his or her thinking, inspired by Andreasen we adapt his definition of a method into: "a goal-oriented rationalization or imagination of designers' work in the form of a standardized work description" (personal communication, 11 April 2011). That is, a design method is a description of a design activity which has been rationalized and abstracted from observations or imagined based upon theory with the purpose of helping designers to see the structure of that activity (so that they can learn or teach it, extent their capabilities, communicate it or reflect on their own or other's actions).

Both in the literature and in practice, design methods are typically categorized into two main classes: systematic methods and heuristic methods (for a definition see the following pages) . Historically, much research in design has focused on the development of systematic methods[4] in the pursuit of providing designers with generalizable and universal instructions for design, a focus that has been articulated for instance by Hubka (1982), Hubka and Eder (Hubka & Ernst Eder, 1987) and Pahl and Beitz (2007).

4 It is important to note that systematic does not mean the same as algorithmic in this context. Rogers defined algorithm as: "a clerical (i.e., deterministic, book-keeping) procedure which can be applied to any of a certain class of symbolic inputs and which will eventually yield, for each such input, a corresponding symbolic output" (Rogers Jr, 1987, p. 1).

The term heuristic has been given multiple meanings in the literature on design (Daly, Adams, & Bodner, 2012; Von Der Weth & Frankenberger, 1995; Yilmaz & Seifert, 2011).[5]

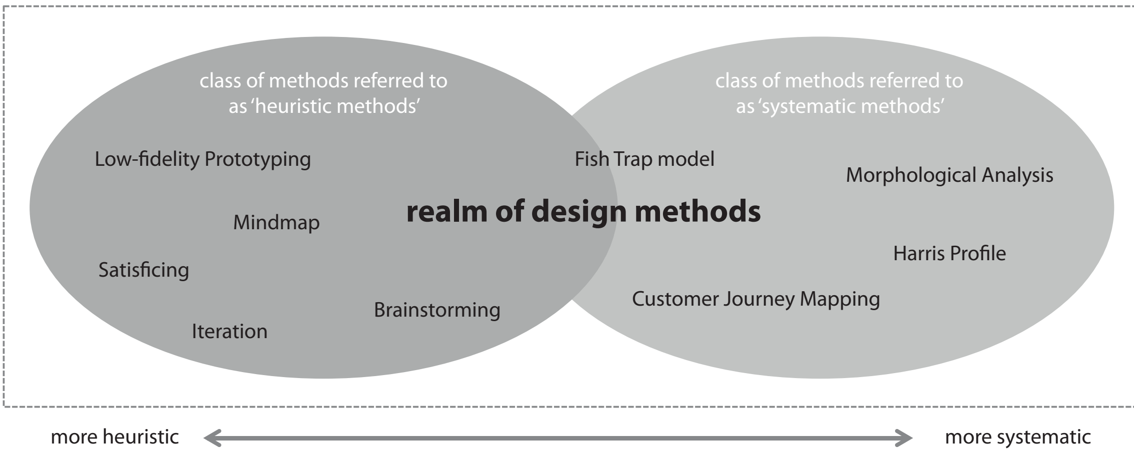

Figure 2.3 Realm of design methods organized along the dimension of heuristic to systematic. Examples of methods are placed along the axis.

In the context of this thesis, we adapt the work by Gigerenzer and colleagues on heuristics in decision making to design, and focus on the underlying information processing prescribed by different types of methods. This means that both systematic methods and heuristic methods aim to guide the cognitive processes of their users by providing prompts for information processing that can assist in learning, decision

5 In design methodology, almost all methods are described as having a heuristic nature. This means that methods can enhance success but do not guarantee it (e.g. Andreasen, 2011). The term heuristics has also been used in different ways. For example, Von der Weth and Frankenberger defined heuristics as "rules for making rules" which are used "to generate action plans for situations for which no useful routine behavior exists" (Von Der Weth & Frankenberger, 1995, p. 368). Quite differently, Daly and colleagues define heuristics as 'cognitive prompts that point designers towards exploration of design variations' (Daly et al., 2012, p. 606).

making, problem solving and reflection. We argue that by looking upon methods in this way, it becomes clear that while all design methods are heuristic in nature in the sense of not guaranteeing results when used (as opposed to being algorithmic) we can distinguish classes of methods that are more or less systematic in nature, requiring more or less information processing from their users. Gigerenzer and Brighton defined heuristics as "efficient cognitive processes that ignore information" (Gigerenzer & Brighton, 2009, pp. 107). Following this line of reasoning, methods are placed on a continuum ranging from 'methods prescribing the processing of as much information as possible' to 'methods prescribing the processing of only certain pieces of information while ignoring most'. The more a design method resembles the former, the more it can be considered to be systematic in nature; the more a method resembles the latter, the more it can be considered to be heuristic in nature (see figure 2.3).

Next, we turn to whether methods prescribe optimal versus satisfactory results and whether a method promotes a deliberative or an intuitive process for decision making (Kahneman, 2003; Kahneman & Klein, 2009; Klein, 1998). When seeking to achieve optimal results, deliberative processes are emphasized over intuitive processes. This is characteristic of systematic methods (such as morphological analysis). For example, Hubka and Eder (1987) and Pahl and Beitz (2007) emphasized the importance of deliberation in design and used it as a starting point for the development of systematic methods in engineering design. Alternatively, when the goal is to achieve satisfactory results, intuitive processes are emphasized over deliberative processes. This is characteristic of heuristic methods (such as 'iteration' and 'satisficing'). For example, Yilmaz and Seifert (2011) define heuristics as cognitive shortcuts, providing an emphasis on reaching satisficing behavior in design work. Based on these differences, we define a basic function of systematic and heuristic methods as follows: a systematic method prompts a designer to include as much information as possible in aiming to reach optimal rather than satisfactory results. A heuristic method prompts a designer to focus on particular pieces of information while ignoring most in aiming to reach satisfactory rather than optimal results. There might be differences in the emphasis that is placed on intuition versus reasoning, by definition all methods require its user to pay attention to it when used. If we accept that method usage requires reasoning, but that intuition plays a major role in explaining the outstanding performance of some expert designers, then it is pertinent to ask: How does method usage relate to intuition and reasoning?

§ 2.4 *Intuition and reasoning in relation to method usage*

Design cognition has been central to the development of design methodology (amongst many others see e.g. Alexander, 1964; Hubka, 1982; Jones, 1972; Pahl et al., 2007) and still is one of the most popular topics in design research (Chai & Xiao, 2012).[6] Reasoning has been articulated as a virtue in the context of product- and engineering design and has been hailed as the main road to the rationalization and professionalization of design

6 In recent years, the topic of design cognition has often been discussed under the label of 'design thinking'. Rowe's articulating of 'Design thinking' (1987) was an early use of the term in the design research literature. In addition, much research under the label of 'design thinking' has been published through the Design Thinking Research Symposia since 1991. With the broadcasting of IDEO's 'Deep Dive' in 1999 and IDEO CEO Tim Brown's publications on design thinking (Brown, 2009; Brown, 2008) the term 'design thinking' caught the eye of a broader audience and became popular as a management approach (Badke-Schaub et al., 2011). Many publications that directly address 'design thinking' in design research literature have been published over the years, (e.g. Adams, Daly, Mann, & Dall'Alba, 2011; Burdick & Willis, 2011; Cross, 2011; Dorst, 2011; Dym, Agogino, Eris, Frey, & Leifer, 2005; Lawson, 2006; Stewart, 2011).

(Hubka, 1982; Pahl et al., 2007). The development and use of systematic methods was advocated and favored over intuition to avoid "jumping to conclusions" (Hubka, 1982, pp. 29). Intuition has been mainly discussed in the context of design expertise to explain the exceptional performance of outstanding designers (see for example Cross, 2004; Dorst & Lawson, 2009; Lawson, 2004). It has also been linked to creativity in design (e.g. Sarkar & Chakrabarti, 2011). Yet how the two types of cognitive function relate in terms of method usage is rarely discussed in the design methodology literature. Rather, there seems to be two opposing positions (implicitly) present in discussions on design methodology.

The first position can be summarized by the statement: the development of expertise of design practitioners should be leading in teaching and nurturing design skill and is the best path to optimal performance in design; methods can sometimes be used to support skill development. The 'expertise'-position is commonly associated with Schön's ideas on reflective practice through which he sought to establish an "epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness and value conflict" (1983, pp. 49). In Schön's view, design research should focus their research on the way skillful practitioners – i.e. experts – act and develop a methodology based on those competencies. In the field of design, research in expertise has shown how expert designers act and how practitioners develop expertise (see e.g. Cross & Cross, 1996; Cross, 2004; Cross, 2010; Dorst & Lawson, 2009). Research outside the field of design has revealed the cognitive processes behind intuitive expertise (Klein, 1998) and how intuitive processes sometimes underlie systematic errors in complex situations (see e.g. the seminal work of Dorner, 1997; Reason, 1990).

The second position can be summarized by the statement: practice should accept the ideals (norms) of systematic design and design science and make deliberate efforts to use its methods systematically to reach optimal performance in design. The 'rationality'-position is commonly associated with Simon's ideas on a 'science of the artificial' through which he sought to establish a 'science of design' consisting of a "body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process" (1996, pp. 113).

Proponents of both positions have sometimes clashed without much convergence as there is little common ground to build on. The debate between Eder (1998) and Frost (1999) is a representative example. A noteworthy exception is Jones' (1971) discussion on the role of methods in mediating intuitive and rational thought in design. Additionally, on a more philosophical level, Dorst touched upon the two opposing positions in his thesis (1997), in which he compared the two 'paradigms' that are represented by Simon's and Schön's work in design. Dorst' articulation of a dual-mode model of design and design methodology was an attempt to bring together two models of designing and to "be a basis for a discussion in design methodology on the use and combination of the two paradigms" (pp. 170). However, the 'two-paradigm approach' that Dorst elaborated has not led to a reconciliation of rationality and intuition in design methodology on a broad scale. Rather it seems to have facilitated two separate research streams: one that focuses on design expertise, and one that focuses on systematic design. To date, virtually no research has focused on reconciling rationality and intuition in design methodology.

In contrast, the relation between intuition and reasoning has received considerable interest in the field of cognitive psychology under the label of 'the psychology of bounded rationality' (Kahneman, 2003) and is a fruitful source for further investigation in the context of this thesis. In the next section I will turn to literature on dual processing theory to develop a more firm foundation for discussing the use of methods in relation to human thought. There are two main reasons to do so. First, the field of cognitive psychology has produced a large amount of empirical studies (Stanovich and West, 2000) providing a more detailed understanding of intuition and reasoning and how they relate to each other than the design literature offers. Second, more recently, the field has seen efforts to reconcile the two opposing positions (Kahneman and Klein, 2009) that have existed both in psychology and in design. One position emphasizes intuition and the other position emphasizes deliberate reasoning as the main determinant of performance. Scholars and intellectuals that promote and study excellent performance of experts, and that focus on the role of expert intuition to explain performance hold the former position. Scholars and intellectuals that focus on the systematic errors that human beings tend to make when relying on their intuition and who advocate adherence to formal norms and models to prevent those errors hold the latter.

Intuition and reasoning in cognitive science

Designers – or virtually all human beings, for that matter – are 'built' according to the same scheme, and rely on the same types of thinking processes for cognition (Stanovich and West, 2011) and on specific types of 'mindware' that are unique to each type of mind (Perkins, 1995; Stanovich and West, 2011). Mind is defined as a control system in the human brain (Dennett, 1996). Mindware is defined as the knowledge bases that are in part innate and partly based on experience and comprise "rules, knowledge, procedures and strategies that a person can retrieve from memory to aid decision making and problem solving" (pp. 793). In general, two types of thinking processes are distinguished in human cognition: intuition and reasoning (Kahneman, 2011). Within the field of cognitive psychology, 'dual processing theory' explains how human thinking happens according to these two modes of cognitive function, which are often referred to as 'type 1' or 'type 2' cognitive processing (Stanovich and West, 2000; Kahneman, 2003; Evans, 2009; Stanovich, West and Toplak, 2011).

Intuitive processing is typically fast, automatic, effortless, associative, implicit and often emotionally charged (Kahneman, 2003; Stanovich, West and Koplak, 2011). Reasoning

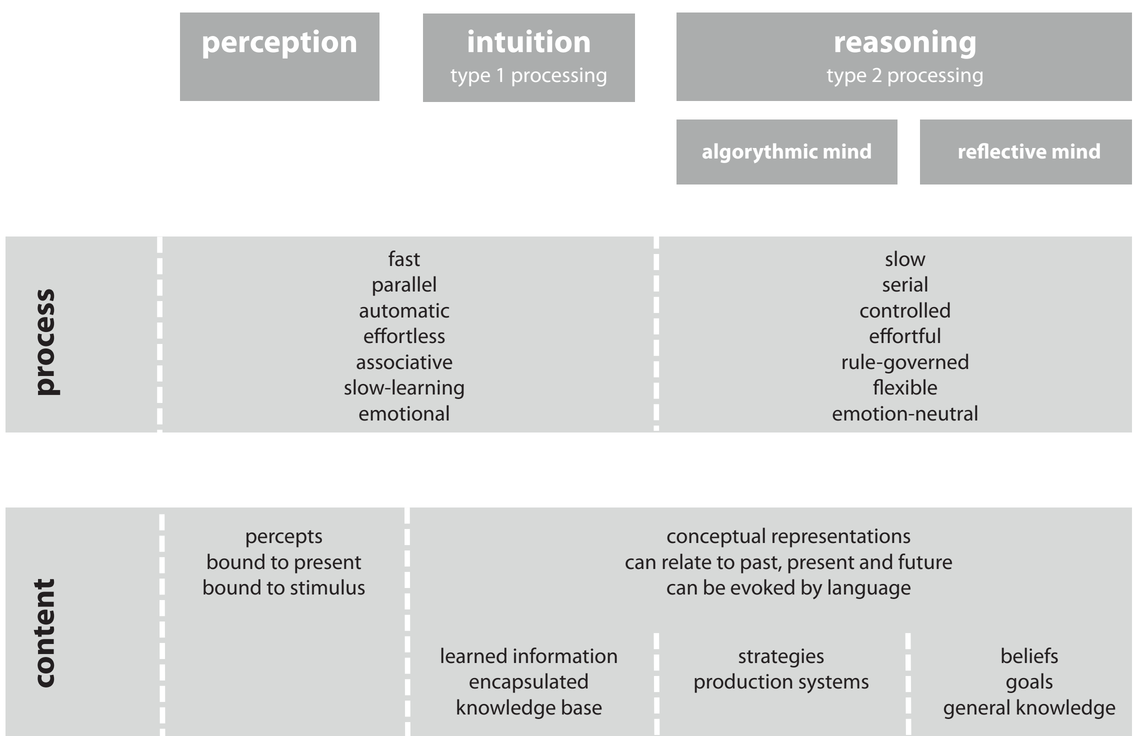

Figure 2.4 Fundamental cognitive processes in the human mind and their content (adapted from Kahneman, 2003).

is slower, serial, effortful and more likely to be consciously monitored and deliberately controlled. It is relatively flexible and can be rule-governed (Kahneman, 2003, 2011). The fact that reasoning can be rule-governed underlies our belief that methods can be used to guide action, and why their usage requires reasoning. It also explains why many design methodologists have focused on the rationalization of design; method usage requires reasoning. The fact that most human behavior is governed by intuition (Kahneman & Klein, 2009) explains why the expectations of many design methodologists about the potential impact of their methods are not met by the actual use of their methods in practice. Figure 2.4 provides an overview of the characteristics of both types of processes. The cognitive systems of perception, intuition and reasoning are outlined with their characteristics in terms of process and content. Dual processing theory has provided researchers with a detailed understanding of human behavior under uncertainty, allowing them to interpret seemingly complex human behavior according to two highly connected modes of thought. In that sense, it is a valuable source for design methodology to reconcile the seemingly opposing views of 'systematic design' and 'design as reflective practice' by explaining how reasoning and intuition are integrated in the whole cognitive system and function in relation to each other.

In general, the more experienced a person is, the more he or she will be able to use intuition to recognize features of situations and come up with actions. For an expert, most behavior is guided by intuition and is often skillful and successful. The way skillful practitioners determine how to act based on experience has been described in a theoretical framework as a recognition-primed process that has been the topic of study in the field of naturalistic decision making (Klein et al., 1993; Zsambok and Klein, 1996). Yet experienced practitioners are not always successful and both outstanding and poor performances are attributed to intuition. Or in other words: "expert intuition is sometimes remarkably accurate and sometimes of the mark" (Kahneman and Klein, 2009, p. 515). Particularly in the context of complex problem solving, human beings are prone to make certain systematic errors that are associated with reliance on intuition (Reason, 1990, Dorner, 1996). One example of a systematic error is the failure to test hypotheses in new situations and instead hold them for being true. Another example is the failure to analyze a complex problem throughout a problem solving process and instead only analyze it early on (Dorner, 1996). In this light, an important function of system 2 operations is to monitor and override responses of system 1 when they are deemed to be irrational – i.e. when intuitive responses do not seem to be efficient means to reach a goal (Kahneman, 2003). In those cases, system 2 processing is responsible for hypothesizing and simulating new responses (Stanovich, West and Toplak, 2011). Whether a situation is perceived to be non-routine is a subjective matter and is driven by level of cognitive comfort: a subjective feeling that determines whether intuition is trusted or whether one invokes the monitoring function of type 2 processes (Kahneman, 2011). Experience of cognitive discomfort is typically a trigger for type 2 processes to come into play with one of its most important roles being to monitor the output of type 1 processes.

Intuition is defined as "recognition of patterns stored in memory" (Chase and Simon, 1973) which is still a valid definition today (see Kahneman, 2003, 2011; Kahneman and Klein, 2009). It is linked to long term memory and is associative. Furthermore, intuitive judgments are typically accompanied by a feeling of confidence. That is, they come to mind as if there is no doubt about their validity. In contrast, doubt and uncertainty belong to the realm of system 2 and are related to the metacognitive awareness of one's own ability to hold conflicting thought about the same thing at the same time (Kahneman, 2003). Human beings differ in terms of their tendency to doubt their own intuitions and monitor its output; a level of cognitive control that has been dubbed 'Rationality' by Stanovich and West (2000). In their view, rationality is associated with the 'algorithmic mind' and the 'reflective mind' which both belong to type 2 processing as illustrated in figure 2.4. The algorithmic mind is typically related to information processing mechanisms (e.g. short- and long term memory). For example, this means that the algorithmic mind is responsible for matching a perception of a particular situation to information stored in long term memory and making a response decision, followed by action. It is also responsible for retrieving rules, knowledge, procedures and strategies from memory. The reflective mind is typically involved in goal setting and prioritization, regulation of beliefs and the choice of action that is optimal given the goals and beliefs (Stanovich, West and Koplak, 2011). Figure 2.5 provides a model of how the different types of cognitive function relate. The similarity of the dual-processing model to ideas in design theory may become clearer when it is framed in terms of performance. The algorithmic mind is typically associated with striving for optimal performance – i.e. striving to meet certain norms. In this light, the algorithmic mind is related to phenomenon that seem to have been at the focus of attention for scholars associated with design science, producing systematic design methods that should be followed to reach optimal results. The reflective mind is related to phenomenon that seems to have been at the focus of attention for scholars associated with reflective practice who strive for satisfying performance given a situation at hand– i.e. striving to frame tasks and reach (partly) self-defined tasks and goals that might change during the course of action. Of course these two concepts represent aspects of cognition that in reality are highly interrelated.

Purposeful action is a response to information that comes in through perception of the external world and an individual's own motivation and goals. Information that comes in through the senses is processed both intuitively and consciously by paying attention to specific aspects of the external world. To be able to act purposefully, one must have well-calibrated beliefs that match reality or available evidence and that are in line with one's goals. Additionally, one must also act appropriately on those beliefs to achieve goals. Belief formation is a property of the reflective mind. For example, one might say that a designer that does not recognize the importance of anticipating environmental effects when designing a product has poorly calibrated beliefs about what product design entails in today's world. Thus, adopting beliefs about the importance of anticipating environmental impact of a product is important for product designers. Belief formation requires designers to be open to – and reflect on – evidence and arguments that show the value of for example an eco-design approach.

Linking actions to goals and beliefs is a property of the reflective mind as well. For example, a designer who believes in the value of eco-design but who does not act accordingly (e.g. arguing that eco-design is too time consuming, or that clients are not paying for it) does not differ much from a designer that does not believe in eco-design at all. In contrast, a designer that decides to create a 'light' approach (a simplified version of eco-design approach that requires low effort and time) when the project budget is tight is

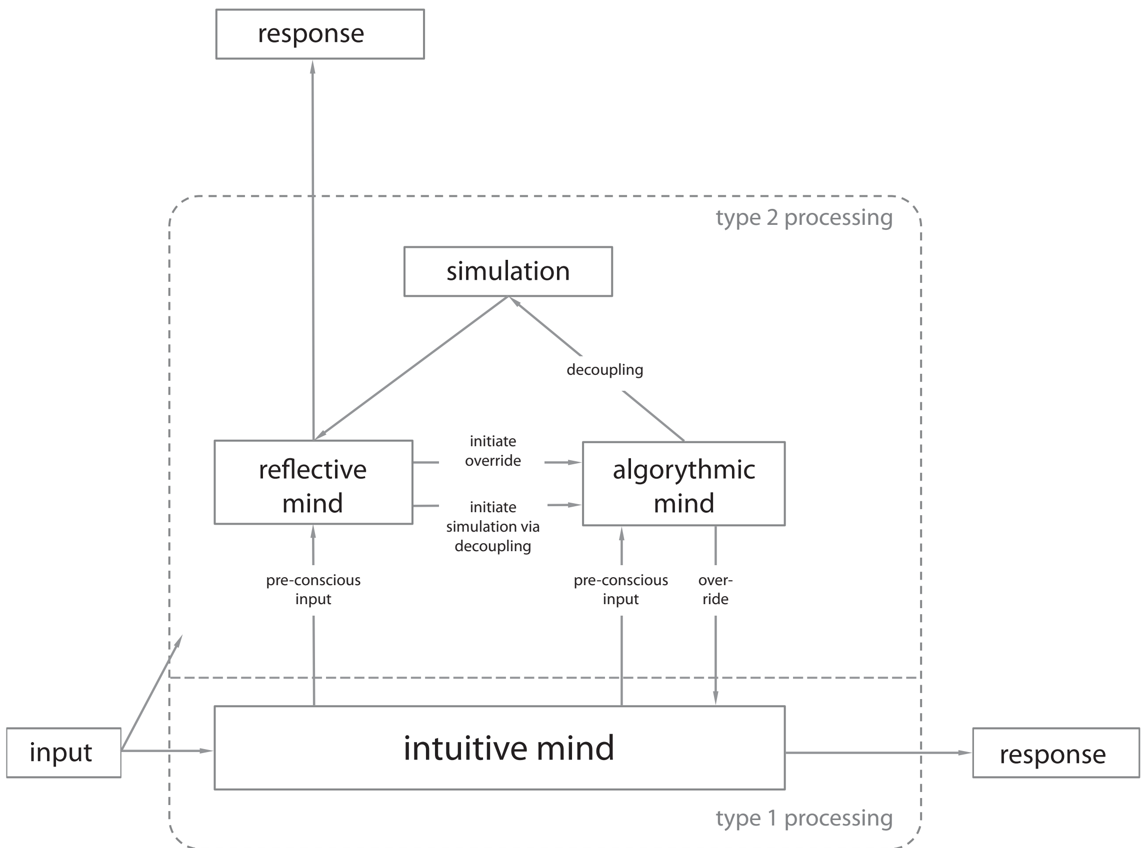

Figure 2.5 Model of cognitive systems (adapted from Stanovich, West, & Toplak, 2011).

more purposeful.

In general, actions can be prompted both intuitively and through reasoning. For example, a designer might immediately think of making paper prototypes when wanting to test a concept-interface for a web-application. Alternatively, when no option comes to mind or when the intuitive option is deemed to be inferior, a designer might take the time to reason about a possible way to test concepts for web-interfaces. The latter process is called ‘simulation’ (Stanovich et al. 2011) and requires sustained ‘hypothetical reasoning’ to come up with an alternative response (Evans, 2007). Hypothetical reasoning entails creation of temporary models of a phenomenon that can be used to test actions or consequences of actions. It requires that a person decouples the imaginary model of situations, actions or consequences from the perception of the actual phenomenon and to temporary suppress any intuitive prompts at the same time.

The initiation of decoupling and simulation activities evokes ambiguity and uncertainty in the mind of a person. Intuitive action is typically not accompanied by a feeling of uncertainty (which is why experts feel confident about their judgments). Or in Kahneman’s (2003) words “doubt is a phenomenon of System 2, an awareness of one’s ability to think incompatible thoughts about the same thing” (pp. 145). For a designer, starting to imagine potential new solutions through the process of ‘decoupling’ mean that he or she will be exposed to doubt. At this point, we can start to imagine how methods might assist a designer who is engaged in ‘innovative abduction’ (Roozenburg, 1993) and is being burdened by the weight of uncertainty. It is no surprise that Dorner (1996) has suggested that intelligence does not predict successful performance in complex problem solving, but that “the capacity to tolerate uncertainty seems to have more to do with it" (pp. 27). In this light, it makes sense to think of design methods as mental tools that help a designer to deal with uncertainty. Both decoupling and simulation are a function of the algorithmic mind and require attention and dedication. Besides receiving information from the external world, they rely on specific mindware for their operation. That is, they need input from the intuitive mind[7] to function properly (Evans, 2009). The reflective mind acts on goals, beliefs and general knowledge. The algorithmic mind acts on strategies and productions systems for processing information (see figure 2.4).

In summary, a model of the human cognitive system has been described based on literature from cognitive psychology on dual-processing theory. The way intuition and reasoning processes relate has been explained. In general, it can be stated that the human cognitive system "is well-adapted to its environment and has two ways of adjusting to changes: a short-term process that is flexible and effortful, and a long-term process of skill acquisition that eventually produces highly effective responses at low cost" (Kahneman, 2003, pp. 1454). The model provides a theoretical basis for relating method usage to human cognition. In short, it can be used as a framework that allows us to answer the following question in detail: how might methods function when designers use them as mental tools to deal with uncertainty, both in a situation and in developing expertise over time?

Roles of methods as mental tools

The dual-processing model of human cognition has provided theoretical entry-points for

7 The original term used by Stanovich, West and Toplak is 'autonomous mind'. For the sake of consistency of the vocabulary in this thesis, the term 'intuitive mind' is used to mean the same.

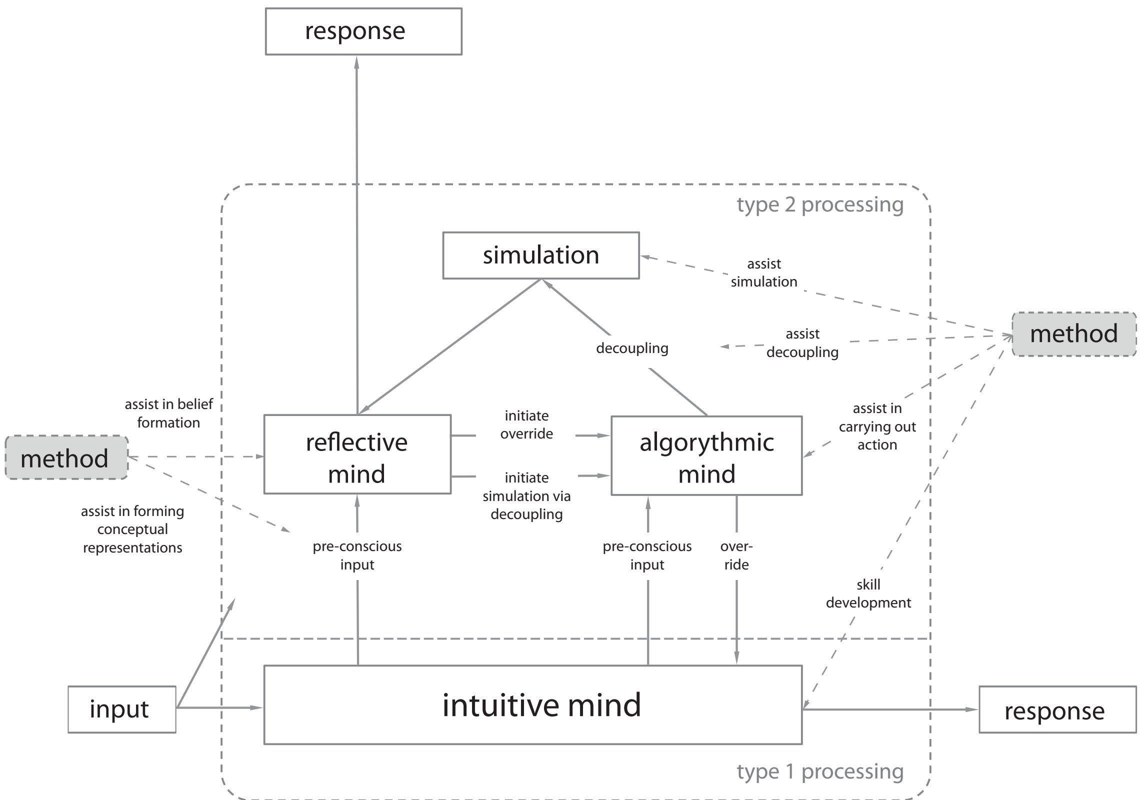

Figure 2.6 The roles of methods in relation to basic cognitive systems. Adapted from Stanovich et al. (2011).

elaborating on the roles of methods. Figure 2.6 illustrates how basic cognitive processes can potentially be assisted by the use of a method. These roles have been elaborated below.

Assisting the designer in calibrating beliefs

Having properly calibrated beliefs about design phenomena is a prerequisite for a professional designer. That is, in order to consistently act in a purposeful manner, a designer needs to understand what design is about, and what it takes to design. For example, a commonly accepted belief in product design is that the end-user is a key stakeholder in design and that their needs and interests should be taken into account throughout a design process. Alternatively, a designer that has learned to use a process tree method (Roozenburg and Eekels, 1995) might have adopted the following belief: 'When I design, I shall take all product-life phases into account'. In this way, design methods can facilitate a designer's belief formation. This means that a method can 'carry' beliefs about a specific design phenomenon that are perceived and adopted by a designer.

Assisting in framing conceptual representation

Having a productive perception of a design situation is crucial for effective design activity. That is, in order to act in a productive, purposeful manner, a designer needs to (frame) a situation in such a way that it allows for fruitful design work. For example, when a narrowly framed design problem is presented to a designer by a client, he or she might want to reframe it before starting with idea development in order to proceed along a more productive avenue as was originally suggested in the briefing. A recent example of reframing practice in the context of the 'designing out crime program' has been described by Dorst (2011). A designer who has learned to use the Vision in Product design (ViP) method (Hekkert & van Dijk, 2011) will probably start a design project with deconstructing the current product, the product-user interaction and the context in which these have (or had) meaning in order to frame the context in a more productive way. In this way, methods can facilitate a designer's framing of a situation.

Assisting the designer in mental simulation

Mental simulation is key to the central mode of reasoning in design (Roozenburg, 1993). That is, in order to create innovative design, a designer has to imagine the form, its use and the reasoning that connect those to its purpose at the same time. Put differently, if a designer is to "change existing situations into preferred ones" (Simon, 1996, pp.) then those preferred situations – and the design that are intended to bring the situations about – need to be imagined first. For all complex design problems, that process of imagining possible situations requires sustained mental simulation, a cognitive process that can often benefit from a method. For example, a designer that is using a method for morphological analysis (Zwicky, 1969) might be assisted with imagining an innovative design concept. The method provided a framework for the generation of a comprehensive set of solution principles for a comprehensive set of functional sub-problems and integrating them into innovative design concepts. In this way, a designer is assisted in sustaining and structuring the activity of imagining potential innovative solutions to a design problem, lessening the effort that is needed to sustain mental simulation and allowing the designer to take on more complex challenges. Alternatively, the ViP method (Hekkert and van Dijk, 2011) might assist a designer in reasoning from a vision on the future context of a design-to-be towards an articulation of a product concept and its intended interaction with users. On a more general level, it has been shown that sketching can be a thinking tool for designers assisting in mental simulation and in resolving uncertainty (e.g. Scrivener et al. 2000). In this way, design methods can facilitate mental simulation by helping to structure the reasoning process.

Assisting the designer in decoupling

Mental simulation requires cognitive decoupling (Stanovich et al. 2011). That is, in order to imagine a new design, a designer needs to differentiate the mental representation of the new design (i.e. the 'idea in mind') from designs that exist in reality. Similarly, in order to imagine a new goal, a designer needs to sustain a distinction between the new, imagined goal from existing goals (e.g. distinguishing between a goal that is being clarified in one's mind from the goal that was formulated in a design brief). Decoupling requires temporary inhibition of intuitive prompts and requires great mental effort and is typically accompanied by high levels of uncertainty. For example, a designer who is in the process of imagining new concepts using the fish-trap method (Muller, 2001) might be assisted in coping with the uncertainty that is experienced while imagining and fleshing out some initial concepts by providing an overview of the whole process. It might invoke the following (comforting) thought: 'I'm probably doing fine and don't have to worry because the method tells me I am only halfway in this process and don't need to know all the details yet'. In this way, a method can assist in the effortful process of cognitive decoupling by helping a design to sustain mental simulation and deal with the feeling of uncertainty that typically accompanies mental simulation and decoupling.

Assisting the designer in timely activating of reasoning

An important function of reasoning is to monitor the output of intuition and interrupt when it is deemed to be inappropriate. Particularly in design however, intuition has also been linked to expertise and creativity. Their successful utilization depends on 'acting on intuitions', 'postponement of judgment' and 'suspension of disbelief''. Thus, the timely activation of reasoning as a way to monitor intuitive output should be seen as a balancing act. For example, a designer who uses the brainstorm method (Osborn, 1979) might be assisted in determining when to postpone and when to allow criticism in the process of idea generation. It might assist in staging idea generation as a phase in which association is stimulated to generate large quantities of ideas (a capacity of the intuitive mind) and criticism suppressed. Later on, it might assist to stage a phase in which critical reflection of ideas in the light of a design goal is stimulated (a capacity of the reflective mind). Alternatively, the use of the 'premortem' method (Klein, 2007) can help to reduce overconfidence and improve decisions in organizational planning. A project team might be assisted in creating a realistic project plan by being asked to imagine that the project has been a disaster and come up with reasons why the project failed. In this way, a method can help in determining when to employ critical thinking and assist in activating critical thought.

Assisting the designer in skill development

Up to this point, we have discussed the role that methods can play on a short term, i.e. how they might assist designers in a situation. Skill development is a slow process that happens over time with leaps and bounds (Dreyfus and Dreyfus, 1992; Lawson and Dorst, 2009). A skilled designer needs to possess appropriate beliefs, rules, knowledge, procedures and strategies to be able to recognize many different situations and to respond to them appropriately. Development of skill requires the opportunity for a prolonged period of reinforced practice. For example, chess players take at least 10 years of practice to become an expert (Chase and Simon, 1973; de Groot, 1978; Kahneman and Klein, 2009). The concept of reinforced practice is crucial to distinguish true skill from overconfidence. Although a tempting one, subjective feeling of confidence is not a good indicator for true skill. This is because people generally do not have access to the origin of their intuitions and intuition – whether appropriate or not – is generally accompanied by a feeling of confidence (Kahneman, 2003; Kahneman and Klein, 2009). Rather the value of an expert's judgement relies on "the predictability of the environment in which the judgment is made and of the individual's opportunity to learn the regularities of that environment" (Kahneman and Klein, 2009, pp. 515). Methods can assist designers by providing 'scaffolding' for reinforced practice and skill development. That is, by assisting a designer (or design student) to recognize patterns in design situations, and by assisting a designer to produce appropriate responses to design situations methods can support reinforced practice that is necessary for skill development. Early stages of the development of skill typically happens in a context of learning – in which the ability to make mistakes and space for feedback on process – are crucial conditions.

§ 2.5 *Method mindset*

In bridging the gap between the analysis of different fundamental roles that methods can have and the individual prerequisites for a person's proper use of a method, the concept of method mindset is introduced here. When learning to use a specific method, designers develop what may be dubbed a 'method mindset'. Development of a method mindset represents the 'scaffolding' function that methods can have in developing expertise. It is likely that over time, and as a mindset is developed, the method itself becomes less important as more and more of a designer's actions will be driven by intuition. A method mindset is a designer's acquired set of knowledge and beliefs related to the use of a specific method. As such it incorporates at least theoretical knowledge and practical knowledge about the method and its use and relevant experiences with using the method (Andreasen, 2003). A method mindset forms 'an important part of a mental framework leading to the execution of a method' (p. 209). Furthermore, in this thesis I argue that a method mindset entails at least three additional elements. First,

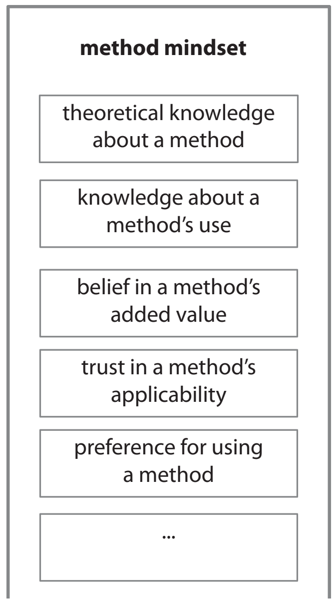

Figure 2.7 Method mindset elements.

method mindset entails a designer's beliefs about a method. For example, a designer might believe in the power of brainstorming as a way to generate creative ideas. Second, method mindset entails a designer's trust in the ability to use a method to his or her benefit. For example, a designer might be confident that he can use a method. Trust in a method reflects both confidence in one's ability to use the method in a way that yields desirable results as well as confidence in the applicability of the method itself to a certain goal-domain. Third, method mindset entails a designer's preference for using a method. Preference can show through choosing a method in favor of alternative methods or strategies and through being on the top of a designer's mind. For example, a designer might prefer to use brainstorming over synectics or might immediately think of brainstorming when wanting to develop creative ideas. Together, a method mindset represents a person's 'mental equipment' that is necessary to purposefully use a method to his or her benefit (figure 2.7). In this light, a designer's method mindset determines the ability to grasp the different facets of a method and its application (Andreasen, 2003). A proper method mindset is – often implicitly – seen as an asset in design, as both practice and education link the development and mastery of specific design capabilities or skill to specific methods. The development of a method mindset is a learning process that takes effort and time. Most cognition is intuitive, underlying routine behavior that is difficult to change. Therefore it is not easy for designers to adapt their work practices according to a method. It is relevant to ask: what does it take for a designer's mind to be equipped for effective use of a method?

Learning how to use a new method typically requires its users to develop an appreciation and ultimately a preference for working with that method (or certain types of methods). For example, for a designer, a decision to 'invest' in learning about a certain method can be instigated by a pragmatic need. That is, a designer might be motivated to use a certain method because he or she recognizes that it yields direct added value for a specific activity. Or a designer might be motivated to invest in a method because he or she recognizes that it can help to acquire certain valuable skills. Similarly, a designer might be motivated to learn to use a method because it allows a claim to certain capabilities. Most design professionals and educators would therefore probably agree that motivation and interest, as captured in the designer's general preference for a method, are key factors in determining whether a designer or student will use a certain method to their benefit on the long term.

In general, learning to use new methods in industry requires proper circumstances for learning, which are often shaped by organizing ‘training days’ or ‘workshops’ around specific skills and methods. At the same time, in developing their professional capabilities, many designers learn about the use of new methods in their ‘own time’. As a method mindset is individually developed, it follows logically that there are large differences between designers’ mindsets. As a result, individual differences are not only relevant for understanding the general effects of method usage but also for understanding the be-nefits students and practitioners gain from the use of specific methods. Given the argumentation above, understanding the role methods play in design in general, and also for individual designers, is topical in reinforcing adaptive method usage in design. Different mindset elements are elaborated (see also figure 2.7).

Theoretical knowledge about a method

A designer can have more or less knowledge about the underlying theory of a method, or the mechanisms that make a method work in certain situations. Such understanding can include knowledge about the phenomenon on which the method is supposed to impinge (e.g. help to understand human creativity), the procedure through which a method will allow a designer to intervene successfully (e.g. by first postponing criticism and stimulating associative thought), and about the effect the method’s use is supposed to have (e.g. produce ideas or decisions, achieve good coordination, etc.). For example, one might know that the method of brainstorming can help to generate good ideas. A designer that has theoretical understanding of the method will know that it is based on the fact that human beings can develop creative ideas by association. They will see that a group setting in which group members can associate on each other’s ideas has the potential of producing many creative ideas. A deep understanding of that human ability will help a designer to make inferences about prerequisites and necessary conditions needed for an effective brainstorming session. For example, by understanding the process of association, a designer can infer that brainstorming works better when there is a commonly understood, and well-defined problem to work with. Moreover, he or she can infer that participants need to have sufficient knowledge of (an aspect of) the problem area to be able to make useful associations, and avoid skimming the surface of the problem with shallow ideas. It becomes clear that having a theoretical understanding of a method can influence its use.

Knowledge about a method's use

A designer can have more or less understanding of a method's use. Practical understanding will be developed through direct experience with the use of a method. Such understanding can include having expectations about what the use of the method will yield in terms of results (e.g. a high number of design ideas) and how it can help in terms of collaboration (e.g. enhance communication, coordination, justification). It will also include understanding the practical conditions and prerequisites for a method's use. Such understanding will allow a designer to adapt a method to the given circumstances and to see how it can fulfil different roles during a design process (e.g. to help justify a project, to help coordinate, to help 'grasp' a complex problem). For example, one might know that brainstorming works best with a group that is not too small and not too big and when participants have experienced a brainstorm session before. That the basic rules of brainstorming should be emphasized and enforced as many people tend to easily criticise ideas instead of associating further. With practical experience, a designer will know when to moderate the group and when to allow them to deviate from the topic. Practical understanding will also entail knowing when enough ideas have been generated and the group can move on to the next phase. It becomes clear that having practical understanding of a method's use influences the efficient use of a method.

Belief in a method's added value

A designer can belief in the added value of a method's use (e.g. belief that brainstorming is a powerful method for idea generation) and he can also believe in the values that are associated with a method (e.g. the user is the most important stakeholder in design). Beliefs about a method can exist relatively independent from the actual use of a method, that is, a designer can believe in a method without actually having used it or know how to use it. A designer's beliefs about a method are typically influenced by the social context, as well as by a designer's personality. For example, one might work in an organization that preaches the use of individual work rather than group work, which might influence a person's predisposition towards the brainstorming method. Next to that, a designer might have heard that the brainstorming method often yields superficial ideas (i.e. when used without care) and infer that the method does not add value. Furthermore, a designer might be a very conscientious and introvert person, and will be predisposed to reject the brainstorming method for its loose procedure and requirement to be extravert in a group of people. It becomes clear that a predisposition to more or less believe in a method will influence its use.

Trust in a method's applicability

A designer can have trust that a method is applicable given certain circumstances. Trust in a method reflects both confidence in one's ability to use the method in a way that yields desirable results (e.g. confidence in being able to use the brainstorming method) and confidence in the applicability of the method itself to help reach a certain goal (e.g. confidence in the applicability of brainstorming for idea generation in groups). Trust in a method will include confidence in its robustness over different situations and the extent to which it can be easily adapted to fit specific circumstances. For example one might trust that when used in appropriate circumstances, using the brainstorming method will generally yield useful ideas. Next to that, one can trust that the brainstorming method will do so in a variety of circumstances (e.g. different group sizes, different types of problems) and each time that it is used (e.g. the first time, but also the twentieth time it is used). Additionally, one can trust that the brainstorming method can be adapted to specific circumstances without losing too much added value. It becomes clear that increased trust in a method influences a designer's motivation to use it

Preference for using a method

A designer can prefer to use a method over alternative methods or strategies. Preference for a method reflects a designer's tendency to use a method frequently and in favor of other strategies or methods. Preference can include a predisposition for a particular type of method (e.g. more systematic or more heuristic), the degree to which it fits a designer's need for control (e.g. if it helps to be as complete as possible, if it allows simplification or clarification of the problem, if it helps to create an overview), and need for articulation (e.g. if it helps to justify, coordinate or communicate certain activities, coordination, communication). For example, one might prefer the brainstorming methods over the synectics method because the latter is too elaborate and systematic for one's preferred way of working. One might have experienced the use of the brainstorming method as liberating because it restricts criticism advocates a rather free and unstructured procedure during some part of the procedure. Such a positive experience might contribute to a preference for the method in the future. It becomes clear that a preference for a method influences its use.

§ 2.6 Conclusions

In this chapter, we have argued that from the perspective of the individual designer, methods are mental tools that aid them in dealing with non-routine situations. We have argued that they can do so along three dimensions: by enhancing a designer's ability to design (e.g. by allowing a designer to grasp more complex phenomena), by enhancing a designer's reflection (e.g. by helping a designer to sharpen intuitive expertise through reinforced practice), and by enhancing a designer's learning (e.g. by helping to develop a new capability to design). Method usage has been brought into context with their users – the designer – and their context of use – the arena of practice and the arena of education. In doing so, method usage has been connected to non-routine situations, design expertise and the individual prerequisites for method usage in design.

In the next three chapters, we report on three empirical studies through which we investigated those three core phenomena: (1) uncertainty and non-routine situations, (2) expertise and method usage and (3) individual differences in method usage.

This chapter is an adaptation of Daalhuizen, J. Badke-Schaub, P and Batill, S. (2009). Dealing with uncertainty in design practice: issues for designer-centered methodology. In the Proceedings of the 17th International Conference on Engineering Design (ICED'09), Palo Alto, CA, USA, Vol. 9, p. 147-158.

•3
Uncertainty & non-routine situations *in design practice*

In the previous chapter, the use of methods has been conceptualized as a situated activity. In doing so, the need for a good fit between designer, context of use and method has become apparent. Many researchers have studied the results of typical design practices and have often developed methods to support them. Yet few studies have addressed the use of methods in itself; as a situated phenomenon. In order to understand method usage in more detail, it is important to study the situations in which the need for methodological support might arise as well as the ways designers respond to these situations. That is, to study the types of situations in which designers might use methods, and to which designers should adapt their method usage. An important question to answer is: what types of situations do designers encounter in their practices? And how do they respond to these situations?

In this chapter, we address these questions by investigating non-routine situations that designers encounter in their practice, as well as their responses to such situations. Drawing on an interview study involving 16 practicing designers working at 6 different design firms the occurrence and characteristics of non-routine situations are studied through the use of semi-structured interviews. It is expected that particularly in situations of high uncertainty designers might feel the need for structure, and might consider the use of methodological support. The contribution of this chapter is twofold. First, we reveal types of non-routine situations that designers encounter, and some of the influencing factors that characterize those situations. In doing so, we provide a detailed account of the design arena in which they work, particularly of the situations in which the need for method usage is expected to emerge most often. As such, the results provide an empirical ground for the development of 'situated design methodology'. Detailed description of situations in which designers might use methods can support method makers with understanding when their method might be used, and develop them in such a way that they are better suited for a designer's adaptation and use in those non-routine situations. Building upon the work of Badke-Schaub and Frankenberger (1999a) who distinguished and studied different influencing factors on the design process, we expected that the occurrence of non-routine situations would extend beyond the realm of the design task. Thus, our study focused on non-routine situations related to the (social) context and the individual designer as well. Second, we reveal designers' responses to a number of non-routine situations, showing a broad spectrum of personal strategies that designers employ to deal with non-routine situations. These responses typically reflect cognitive strategies that resemble 'rules of thumb', and can be seen as alternatives to the many formal design methods that exist in the literature. When assessing the impact of (new) methods in design, they are usually not compared to such alternative (intuitive) strategies (responses). As a consequence, informal and/or intuitive strategies are rarely associated with systematic or heuristic methods or with the study of methods in design. Such strategies typically enter design practice 'bottom-up'. They emerge from designers' experiences with certain situations for which they have developed their own strategies. Whenever a designer externalizes such a strategy and articulates it in some way, it becomes a method. Over time, these and other 'informal' ways of working are often locally produced and, as they mature and are articulated, can become part of an organization's product development knowledge, and in some cases enter the scope of design researchers. Thus, this study contributes to developing a more detailed understanding of the suite of strategies with which practicing designers' respond to non-routine situations. As these are the strategies that design methods need to 'compete' with in the design arena, they should be taken into account when developing and evaluating methods in design.

Theoretically, the perceived need for methodological support is expected to arise in non-routine situations. Yet is this expectation a realistic one? Or are there other – perhaps even more frequently used – resources at the top of designers' minds in situations of high uncertainty? This question is particularly pertinent because methods are commonly seen as procedures that designers follow from start to end, and are expected to be commonly used in practice. A number of empirical studies have been published that show that designers' behavior is much more opportunistic in terms of method usage than was previously believed (e.g. Bender & Blessing, 2004; Visser, 1994). Seen in this light, it is expected that methods are part of a wide spectrum of resources that a designer has at his or her disposal. In order to investigate what kind of non-routine situations designers encounter and how they respond to these situations, we shall broaden our scope beyond the focus on method usage as taken in chapter 2. The research was guided by the following research questions:

- What types of non-routine situations do professional designers encounter in their practice?
- What types of responses to non-routine situations do professional designers evoke in their practice?
- What influencing factors characterize non-routine situations?
- What are patterns in the relative frequency of occurrence of types of non-routine situations and responses to non-routine situations?

§ 3.1 *Research method*

The aim of this study was to obtain insight into the range of non-routine situations that practicing designers encounter and the way they respond to these situations. The interviews were designed to address non-routine situations which they had encountered in their practice. Non-routine situations were defined as situations in which they felt 'inefficient or ineffective' or 'out of their routine' during specific projects. Participants were probed to talk about the factors that brought about these situations in-depth to reflect upon how they dealt with these situations.

Sample

In answering the research questions, 16 practicing designers were interviewed about their experiences regarding non-routine situations. The practitioners worked in six different design firms, of which five were located in the Netherlands and one in the USA. All firms were typical 'design consultancy firms', offering design capabilities as a service to external clients. One consultancy was affiliated with a large multi-national company. This consultancy also offers their services to third parties and all interviewees affiliated with this consultancy were mainly associated with working for external clients. In that sense, their work practice was comparable with the other participants of the study. The sample was heterogeneous in terms of experience-level, expertise and work-domain. The experience-level ranged from 1 to 30 years of working experience. The expertise-domains ranged from new business development to developing manufacturing strategies to project management in the field of design. The working-domain ranged from product design to user research and mechanical engineering in the context of design.

Data collection

The data was collected through open-ended, semi-structured interviews. All interviews were held at the location of the participant's firm except for two participants who were invited at the author's university for the interview. The interviews were performed in English by two interviewers. Both were familiarized with the topic and the interview guidelines (see Appendix A). The interviews took between sixty to ninety minutes. In providing context for the participant's answers, the purpose of the interview was explained at the start of each interview. During this introduction, the participants were also briefed on the broader aims with the specific study (the goals associated with the author's PhD project). In order to develop a common ground, the interviewer explained the way the term 'method' was framed in the research, including some examples of methods.

Data analysis

The data was analyzed based on thematic coding in Atlas-ti. Following Noaks and Wincup (2004), the data assessment was guided by a five-stage method. The method assisted in comprehensively assessing the large amount of data in a number of steps from familiarization with the data until verification of the emerging framework with the whole dataset and identification of patterns in the data. First, the author familiarized himself with the body of data comprising of 16 audio recordings. Familiarization started with a full transcription of the interviews, covering all utterances made by the interviewees. Second, after familiarization, recurrent themes (e.g. different types of non-routine situations) were identified. At this point, an initial list of non-routine situations was compiled as well as a list of responses. Some themes emerged from this phase that led to an initial categorization of the data into situation- and response-types. Third, in assessing the compiled lists, a thematic framework could be developed by abstracting the data and conceptualizing more precise themes. Fourth, in order to validate the framework, a number of interviews were indexed through the application of the thematic framework to the data. In confronting the raw data with the framework, it could be fine-tuned and finalized. The final framework consists of 33 categories divided over (1) non-routine situations, (2) responses to non-routine situations and (3) influencing factors that characterized non-routines situations, which are presented in the results section below. Subsequently, the final framework was applied to the whole dataset for indexing. Fifth, in investigating how the data was distributed over the themes, the indexed data was charted according to the themes of the framework. The charted data allowed seeing how often some of the non-routine situations and responses occurred over the whole sample, providing a sense of how important the different types of non-routine situations and responses are in the participants' perceptions.

§ 3.2 *Results*

Non-routine situations

In answering the first research question, the non-routine situations as described by the participants were clustered and grouped into nine different types of non-routine situations. Practicing designers typically described a large variety of non-routine situations. In the course of the 16 interviews, 54 non-routine situations were identified. For example, the participants raised issues concerning the way a project briefing should be framed, as is illustrated by a comment of an experienced designer and owner of a

design consultancy firm: “We have a huge issue understanding the scope of what a client needs. Like what is the right question to address in this project?” On the other side of the spectrum, the participants raised issues concerning problems in composing good teams for specific projects, as is illustrated by a comment of an experienced design manager: “one of the most difficult things that I find is finding, getting, the right people, because they could be all on different things here. Then, assuming you get some of the right people, getting them all aligned and then getting them to stay focused on the project”.
In order to decrease the number of situations to a manageable set, the 54 situations were grouped according to our thematic framework as is described in the previous section. The goal of this analysis was to identify types of non-routine situations and patterns in their occurrence. In analyzing the interview data for responses to non-routine situations, 9 different types of non-routine situations were revealed. The non-routine situations were characterized as situations in which: (1) designers' understanding of the design problem evolved, (2) designers had to work on a strategic level, (3) unexpected results were encountered, (4) designers needed to shift from analysis to a synthesis mode of thinking, (5) designers were inappropriately committed to a specific idea, (6) designers framed a design problem inappropriately, (7) designers had to interface with other stakeholders, (8) a design team needed to be composed and (9) there was a lack of leadership. In the following section, the nine types of non-routine situations are described according to their frequency of occurrence in the dataset (see section 3.3.1).

Evolving understanding of the design problem

Many non-routine situations were characterized as being caused by an evolving understanding of the problem during the process. That is, the definition of the design problem as described at the start of a project, changed as the project progressed. Occurrence of such non-routine situations was typically related by the participants to a (sudden) change in the design brief or a new interpretation of the task by external stakeholders. In such cases, the participants described that their understanding of the task shifted and a new way of approaching the problem was needed. This type of non-routine situation was typically described as an inherent property of a design process, as is shown by the comment of an experienced designer and owner of a design consultancy: "I think that's it's impossible to create a design process, where everything is moving the way you expect it to move. So in a design process itself, always things will happen that influence or you think have a negative effect on the feeling you had beforehand. So don't solve that. You must not solve that problem, because it's inherent."

However, in some cases it was tied up with the client's influence on a project. Participants described several situations in which a client introduced new requirements at a late moment in a project, as the following comment by a design manager shows:
"They [clients] come with requirements that should have been mentioned earlier, and can totally ruin the concept for a reason. I think that is always a big challenge."

The designers who talked about this type of situation were very clear that they are bound to encounter it in any design process, supporting conclusions from earlier studies on the 'co-evolving' nature of design problems (Dorst & Cross, 2001; Lloyd & Scott, 1994)

Operating on a strategic level

Also many non-routine situations occurred because designers needed to operate on

a strategic level. That is, designers were required to work with higher management and articulate the business value of design work. In this type of situation, designers were typically required to analyze and interpret strategic issues and develop strategic propositions, in parallel to working on the design of the product itself. In these cases, designers needed to grasp new (unfamiliar) types of issues. For example, designers needed to make sense of their design proposals in terms of strategic positioning of the client organization as a whole. Additionally, results needed to be articulated in a language appropriate for strategic decision-making by the client, as is illustrated by the following comment of an experienced design manager:
"Yeah, we're in a kind of critical transition period now of maturity in [name organization], where we have a lot of very important responsibilities in the company on a strategic level. So we are involved in proposing potential solutions, and we have to know what we're talking about, and [be] very plugged in to what's going on, and what's likely to happen in the future."

This type of non-routine situation is particularly pertinent because it is a relatively new responsibility for designers, as the following comment by the same manager illustrates:
"We have very good tools for that and we can also articulate that very well which is a unique skill for design, that management has now discovered, this communication ability, and this creation of a long term vision and a utopia to strive for."

Unexpected results

Some non-routine situations were described as occurring when a design activity produced unexpected (counter-intuitive) results. That is, while relying on their experience in working on a certain design problem, designers were surprised by unexpected outcomes that they (initially) could not explain. This type of situation typically requires a designer to move outside of his or her comfort-zone, and open up to learning something new, as is illustrated by the comment of an experienced engineering designer:

"So you come up with something that your intuition tells you, and then you actually go and try and prove it. And something doesn't pan out. And I think that is where the greatest learnings occur, because now you have to shift your mental model."

Shifting from the analysis to the synthesis phase

Some non-routine situations were described as occurring when designers make a transition from the analysis phase of a project to a synthesis phase. That is, designers need to shift their mindset from being focused on gathering and interpreting information about the design problem to a focus on imposing a new structure to that information (framing) and developing coherent concepts. A number of participants indicated that this transition sometimes evoked non-routine situations, as it moved them out of their comfort-zone, illustrated by the comment of an interaction designer:

"Well, for us it is coherence, determining coherence. You have al your research factors, you mapped your research and then you go to the coherence, and first concepts. First the statement or mission and then concepts. And that is a very, every time that appears to be a difficult phase to get it into, to put it into a framework."

In providing an explanation for the why such situations can be experienced as non-routine by designers, she offers the following comment:

"Well, in part this is in the character of designers (laughs). Because we are the type of designers who demand from our first ideas to be good. Or, we are not very eager to try" and "that means that you first have to have thought of everything before you go on. So then first things have to make sense in your head, and then you move on. But that is not always the case, it is not this black and white."

Escalation of commitment

In some cases, designers encountered non-routine situations that were caused by 'escalation of commitment' (Staw, 1981). In those cases, a designer or design team chooses to stick to a certain product idea because the resources that have been spent to develop it have troubled a rational view of its quality. This can happen in spite of evidence against the feasibility or viability of the idea. The phenomenon of is described by an experienced mechanical engineer and consultant at a design form in the following comment:

"You start going down a path, and then you committed too much resources to that path to see it clearly, to say we should step back and do something different. And I have seen that happen in two or three project where people get attached to an idea simply because of where you are in a timeline and not because it is a rational thing to be doing right now."

Another experienced designer and owner of a design firm recognized the danger of committing to an idea because of the effort that has been put into its development, as is illustrated by the following comment:

"Because you create insight in the process itself, you want to include this insight in the end result, because otherwise it feels shit. [Yet] because of that it takes more time to… Because otherwise you are fooling yourself. Because otherwise you say; I only have 200 hours, I said ok [to the client], so I make a decision over here, and this is the decision I have made. That's stupid of course. Because you know that somewhere here, at 80% of the project, you really embody the complexity of the assignment. And you know that some decisions over here were the wrong decisions."

Improper framing of assignment

Many non-routine situations were associated with the discovery that the initial way a problem was framed by the designer was not correct. This type of non-routine situation is similar to those in which the understanding of the problem evolves (see above). However for this type of situation, the individual designer has caused it to occur by insufficiently framing the problem at the start of a project, as the following comment shows:

"At the beginning of the project, which is the start of a project, I have the idea that it [improper framing] is often the case. Not only us, but often the case that for very few assignments, attention is paid to the proper framing of the assignment. And the sort of defining of the domain. What is it about? So first, often they start immediately. Like we cannot loose time, we have to go forward. And I think that this first step is very important to, like with a research project, and you learn it like this, but in practice... Yeah, things go very fast."

Interfacing with others

Many non-routine situations occurred that were characterized by problems in interfacing with other stakeholders of a project. That is, in this type of situations the

designer and others stakeholders (e.g. clients, users, colleagues) did not have a similar understanding of the issues at hand, leading to a loss in efficiency or effectiveness of the project. As shared understanding is a crucial issue in design, a balance must be found between sufficient overlap in mental models to be able to cooperate, yet at the same time sufficient differences to complement and challenge each other when needed (Badke-Schaub at al., 2007), as is illustrated by the comment of a design manager:
"There are many stages that take longer than you actually like. Well, what it usually really holds back, I would say: you need to fire up creativity, and you need to have a team with a common interest, common way of thinking, but still with some differences as well."

Composing teams

Some non-routine situations were characterized as being caused by problematic team composition. According to some of the participants, composing a team and achieving good team performance is often problematic, yet crucial for team performance. That is, composing a team with individuals that complement each other to fit a project's profile and that can work together productively is often challenging in design organizations, as is illustrated by the comment of an experienced design manager:
"One of the most difficult things that I find is getting the right people, because they could be all on different things here. Then assuming you get some of the right people, then getting them all aligned and then getting them to stay focused on the project, versus all the other distractions that people have."

Lack of leadership

In some cases, a non-routine situation was caused by a lack of clear leadership at the client's side. That is, as there was no clear decision maker at the client's side, conflicting

interests between client stakeholders prevented them to make crucial decisions. In these cases projects might suffer a loss in efficiency or even lose momentum. Some participants described how projects often involve a number of stakeholders from the client's side, for example a marketing representative, a development representative etc., each having their own specific interests, as is illustrated by the comment of an experienced design manager:
"On top of them are usually a sales-force of some kind, and on top of them is a marketing department. And on the other side of them is a development group, and project management. But above all of them is the senior executives."

When clear leadership is lacking, their interests might conflict when a crucial decision has to be made, potentially leading to conflict or standstill of the project, as is explained in a comment of the same design manager:
"And when you're dealing with development and marketing and the end-customer there is a conflict. Because they have different motivations. What often happens is, that you get this whole mechanism working, when you involve everyone, and everyone feels like they're a contributor and they're understood and moving. The decision maker will ultimately show up near the end and make some statements that make everyone panic."

Responses to non-routine situations

The participants typically described a broad variety of responses. In the course of 16 interviews, 80 responses were identified. For example, participants described how they involved stakeholders in certain phases of the process to ensure commitment and decision power of the client throughout the project, as is illustrated by a comment of an experienced design manager: “we always involve the client in the discussion; I think it’s dangerous not to do that. And also we involve their customers in our discussion.” On the other side of the spectrum, participants described how they kept going under high levels of uncertainty to avoid getting stuck on a particularly difficult problem, as is illustrated by a comment of a novice design engineer: “don’t stare at the computer forever trying to get stuck on a problem, get yourself unstuck.”

In order to decrease the number of responses to a manageable set, the 80 responses were grouped according to our thematic framework. The goal of this analysis was to identify types of responses to non-routine situations and patterns in their occurrence. In analyzing the interview data for responses to non-routine situations, 9 different types of responses could be revealed. The response types included: (1) involving stakeholders in the design process, (2) invoking strategies to be able to keep going, (3) articulating the business value of a project, (4) explicitly framing the design problem, (5) creating an open communication culture between project stakeholders, (6) relying on intuition, (7) introducing team members from different disciplines, (8) visualizing information to build narratives and (9) taking ownership of a project. The nine types of responses are described in the following section according to their frequency of occurrence in the dataset (see section 3.3.2).

Involving stakeholders

Designers have to deal with multiple stakeholders – for example clients, users, manufacturers, etc. – that have different backgrounds, beliefs, routines, etc. These stakeholders typically have different, and often conflicting, interests in design projects and can have an influence on its success. Different stakeholders have different understandings (mental model) of a design project, often causing problematic situations. A typical response to non-routine situations is involving stakeholders throughout the process. In doing so, designers increase common understanding of both the problem and the design process and decrease the chance of misunderstandings that are potentially detrimental to a design project. For example, involving a client in a project will evoke them to adjust their (business) scope to a wider scope, considering the needs of other stakeholders as well, as is illustrated by a comment of an experienced brand manager: "We always involve the client in the discussion; I think it's dangerous not to do that. And also we involve their customers in our discussion, whether it be physical contact or interviews with the end-customer, or if it's gathering information about users. Because I think quite often there is so many business issues that they tend to think less about the satisfaction of the customer, or the use-experience, or the total brand-experience."

Additionally, involving stakeholders early on is used to create 'buy-in', resulting in more commitment and increased chances of success of a project, as is illustrated by a comment of a design engineer on how they involve clients in the kick-off meeting for projects: "We really try to be a lot more transparent throughout the process and get them [clients] involved. So I think really the responsibility falls to us as design consultants, to warm up the client and engage from the client what range of solutions they are looking for, what is their appetite for technical risk? Do they really want a game changing innovation here? Or do they just want just a model-year rev [revenue]? So I think that's where the kick-off meeting is really pivotal and if you have a kick-off meeting that leaves you with a clear vision of how the client thinks about things and about what they want to do, then you can be a lot more efficient in your design process."

As top-management involvement was mentioned to be a key issue for many projects, participants discussed specific strategies for acquiring attention from them, as is illustrated by an experienced design manager:
"So we have to establish a very high perceived value in the companies we deal with, in order to get the attention of the top management, and to make sure that the benefits are communicated about design innovation and about validity in business of what design can offer."

Keep going

Designers encounter many situations with high levels of uncertainty. In those situations goals are typically ill defined and the solution space is typically large. Such situations can induce a strong feeling of ambiguity and cause the designer to hesitate and potentially "get stuck". In order to keep going, designers invoke a range of strategies, such as involving colleagues, building prototypes or keeping a positive or playful attitude, as is illustrated by a comment of a novice design engineer:
"Prototyping would be another one [strategy]. To fail from prototypes, don't get attached to them, make them, built them, learn from them. And don't stare at the computer forever trying to get stuck on a problem, get you unstuck. And then I mean again the other one, brainstorming, encouraging lots of ideas, and not thinking that you can create it in your cubicle, but that you can seek other people and seek other expertise to."

Articulating business value

Many non-routine situations occur when designers work on a strategic level, having to

collaborate with higher management. In these cases the client expects that the potential business value of a solution is articulated, even during the conceptual phase of design, when success is still hard to exactly predict. These situations require designers to present their solutions in a business context, and in a business language. As a response, designers often try to articulate the value of a proposed solution in terms of how it could add value for a user, in a market, and – in the end – for a client. Often these articulations have the form of narratives that tell how a proposed solution has value for users in context. In doing so, designers express the strategic value of the solutions they are developing, as is illustrated by a comment of an experienced design consultant:
"You have to have a narrative to tell the client at the end of the day. [This is] frankly all the structure you need to understand the project you are doing. How are we are going to build a narrative that makes sense? And a very cross way of putting it is: these people have spent 200.000 dollars, they want a story about where that 200.000 went."

In nuancing this comment, the same consultant comments on how to manage a client's expectations in a phase when exact predictions of market success are still hard to make:
"Of course they want success too. But if you tell a story that makes sense, they can understand, then you will justify that. It doesn't even have to include the success expected as long as the story is good."

At the same time, some participants mentioned that by articulating the role of future technologies and products in terms of roadmaps designers can help organizations to reason about their strategic position in the future, as is illustrated by a comment from an

experienced design manager employed in a large multinational:
"And a critical part is developing future roadmaps and targets. So it's not just about making something cool, it's about looking at society and drawing some sharp conclusions about what kind of company we need to be in the near future."

Framing the problem

Many non-routine situations are related to difficulties in framing a design problem appropriately. Design problems are often complex and ambiguous and resist a comprehensive understanding in the early phases of design, as their understanding tends to evolve along with the development of a solution (see e.g. Groeneveld, 2006). Designers try to frame the problem explicitly, sometimes together with their client, to create a shared frame of reference, as is illustrated by a comment of an experienced designer and founder of a design firm:
"So you first create a frame of reference, and if you agree upon this frame of reference, then everything is related to this context. So your judgment is not an absolute judgment, but a relative judgment. And because it is relative, you can have communication with the client. Because it is not anymore about: 'ok I like this color, and because I am a designer, and I have a lot of success this color [...]'. No this color has meaning in relation to the context I have defined over there, and we have agreed upon this context. So, what we do with the client, we first work together in creating this context, and then we have to say ok do you agree on this context? And if we agree on it, then this is the frame of reference. And this creates a lot of clearness in the rest of the process. So, when we present something, clients never say: 'OH what's that?' because we can explain exactly where it comes from."

Creating an open communication culture

As design is characterized by uncertainty about the outcome, many non-routine situations occur when stakeholders in a design process feel uneasy with not knowing it early on, simply put by a design manager as: "There is always the problem that when you design, you can't start out with a final design, obviously". Yet particularly for innovative design projects, it is crucial that stakeholders comments upon the object of design as it is being developed in order to take their interests into account, as is illustrated by a comment of the same design manager:

"Whatever stage design is [in], it is a common understanding of how the future could look like. And it is a tool for everybody to comment to that. So a product manager on his own cannot describe how his future product could look like, and let his brand manager comment on that. But if you as a designer create an image, create a physical or virtual model, that's a vessel for communication, for discussion. Design and communication and discussion are really one thing."

Participants described that an important response to this phenomenon is the creation of a culture of open communication. That is, to enable the effective evaluation of information designers try to create a culture in which the stakeholders that are directly involved in the design process have the feeling that they can communicate freely without being judged or criticized and discuss the design object as it is being developed, as is illustrated by a comment of a design manager:

"And managing that [communication and discussion] is still the most important part of success for us - and that's within teams and to clients and to stakeholders - and so I think that [if] you try to maximize communication is great. And then I feel that you can solve pretty much any issue by owning up to it. I think it's very, very important to create a forum where people can be honest about how they feel they're doing, how they're going, both internally and especially to the client."

Relying on intuition

Many situations in design require decisions without a complete understanding of the design problem. Inability to acquire a complete understanding of the design problem can be associated with for example time pressure or with incomplete or ambiguous information that is available. In these cases designers try to find familiar patterns and intuitively frame the problem or make an intuitive decision. This type of response is inherent in designing (see e.g. Groeneveld, 2006) and when used with care and sufficient experience can be reliable strategy, as is illustrated by an experienced designer:
"If you have a lot of context factors you understand that it's almost impossible to make a statement [decision for strategic direction]. Because there are so much parameters, you can not get a grip on all these parameters at one time. And we always said you have to use your intuition to get the statement right. But this is only one tool, to use your intuition."

Also in deciding between different approaches, intuition sometimes plays a role when designing, as is illustrated by a comment from an experienced engineering designer:
"I rely on my experience, we talk about four different ways to, you know, to solve a problem. And you know, which ones ring alarm bells? And you know which ones they feel like they have promise?"

Introducing multidisciplinary team members

Many design problems are very complex due to their multifaceted nature. They are for example complicated due to issues related to user behavior, to competing technologies, to sustainability issues, etc. Knowing about certain specific issues early on in a design process can help to avoid redundant work later on, as was observed by a design engineer in a project when they choose to work with the manufacturing technique of foil forming: "the team didn't had expertise in a particular area of manufacturing, and you know had we had someone on the team knew exactly how foil forming works, we would have known long ago, not to do that". In these situations designers include specialists from relevant areas to ensure a more comprehensive view on the design problem and the solution, as is illustrated by an interaction designer:

"I think that everything is useful to design. I can use everything to do a research, every type of information, every specialism. And that I like to look further then the specialism of design to. Much from psychology and sociology is integrated in designing."

Visualizing information, building a narrative

Information associated with conceptual design solutions is often hard to articulate verbally in a way that can be easily grasped by all stakeholders. Attempts to do so often leads to communication problems with various stakeholders. Designers often respond to those kinds of problems by presenting information visually, as is illustrated by a comment of a design manager: "but if you as a designer creating an image, creating a physical or virtual model, that's a vessel for communication, for discussion". That is, designers visualize information related to the design problem or the solution by creating narratives (scenarios) and sketches of product ideas or concepts to increase shared understanding between the stakeholders to enable more effective communication and discussion. Storytelling has received considerable attention in the design management literature, being acknowledged as an important responsibility of design in a business context (see e.g. Baek, 2006; DeLarge, 2004). This is also illustrated by a comment of a design manager:

"Now I learn more and more that I've got to realize that many of our clients, the person who has to internally justify themselves 200.000 dollars. That's not a way of reaching them [verbally], and making them understand the value of their work, you have to tell the story in a very different way. Very graphically, very visually. Things like video. Things that people relate to from almost an entertainment world."

Taking ownership of project

When designing, some non-routine situations occur when a clear organizational structure is lacking in a design team. Although a 'flat' team organization is often seen to support an open-team climate, it can also lead to situations in which team members do not take responsibility for the whole of a project. In these cases designers sometimes responds by taking ownership of a project themselves, enforcing commitment of team members by setting common goals and approaches, as is illustrated by an experienced design manager:

"You contribute and you figure out what part you play and how to support each other. I think that's really important. I think that comes from the kick-off meeting and the leadership of the team – to establish that – and also to neutralize potential problems. So by saying: 'this is our goal, this is our approach... do you agree with this?' We improve it, before we start and find out if it's not optimum."

Influencing factors that characterize non-routine situations

In answering the third research question, the factors that were used by the participants to characterize non-routine situations are analyzed. These influencing factors were typically brought forward as indicators of specific non-routine situations, as they were describing non-routine situations in detail. In some cases participants described how such factors were also useful in determine an appropriate response to deal with the non-routine situation. That is, designers usually described one, two or more factors that in their perception had led to the occurrence of the non-routine situation or that had guided the choice for a specific response to a non-routine situation. For example, a mechanical engineer described how certain factors influence his choices for a certain strategy: "How you're going to tackle problems (...) depends on the external circumstances, and the timeline and the complexity". Through analyzing the data, 72 instances were identified in which participants described influencing factors to characterize non-routine situations. The 72 instances as described by the participants were clustered and grouped into 17 types of influencing factors (see appendix B). Furthermore, the factors were organized according to the main source or origin to which they could be attributed. That is, factors were attributed either to the task, the individual designer or the context of a design project.

§ 3.3 Data assessment

In answering the fourth research question that was articulated earlier in this chapter, and in going beyond the individual types of non-routine situations and responses to them, we investigated patterns in their frequency of occurrence.

Non-routine situations

The non-routine situations that were described by the participants were attributed to their main category and summed up per type. Following the conceptualization of method usage as a situated activity, as articulated in chapter 2, three main categories were defined as situations attributed to (1) the designer himself, (2) the (social) context for the design project and (3) the design task. Each of the 54 non-routine situation mentioned during the interviews was attributed to one of the above-mentioned categories. Non-routine situations that were described as being an inherent part of the design task, were categorized as 'task-related' situations. For example, some participants described that their task included to work with higher management when designing, forcing them to operate on a strategic level. Non-routine situations that were described as being caused by (erroneous) behavior of designers were categorized as 'related to the individual'. For example, one participant described that a non-routine situation occurred when a team member was overly committed to an idea merely because of the effort put into its development. Non-routine situations that were described as being caused by interactions with stakeholders in the social context, in which a project takes place, were categorized as 'related to the social context'. For example, some participants described how clients sometimes present requirements in an untimely manner, or introduce new requirements late in the process, leading to non-routine situations.

Applying the categorization scheme to all 54 non-routine situations led to an overview of their frequency of occurrence as mentioned during the interviews and the main causes to which they could be attributed (figure 3.1). What stands out from mapping the types of non-routine situations in terms of their frequency of occurrence?

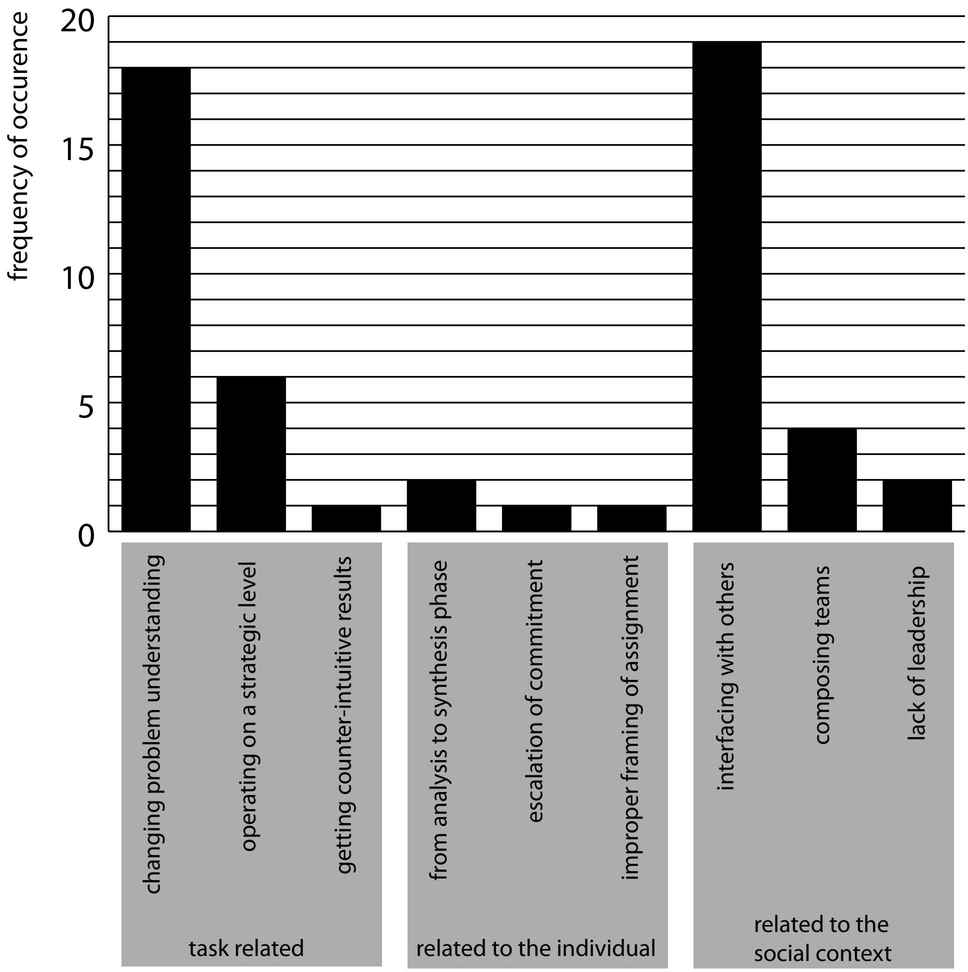

Figure 3.1 Frequency of occurrence and attributed cause of non-routine situations in design practice.

First, our participants often reported a type of non-routine situation in which they struggled to interface with other stakeholders during the design process. That is, as a design project was progressing, the process got stuck on a lack of understanding or commitment of one or more stakeholders to the project. Together with the co-evolution of problem and solution, interfacing-problems forced our participants most often (37 out of 54 non-routine situations) to reconsider current perceptions and expectations surrounding their projects, and to come up with a new response. Second, many non-routine situations occurred because of designer's evolving understanding of the design problem. That is, as the design solution is clarified more and more, new aspects of the design problem are brought to bear, which need to be taken into account. Such situations were mentioned relatively often in relation to non-routine situations as they forced a designer to reconsider his or her current perception of the project and approach. The phenomenon as described above is associated with problem solving in design and has been described in the literature as the 'co-evolution of the design problem and solution' (Dorst & Cross, 2001; Lloyd & Scott, 1994). As such, our data underlines the importance of recognizing the 'innoductive' nature of design reasoning, as has been articulated by Roozenburg (1993), which was also discussed in section 2.1. Third, six participants reported non-routine situations that occurred due to their strategic role in a project which required them to operate on a strategic level. In recent years, designer's strategic role has received increased attention in the literature (see e.g. Brown, 2009; Verganti, 2009). In this role, designers are typically portrayed as consultants who assist companies with innovating, oftentimes on the level of the organization (e.g. proposing changes in product portfolio or market strategy of a company). Again, our data underlines the literature by showing that designers recognize their strategic roles, and that this position brings about non-routine situations. Fourth, very few non-routine situations were attributed to the designer himself. This does not come as a surprise, as self-criticism towards one's own behavior is no small endeavor for human beings in general as is

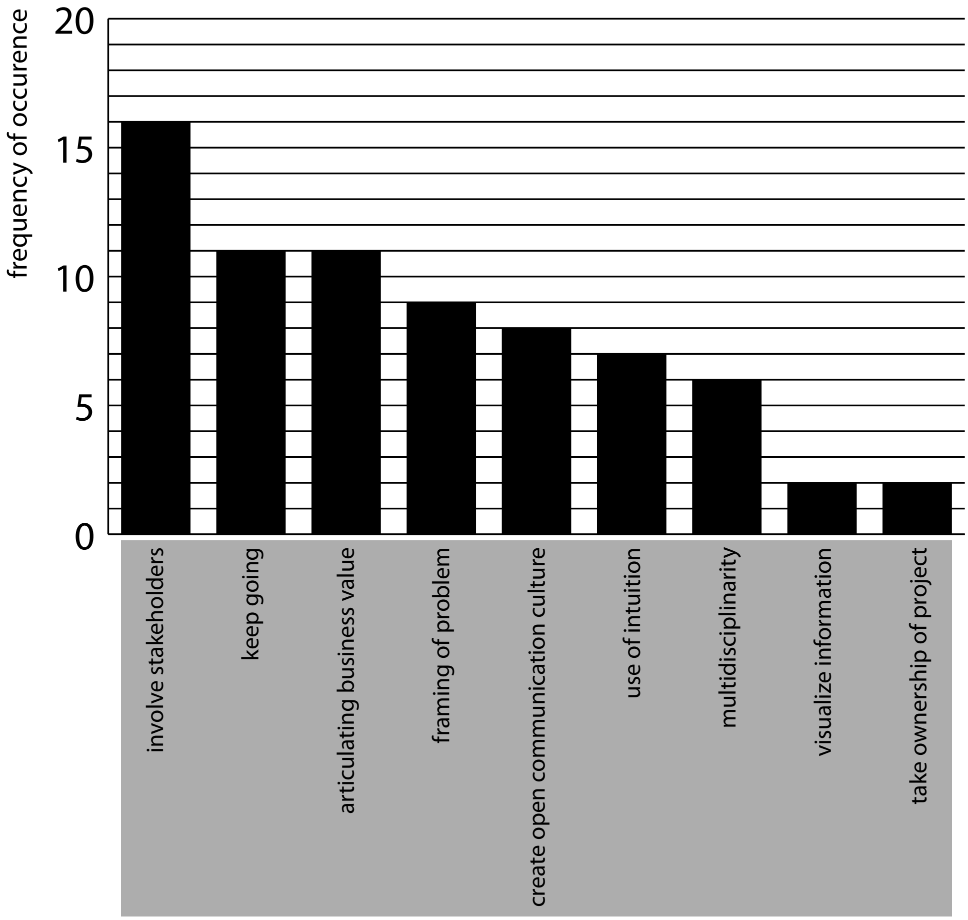

Figure 3.2 Frequency of occurrence of responses to non-routine situations in design practice.

explained by the concept of attribution bias (Heider, 1958). Yet it should worry method makers as the use of their methods depends – to some extent – on designers' awareness of their own limitations and proneness to certain errors.

Responses to non-routine situations

The response types that were mentioned by the participants were accumulated per type. Mapping all 80 responses led to an overview of their frequency of occurrence as mentioned during the interviews (figure 3-2). What stands out from mapping the response types in terms of their frequency of occurrence?

First, the responses that were described by the participants seem to fall outside of the scope of mainstream design methods. That is, they do not resemble typical 'design problem solving' or 'decision making' methods that make up the majority of the design methodology literature. A case in point is the most frequently mentioned response aimed at involving stakeholders. It is quite surprising that although almost all participants mentioned it as a response to certain non-routine situations, very few methods in the literature address this issue specifically. The methods that do exist to deal with involving stakeholders are mostly practice-based. Second, the participants' responses were described as having a strong heuristic nature. That is, they were described as rules of thumb that provide a general sense of guidance or priority to the designer employing them, without prescribing detailed procedures for how to go about designing. A case in point is a frequently mentioned response aimed at framing the design problem. This response is sometimes employed when confusion exists about the design problem, which has led to inefficiency or even getting stuck. The activity of reframing has only received mild attention in the literature (see e.g. Paton & Dorst, 2011) – particularly in terms of method development – yet it was regularly mentioned by our participants. Third, unlike the occurrence of non-routine situations within our sample, the response types were much more evenly distributed in terms of their frequency of occurrence. That is, with a total of 80 response types mentioned, 7 out of 9 types were mentioned 6 or more times. The designers in our sample apparently utilized a varied set of responses for a skewed set of non-routine situations. Or in other words, for the same type of non-routine situation, designers have several possible responses available.

§ 3.4 *Conclusions*

Traditionally, methods are aimed at helping designers to deal with the design task in a strict sense. The broad variety of non-routine situations as presented in this chapter provides an empirical argument for reconsidering the scope of design methodology to include the (social) context as explicit elements. That is, method developers should also take into account the social dimension of designing as they are a source for non-routine situations and potentially for the need for methods. That is, design methods might support designers with more than bringing structure to designing in a strict sense – i.e. with more than understanding the design problem or manipulating the object of design itself. For example, methods might support designers with bringing structure to their communication with clients, with involving stakeholder into the design process, or even with reinforcing their own confidence in the effectiveness of a certain way of working. We are quick to note that some methods exist that do address problematic issues that go beyond the design task. A case in point is the Scrum method (Takeuchi & Nonaka, 1986), which has become popular in software development and new media design not only for the purpose of structuring development processes, but also for enhancing collaboration and client involvement in development processes (Schwaber, 2004). Furthermore, we might speculate that the personal realm is also area in which methods might be beneficial, but is underreported. A more detailed understanding of the types of situations in which designers feel that their own experience is not sufficient for determining how to proceed is expected to serve as a stepping stone for more designer-centered method development. More specifically, by providing an overview of types of non-routine situations, we hope that method developers will become more aware of the context and purpose of designers' potential need for method usage.

An important outcome of the study in this chapter is that designers mainly attribute the occurrence of non-routine situations to sources outside themselves. They most frequently refer to characteristics of the task and of the social context as sources of uncertainty. Another outcome of the study is that two types of situations stand out in our results: situations in which a designer's understanding of the problem changes, and situations in which designers have to interface with other stakeholders were mentioned relatively often by the participants. Both types of situations typically occur ad hoc – i.e. in the midst of action – and can cause increased uncertainty for the designer. As such, both types are good examples of situations in which a need for a method can arise in an ad-hoc manner.

The results also revealed that designers have a broad variety of responses at their disposal to deal with non-routine situations. These responses seem to differ from individual to individual, and from project to project. The responses found indicate that designers employ a rather rich repertoire of (cognitive) strategies to deal with non-routine situations that go beyond the use of typical design methods that refer to 'problem solving', 'creative idea generation' or 'decision making' in design.

Moreover, although some participants commented on methods in their practice, they were not mentioned as responses to the non-routine situations that they described during the interviews. This might be explained by the fact that the non-routine situations that were mentioned by the participants are typically not areas for which design methods have been developed. For example, the two most frequently mentioned situations, ‘changing understanding of the problem’ and ‘interfacing with others’ have been not the subject of much method development in design.

Limitations and further research

These results are a first step towards an improved understanding of the behavior of designers when facing non-routine situations. Through this understanding more appropriate ways of assisting designers can be developed as we continue to explore how design methods can support designers in dealing with uncertainty. Two particular aspects are important. First, there is a need for research to explore the relationship between the designer’s perceived source of uncertainty and the way in which a specific design method might allow for an effective response to that situation. A framework is needed to analyze specific non-routine situations and characterize them according to the immediate needs of the designer. Second, there is a need to encourage the designer to take a more comprehensive look at non-routine situations by reflecting on his own contribution to the situation. This study implies that designers focus primarily on issues related to the task and to the social context. If one could enable designers to reflect more effectively on the determining factors in non-routine situations, it may be possible to provide them with design methods that would support them in more appropriate ways. Although I make no claim as to the completeness of the list of non-routine situations, they do extend the basis for design methodology as a field of study, and as the body of design methods and tools. More specifically, they form an argument to consider contextual and personal factors as an object of study in design methodology, and as a basis for the development of future methodological aids.

This chapter is based on: Daalhuizen, J. & Badke-Schaub, P. (2011). The use of methods by advanced beginner and expert industrial designers in non-routine situations: a quasi-experiment. International. Journal of Product Development, Vol. 15, Nos. 1/2/3.

•4
Method usage & design expertise

Design expertise has been put forward as a major determinant of design performance (see e.g. Cross, 2004; Cross, 2010; Dorst & Lawson, 2009; Lawson, 2006). The development of expertise has been described as skill acquisition in which individuals go through distinct phases from novice to expert (Dreyfus & Dreyfus, 2000). The different phases of skill acquisition towards expertise entail the use of rules, recognition of situations, goal-directed action, planning, prioritization of actions, adaption of maxims to situation, use of intuition and development of vision to guide action (Dreyfus & Dreyfus, 2000). Progression from one phase to the next is not continuous but happens in leaps and bounds which are characterized by the subjective experiencing of uncertainty. Any individual will have acquired different levels of expertise in different domains. The aforementioned elements of skill acquisition have also been found to be relevant for the development of design expertise (Dorst & Lawson, 2009) Arguably they are closely related to method usage and – as both design methodology and design expertise make up two core phenomena in the design literature – they deserve to be studied in accord. In this context, an important question to ask is: how does expertise relate to method usage in design?

Design expertise has received ample attention in the literature in the past one and a half decade with numerous studies that have focused on differences between novice and expert designers (see e.g. Ahmed & Wallace, 2004; Atman, Chimka, Bursic, & Nachtmann, 1999; Atman, Cardella, Turns, & Adams, 2005; Casakin & Goldschmidt, 1999; Cross, 2004; Ho, 2001; Ozkan & Dogan, 2013; Popovic, 2004; Seitamaa-Hakkarainen & Hakkarainen, 2001). Close to the topic of design methodology, a German research group of engineers and psychologists studied the influence of individual characteristics – including level of experience – on the design process revealing substantial differences between designers with distinct educational background and level of experience (Pahl, Badke-Schaub, & Frankenberger, 1999).

However, the relation between a designer's level of expertise and his or her method usage has only been sparsely addressed in the literature. Thus, important questions to ask are: does the level of expertise influence a designers' tendency to use methods in a non-routine situation? And, how does method usage influence performance of novices and experts?

In this chapter we investigate the use of methods by practicing industrial design engineers that differ in terms of level of expertise. Drawing on a study involving 17 industrial design engineers, method usage and its effect on performance is studied for solving a design-planning problem. The participants were asked to create a project planning for a design project in packaging design. This means they had to 'stage' a project by formulating a process for it. A number of measures were taken to induce a non-routine situation for the participants and increase the level of uncertainty they perceived. The increased uncertainty was then expected to draw them out of their comfort-zone and consider levels other than skill-based, routine performance, including the option to use methodological support. At the same time, method usage was stimulated through a lowered threshold for using methods. That is, the accessibility and usability of the methods was enhanced. This was done because practicing designers are typically hesitant to use new methods for their work (Andreasen, 1991; Gill, 1980; Hein, 1994) and some authors have proposed that this is caused in part by the poor transfer of methods (Araujo, 2001; Stetter & Lindemann, 2005) and by the poor quality of the way methods are often described (Araujo, 2001). Therefore, the availability of methods was enhanced for the participants through providing a method database including an interface to navigate the database[1]. The conditions as outlined above allowed us to ask how – given a challenging problem, non-routine situation and access to methods – method usage of advanced beginner and expert designers compared to each other. Furthermore, the set-up allowed us to ask how method usage is related to their performance.

We hypothesized that the experts in our study would outperform the advanced beginners on average. And that they would do this in spite of the non-routine character of the activity, and irrespective of using methodological support. Expertise in design is commonly believed to be a decisive factor in determining performance. Particularly for a design planning task, the experts were expected to have a much larger set of relevant experiences at their disposal to choose from in order to create their project proposals. It was expected that experts would outperform advanced beginners.

§ 4.1 Design expertise & method usage

Research into design expertise has shown that expertise should be distinguished from innate talent and is a teachable and learnable form of thinking that is acquired through dedication and reinforced practice (Dorst & Lawson, 2009). From a psychological perspective, a designer's previous experiences will shape the perception of a situation and subsequent response to a great extent. Expertise allows a person to recognize

1 The method database did not contain planning methods, but rather design methods that could be used to reason about and plan the general structure of the project as well as specific design activities. furthermore, the participants were told that the use of the database was optional.

certain features of a situation and come up with a response. This process happens intuitively. It was elegantly described by Simon (1992) as a process in which: "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" (p. 155). Moreover, several studies have shown that expert and novice designers display different behavior, reflecting different cognitive strategies. See for example Cross (2004) for instances from the field of design and see for example Klein (1998) or Ericsson (1996) for instances from other professions.
The processes of perception and formulation of action are not necessarily accessible to conscious attention. Depending on the designers' perception the situation at hand will automatically be compared to cases that are stored in memory. These cases are a combination of a specific situation and one or more corresponding responses. The more relevant experience a designer has, the more often this will lead to intuitive responses. If, however, there is an element of newness to the situation this is likely to come to the designers' attention. At this point we can start talking about non-routine situations; the designer is required to consider his perception of the current situation and perhaps even to adapt his behavior to the elements of newness of the current situation. However, there is a threshold that might prevent him to start spending effort and time to reflect on how his intuitive approach should be adapted. The threshold to perform on a knowledge-based level (Rasmussen, 1974) and bypass routine behavior will be determined partly by the available resources – i.e., time, mental capacity, knowledge of the situation and possible actions, methods, motivation, confidence, etc. – and partly by the conditions of the situation at hand – i.e., risk of failure, impact of failure or success, social pressure, etc.

Uncertainty can arise from any of these issues, both related to the individual (e.g. self-confidence) as well as to the outside world (e.g. organizational goals, shifting priorities of the client). It arises at the level of the individual and thus the level of perceived uncertainty is likely to vary between individuals in the same conditions. Uncertainty will however only be represented in the designers' mind when she/he is consciously perceiving the situation and thinking about it. In the case of intuitive perception human beings are "biologically programmed to act on the perceptual best bet, as if this bet involved no risk or error" (Kahneman & Tversky, 1981, p. 8). It can be expected that experts are better equipped to act intuitively – and thus efficiently – but does this necessarily lead to superior performance when non-routine situations are involved? In situations that have a relatively high degree of newness to them – which is characteristic for design contexts – it appears to be beneficial for a designer to draw attention to situation's 'newness' (e.g., new type of problem, new discipline involved in the team, new technology involved, difficult client) and actively perceive and reason about such elements. Unfortunately, this will be at the expense of cognitive workload and time. And perhaps even more important; it will add uncertainty and doubt in the mind of the designer.

§ 4.2 *Accessibility & usability of methods*

Before a method can be applied, a designer has to perceive the need for it, find it, possibly select it amongst alternatives and understand its content and how to apply it. That is, the use of a method starts with a designer in a problematic situation and the awareness of a need for methodological support. The use of a method should thus be seen as a process (see Figure 4.1). Two important factors in this process are the

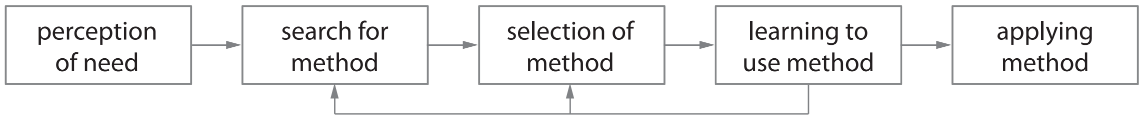

Figure 4.1 The process of method usage in design.

accessibility and usability of methods. Accessibility of a method is related to the ease with which it can be accessed by a designer. This can refer to the method description as a whole or elements of it (e.g. its name, a visual representation, etc.). Usability of a method is related to the ease with which it can be applied after it has been selected. This can refer to the format in which it reaches the practitioner (e.g. use of proper language, use of illustrations or examples of application) or to the additional information that is needed to apply it in a proper way (e.g. conditions of use, theoretical underpinnings). Accessibility and usability of methods are certainly no trivial issues under the pressures of industrial practice. Complexity of designing in practice involves for example time pressure, projects with multiple stakeholders, stringent quality requirements which can be detrimental to an organization's or designer's motivation to consider the use of new methods (Araujo, 2001; Frost, 1999; Hein, 1994; Stetter & Lindemann, 2005). In summary, if the need for a method arises, then accessibility and usability of methods become key issues for method usage as well. Thus, from the perspective of practicing designers, we set out to study the relationship between level of expertise and method usage in design. In doing so, the following research questions guide our inquiry:

- Given a challenging design planning problem and a non-routine situation, as well as access to usable methods, how does method usage of advanced beginner designers and expert designers compare? And,

- Given these conditions, how does method usage relate to the quality of their outcome?

§ 4.3 Research method

In answering the research questions, the method usage and performance of advanced beginner and expert designers was studied when solving a design-planning problem. The participants were all practicing designers with a background in product- or engineering design. All participants had received university level training in design and were familiar with using methods through that training. They were presented a design-planning problem, which they were asked to solve under time pressure (105 minutes). All participants were asked to deliver a detailed planning for a packaging design project in response to receiving a project briefing. The complexity of the task in combination with the time pressure was expected to challenge the participants, and evoke non-routine behavior. However, to ensure that the participants experienced a non-routine situation, a standardized intervention was introduced. A project manager insisted after approximately 35 minutes into the exercise on receiving the intermediate results via e-mail. Within 10 minutes after sending the results, participants would receive critical feedback on their work so far. A database containing over a 100 methods was available, and optional for usage. Additionally, participants could get assistance from an online helpdesk to support search and selection of methods from the database. Both measures enhanced accessibility and usability of methods for the participants.

Sample

The data was collected from 17 individual expert and advanced beginner designers. The eight experts were industrial designers with more than 10 years of experience in practice. The nine advanced beginners had 1–3 years of experience in practice. All participants were practitioners to ensure that they were used to a context of performance rather than a context of learning (see section 2.4) in which the use of methods is often a prerequisite. Participants were affiliated with 14 different design organizations in the Netherlands. Three participants worked in a single organization, of which one expert and one advanced beginner worked in the same department. Another expert and advanced beginner shared their employer as well. All designers had a background in methodological design to ensure familiarity with design methods.

Project Briefing & Task Description

Participants received an elaborate project briefing for which appropriate complexity, relevance and clarity was sought in consultation with an experienced practitioner who commented on these issues. The expert was employed in a large multinational corporation as design manager and was familiar with formulating and receiving project briefings on regular basis. The project briefing consisted of three main parts (see appendix C). The first part introduced the assignment, the fictional client and the participant's own agency. The assignment asked the participants to create a project planning in two hours, resulting in a PowerPoint presentation that a fictional colleague would present to the client. Both the fictional client and the participant's own agency were introduced as well. The choice for a planning problem was motivated both theoretically and pragmatically. Theoretically methods can be seen as reasoning-aids (see chapter 2). Although traditionally methods are viewed as instructions for a certain design activity (Jensen & Andreasen, 2010) that can be followed in order to enhance performance, in this thesis I argue that methods can have multiple roles for a designer, including assisting the designer in 'planning ahead'. So, using methods to assist in a design-planning activity is a type of method usage in its own right. That is, a designer can use a method to assist his reasoning about (potential) future design activities. In this light, methods can be seen as reasoning-aids that might help a designer to either consider more alternative procedures, or to reason about them in more detail. Seen as such, methods can enable a designer to foresee and reflect on the consequences of planned activities better. Pragmatically, a planning problem requires designers to consider a multitude of design activities rather than one or only a few. So, in aiming to investigate method usage in a quasi-experimental setting, it was deemed more realistic to choose for a planning activity because it involves reasoning about a multitude of design activities and, potentially, related method usage. Moreover, a designer will have to consider the coherence between different design activities as well. In comparison, a setting in which the designers would have been asked to perform a single design activity would have yielded much less data on intended method usage, and was deemed less feasible within the scope of this study. As a consequence of the choice for a design planning problem, it was possible to study and compare intended method usage for a broad range of design activities, resulting in a substantial set of data.

The second part of the project briefing described practical information that could be used to devise the project planning. It included a description of the client company in more detail as well as describing details regarding technical specifications, market, managerial goals and target group. Some practical information regarding the project was given, including project deadlines. Third, the available staff for the project was described introducing 5 team members, which the project planning could incorporate. Team members were introduced in terms of function, background and experience.

Set-up and procedure

In developing a planning for the proposed project, the participants were instructed to develop a design approach and detailed planning. Participants were asked to take place at a desk in a neutral lab room. A laptop computer was available with PowerPoint, an e-mail client, chat-software and the method database. Within the boundaries of a quasi-experimental set-up, conditions were created in order to (1) mimic a realistic setting for the participants, (2) evoke the need for methods, and (3) lower the threshold for the actual use of methods through an increased availability of methods. A realistic setting was mimicked through a number of measures. First, a realistic design planning problem was introduced, which the participants had to solve under time pressure. Time pressure is typically called upon as a main reason to ignore methods in practice. As the use of a method typically requires an investment in terms of mental effort and time spent, methods are often perceived as adding burden to a project. Second, the participants were 'disturbed' by a project stakeholder (a supposed project manager) requiring them to show intermediate results and providing critical feedback on those results. Third the participants were asked to deliver their results in the form of a PowerPoint presentation. In this way, they were forced to consider the way they presented the results besides focusing on the content of the planning itself. Together these measures were aimed at creating a challenging experience for the participants. The potential need to use a method was evoked by introducing a non-routine situation. More specifically, this was done through the introduction of a standardized intervention involving a hypothetical project manager. The manager required the participant to show intermediate results, and provided critical feedback on those results, outlining flaws and gaps in the work. All together, these measures were intended to increase the level of uncertainty for the participants while working on the problem. The increased uncertainty was then expected to draw them out of their comfort-zone and let them consider other levels of performance, including the option to use methodological support. At the same time, method usage was stimulated through a lowered threshold for using methods. Practicing designers are typically reluctant to use new methods for their work. Recent literature has revealed that this is caused in part by the poor transfer of many methods (see e.g. Araujo, 2001 and Lindemann and Stetter, 2004) and by the poor quality of the way methods are often described (see e.g. Araujo, 2001). Therefore, the availability of methods was enhanced for the participants.

Method database

The method database was available (optional) for use including more than 100 methods from various sources (van Boeijen et al., 2009; Cross, 1989; IDEO, 2003; Pahl and Beitz, 1995). It was explicitly mentioned at the start of the experiment that the use of the database was optional. However, participants were urged to use methods from a method database, if they felt the need to do so. The methods that were included ranged from phase-models, e.g., VDI 2221 (VDI-Richtlinie 2221, 1993) to small-scale methods as described on the IDEO method cards (IDEO, 2003). The database provided a basic navigation menu (Figure 4.2) to access the methods. It facilitated high accessibility and

Figure 4.2 Screenshots of the navigation menu (top) and descriptions of a method in the database (bottom).

usability of design methods during the procedure, i.e., to lower the threshold for using methods. In enhancing accessibility, he database allowed the participants to access a description of a method within 2–3 clicks with the mouse.

In addition a methods-helpdesk was available for help with searching, selecting and applying methods from the database via an online chat program (MSN messenger). A research assistant familiar with the contents of the database responded to questions from the participants.

Procedure

Before the instructions were given, the participants could familiarize themselves with the workspace and the method database. Questions could be posed regarding the functioning of the database (e.g. questions concerning navigation). However, questions regarding the content of the database were not answered at this point. After familiarization the project briefing was presented and deadline for delivering the final result was announced (105 min). In preparing the participants for the intervention, they were notified that at any time during the process, their intermediate results could be summoned in the form of a PowerPoint presentation. After approximately 35 minutes, a standardized intervention was introduced by the project manager via e-mail. The participants were requested to send their approach and planning in a PowerPoint in intermediate state for review. After that, they received criticism on specific points in their intermediate results that were lacking. The emergence of a non-routine situation for the participants was conceptualized as follows. First, upon receiving the request, it was expected that participants suddenly realized that an external party would assess intermediate results, which were still incomplete. The prospect of critical review of work is a strong motivator for deliberate, non-intuitive behavior (Kahneman, 2011a), and so participants were expected to switch to non-routine behavior – if they had not done so already. Second, after sending the intermediate results, participants received critical feedback on their work so far, triggering reflective, non-routine behavior. After the intervention, the participants then could finish their project approach until the time of the deadline. At this point, participants were requested to finalize their design planning and send it to the project manager via e-mail.

§ 4.4 Data collection

Data was collected at two occasions. First, the solutions to the design-planning problem were collected through the procedure as described above. This resulted in 17 design project approaches, one from each participant that consisted of minimal 2 up to 10 PowerPoint slides. Next to these outcomes, the participants' method usage was cross-examined using two sources of data. A method was coded as "used" when (1) the participant had explicitly named a method from the database in his planning, and (2) when video recordings showed that a participant also had spent time looking at the description of the method in the database. The second check was deemed important because it allowed us to state with more confidence that the method used in the planning was prompted by the database.

In order to gain a measure of performance, the participants' outcomes were assessed by two highly experienced project managers from practice and one of the authors. The assessments were performed independently of each other. The author's assessment was done prior to the assessments by the external raters. The assessment was performed according to two related procedures, devised to both enable comparison on specific performance criteria and to capture the expertise of the raters more comprehensively. First, outcomes were rated based on a set of five pre-defined criteria. Four criteria were extracted from the brief, one criterion ('inspiring') was added afterwards and was verified with the external raters for relevance. We do not claim that the performance criteria are a comprehensive set for measuring design performance, however, they do relate to relevant elements of design planning as was confirmed by the external raters. The raters assessed the quality of the results for each criterion, on a scale from 1 to 5 (1: very low to 5: very high). The five criteria were defined as: (1) *trustworthiness* of the outcome, conceptualized as the design project planning being valid and appropriate for the problem, (2) *inspiring* outcome, conceptualized as the design project planning being original and providing an interesting perspective to the problem, (3) *insightful* outcome, conceptualized as the design project planning providing detailed insight in what will be done during the process, (4) *clarity* of the outcome, conceptualized as the design project planning providing a clear and coherent storyline, and (5) *overview* as perceived through the outcome, conceptualized as the design project planning providing a sense of overview of the project.[2]

Assessing design performance is still a challenging task surrounded by many uncertainties and is relatively underdeveloped from a research perspective (O'Donnell & Duffy, 2005). As a consequence a comprehensive set of performance criteria are lacking, particularly for the task that was presented to the participants in this study. So, in addition to assessing the outcomes based on pre-defined criteria, we opted to have the raters rank the outcomes based on their own expertise – based on their overall

2 In assessing the inter-rater reliability the intra-class coefficient (ICC) was calculated per performance criterion. The inter-rater reliability ranged from acceptable for trustworthy (ICC=0.51) and inspiring (ICC=0.59), to moderate for insightful (ICC=0.63) and clarity (ICC=0.69). Overview was excluded from the dataset due to a low inter-rater reliability (ICC=0.13). Therefore, the three performance scores per criterion were averaged for 4 out of 5 performance criteria following Dunn (1989) and are presented in Table 4.1.

Table 4.1. Method Usage and Performance

Participants		**Use of Methods**	**Performance**				**Overall performance**
identity	level of expertise	number of methods used	I	II	III	IV	rank
G	A	4	2,7	2,7	2,3	2	1
C	E	0	2,7	2,3	2,7	2	2
F	A	5	3,0	3,3	3,3	4,0	3
H	A	2	3,7	2,3	3,3	3,7	4
D	E	5	3,7	2,3	3,3	3,3	5
J	A	3	3,0	2,7	3,7	2,7	6
M	A	0	4,3	3,3	3,7	3,3	7
P	A	0	3,7	2,0	3,0	4,0	8
E	E	0	2,7	1,0	2,7	2,7	9
N	E	0	3,0	4,0	3,0	3,0	10
Q	E	0	2,0	1,3	1,3	1,7	11
L	E	4	3,0	3,0	2,7	2,0	12
B	A	1	3,3	2,7	3,7	3,3	13
A	E	0	2,7	2,0	3,0	3,3	14
I	A	0	1,7	2,0	2,0	1,7	15
O	A	1	3,0	4,0	2,7	3,3	16
K	E	0	3,0	2,3	3,3	3,3	17

Note: level of expertise (A = advanced beginner, E = expert), use of methods, and performance measures of participants. Holistic ranking, (Rank) and average performance for individual criteria (trustworthy (I), inspiring (II), insightful (III), and clarity IV) accross three raters. The fifth criterion 'overview' was dropped because of a low intra-class coefficient.

assesment. This procedure led to a single performance assessment per participant, which imposed a comparative order (ranking) to the 17 outcomes per rater. In assessing the inter-rater reliability, the intra-class coefficient (ICC) was calculated based on the rankings for each judge. The inter-rater reliability was acceptable (ICC=0.57). Therefore the three rankings could be averaged following Dunn (1989) and used as single performance measure (rank) for the participants. The performance scores based on the rankings are presented in table 4.1.

§ 4.5 *Results*

Comparing method usage advanced beginners and experts

In response to the first research question, method usage of the two groups of participants was assessed and compared. From the sample of 17 participants, 8 used one or more methods (47,1% of the sample) from the database. Of those 8 participants 2 were experts (25% of method users) and 6 were advanced beginners (75% of method users). The Pearson's X^2-test revealed a marginally significant negative association between level of expertise and the tendency to use one or more methods X^2 (1) = -2.95, p = .09. Based on the odds ratio, a measure of effect size, the odds of using one or more methods were 9 times higher for advanced beginners than for experts. Considering the small sample size, the latter measure seems more informative than solely looking at the significance (as the probability of finding significances is known to increase with bigger samples).

Comparing performance of advanced beginners and experts

In response to the second research question, we compared the average performance of the advanced beginners with the average performance of the experts. The means and standard deviations are reported in Table 4.2.

Table 4.2. Performance scores: advanced beginners vs. experts

	Performance scores								
	Rank	I		II		III		IV	
	mean	mean	SD	mean	SD	mean	SD	mean	SD
Advanced beginners	8,11	3,16	0,74	2,78	0,61	3,08	0,63	3,11	0,82
Experts	10,00	2,85	0,48	2,28	0,94	2,75	0,64	2,66	0,67

Note: mean rank (lower rank means better performance), mean and standard deviation for average rating on four performance criteria for advanced beginner and expert designers (on 5-point scale, higher score means better performance).

As can be seen in Table 4.2, on average, the advanced beginners received higher scores for their work than the experts. However, in comparing the performance of the advanced beginners and experts based on the ranked data, performance of experts did not differ significantly from advanced beginners, $U = 28.00$, $z = -0.77$, $p = .48$, ns, $r = -.19$. In comparing the performance of the advanced beginners and experts for the single performance criteria, the following results were found:

On average, advanced beginners performed better in terms of trustworthiness of their work ($M = 3{,}16$, $SD = 0{,}74$) than experts ($M = 2{,}85$, $SD = 0{,}48$). This difference was not significant, $t(15) = 1.00$, $p = .332$; however, it did represent a small to medium-sized effect, $r = .24$.

On average, advanced beginners performed better in terms of inspiring content of their work ($M = 2{,}78$, $SD = 0{,}61$) than experts ($M = 2{,}28$, $SD = 0{,}94$). This difference was not significant, $t(15) = 1.29$, $p = .22$; however, it did represent a medium-sized effect, $r = .30$.

On average, advanced beginners performed better in terms of the insightfulness of their work ($M = 3.08$, $SD = 0{,}63$) than experts ($M = 2{,}75$, $SD = 0{,}64$). This difference was not significant, $t(15) = 1.07$, $p = .30$; however, it did represent a small to medium-sized effect, $r = .25$.

On average, advanced beginners performed better in terms of clarity of their work ($M = 3.11$, $SD = 0{,}82$) than experts ($M = 2{,}66$, $SD = 0{,}67$). This difference was not significant, $t(15) = 1.22$, $p = .24$; however, it did represent a small to medium-sized effect, $r = .28$.

Beyond level of expertise: comparing method usage and performance

In going beyond the differences between the two groups, we correlated method usage to performance. Here, the results are ambiguous. Based on the ranked data, method usage correlated positively with performance, $\rho(17) = .43$, $p = .09$, a medium to strong effect. Yet, this medium to strong effect was not mirrored in the performance scores for the individual, predefined criteria. They yielded only small to medium-sized effects for the outcomes: $r = -.19$, $p = .61$, for how trustworthy they were; $r = .26$, $p = .31$, for how inspiring they were; $r = .20$, $p = .43$, for how insightful they were; and $r = .091$, $p = .74$, for how clear they were. Again, due to the small sample size, the magnitudes of the correlation coefficients seem more informative that the significances.

§ 4.6 *Discussion*

A detailed understanding of how methods function for different types of designers is lacking with few empirical studies addressing designer-dependent aspects of method usage. In particular, the question what very role methods play for designers of different levels of expertise has remained largely untouched in the literature. So, although there is little doubt that methods can be useful in the hands of designers and design educators, it

is not clear how designers of different level of expertise use methods, or to what benefit. Moreover, as method developers are lacking a sound basis for distinguishing between the needs of their potential target groups (e.g., experts vs. novices), the methods they produce might risk failing to meet their user's specific requirements. In this study we address this gap in the literature by investigating method usage and design expertise.
In answering the research questions posed in the introduction of this chapter, the contribution is twofold.
In comparing the participants' method usage, we found a marginally significant association between level of expertise and the tendency to use one or more methods – given conditions that were shaped by time pressure, a complex project planning task and the introduction of a non-routine situation. Two factors related to the sample size and the nature of the planning task might explain the findings. However, since we found the odds of using one or more methods to be 9 times higher for advanced beginners than for experts, we do see reason to believe that there exists a correlation between level of expertise and method usage in design and that it deserves to be studied further.
In comparing the performance of the advanced beginner and expert designers, no significant difference was found on average. However, since we did obtain a number of meaningful effect sizes, and since the work of the advanced beginners was scored higher on average than that of the experts, the results are discussed below.
First, the experts did not rank higher than the advanced beginners, rather the advanced beginners had a higher mean rank ($M = 8.11$) than the experts ($M = 10.00$). The same pattern was true for all performance scores and this finding seems to go against the general expectation that experts do better than novices. This is because experts and

advanced beginners differ in relation to the amount of domain-specific knowledge, the organization and integration of schemata in memory (Sternberg, 1995). Accordingly, the level of experience is commonly seen as the major determinant for performance as it allows experts to be much more efficient than novices and with less mental effort. In this light, the finding was a surprising result. It was expected that the groups of experts would outperform the advanced beginners, irrespective of their method usage, but they did not. In attempting to explain why the experts did not perform better than the advanced beginners, we first turn to a recent study by Von Der Weth (1999). He constructed a model that describes how some experts develop successful strategies early on in the design process without systematic analysis and employment of methodological procedures. The latter was observed for most of the experts. However, the success of these strategies depends on the validity of 'predictors' the designer has at his disposal. For example, participant C (an expert) might have had predictors available that allowed him to successfully identify the situation appropriately and act accordingly. At the same time, most of the other experts might have had slightly inappropriate predictors in mind, explaining their relatively poor performance.

In going beyond differences between novice and expert designers, method usage was compared to the performance of the whole group of participants, resulting in a more ambiguous picture of the role methods play. In acquiring a comprehensive measure of performance of the participants, it was assessed in two ways as described in section 4.3. No significant correlation was found when comparing the scores for the individual performance criteria to method usage. However, a comparison to the ranked performance data revealed a different picture. A medium to strong positive correlation was found between method usage and the performance of the participants.

Our results should be interpreted with caution due to the lack of significant effects. We therefore explicitly refrain from drawing strong conclusions from the data.

Taken together, the findings offer an ambiguous picture of method usage and design planning performance. The findings of this study revealed that for the pre-defined criteria, method usage did not seem to significantly add to the participants' performance. That is, the pre-defined criteria addressed certain aspects of planning performance that were not sensitive to method usage. However, the ranked performance measure that captured a broader, yet less well-defined, spectrum of performance aspects did reveal sensitivity to method usage to some extent. Following the latter results, it seems that methods correlate to better design planning performance and that experts tend to use less methods than advanced beginners. More specifically, they suggest that the use of methods correlates with higher performance in project planning: most of the participants whose performance was ranked at the top also used methods from the database during the execution of the task, mostly more than one method. It should be noted that in attempting to diminish a crucial threshold for method usage in practice, the quasi-experimental set-up included enhanced availability of methods to the participants. Therefore, the results should be interpreted also with this in mind; the designers that used methods might have decided to do so because it was relatively easy to access and use them. At the same time – and perhaps working against the participant's motivation to use methods - the participants had to complete a complex task under severe time pressure.

Limitations & further research

In this study, the focus lies on comparing method usage between experts and novices, providing a starting point to the study of designer-dependent factors regarding method usage in design. A number of limitations are inherent for the type of study in this chapter and provide a number of opportunities for future research.

First, for this study I opted for a quasi-experimental set up to strike a balance between providing the participants with a realistic task while maintaining an appropriate level of control over the conditions in which it was performed. We aimed to ensure that the participants could recognize the kind of work they were asked to do. In doing so, the results of the study are believed to be valid for practical design settings. However, the reliability of a quasi-experimental study such as the one in this chapter is at least in part dependent on the sample size. In order to further increase the reliability of the results, a study with larger sample size is suggested.

Second, in using two types of performance measure, the findings go beyond comparing method usage alone. Performance measurement in design is a complicated matter (O'Donnell & Duffy, 2005), and no generally accepted measurement instruments exist in the literature. It was found that the two types of performance measurement used in this study (rating based on pre-defined criteria and ranking based on the expertise of experienced design project managers) revealed different results when compared to method usage of the participants. The performance ranking based on the expertise of project managers yielded significant results for method usage, while ratings on predefined criteria did not. It is likely that the expert rankings were probably implicitly encompassing a broader set of criteria than the four pre-defined criteria used for the performance rating. However, because the experts' ranking is based on implicit criteria, it is not clear which ones they used. However, the intra-class reliability score was acceptable indicating that the raters used similar criteria to a sufficient degree. Hence, in bringing the quality of design performance measurement forward, research efforts must be directed towards the development of reliable scales.

Implications for practice

The study in this chapter revealed that advanced beginner and expert designers differ in terms of their use of methodological support. Additionally, the results suggest that particularly advanced beginners might benefit from using methods for planning design projects. When considering policy or implementation of methodological support in their organization, it is suggested that design managers take this into account.

This chapter is an adaptation of: Daalhuizen, J., Person, O. and Gattol, V. (2013). A personal matter? An investigation of students' design process experiences when using a heuristic or a systematic method, Design Studies, Volume 35, Issue 2, March 2014, pp. 133–159.

•5 Individual differences in method usage *in design*

In this chapter, we study method usage in design education and how the use of systematic and heuristic methods shapes the process experiences of students in the conceptual phase of design. In doing so, we also adhere to the notion that students and designers develop a 'method mindset' as they learn to use different methods (Andreasen, 2003). A method mindset pertains to the knowledge, skills and beliefs students and designers acquire in the process of learning to use a method. It covers at least the relevant experiences that are needed to use a method as well as the relevant experiences that influence whether a method will be preferred over alternatives. A method mindset represents the 'mental equipment' that a designer must have in order to purposefully use a method to his or her benefit. A method mindset determines a designer's ability to grasp different facets of a method and its application (Andreasen, 2003). In engineering and design education, method teaching is introduced as a means of providing students with valuable learning experiences on their way to becoming designers. We recognize that teaching students to use different methods often includes the aim of building a proper method mindset (if not explicitly, at least implicitly).

Several authors have questioned the effectiveness of method teaching in design education. Acknowledging this gap in knowledge, the contribution of the study presented in this chapter is twofold. First, we extend past discussions on method usage in design by showing how designers experience working with a design method (i.e. their design process experiences) in order to advance our understanding of method usage in practice. Daly, Adams and Bodner (2012) recently argued that while much research focuses on isolated design skills and knowledge structures, few studies address how they tie together in preparing students for the challenges they will face in practice. As such, they suggest that one should "purposefully investigate the ways people experience design and what they understand about design through these experiences" (p. 188). Gerber and Carroll (2012) note that few studies have focused on how designers experience different design practices. They argued that understanding how designers experience the use of specific methods can help explain how these methods function for designers and can bring understanding about the benefits, limitations and prerequisites of method usage in design. Similarly, Günther and Ehrlenspiel (1999) noted that a key area for future study should be the more experiential aspects of method usage (for example, how method usage affects the tendency to give up or to cope with failure). With the study in this chapter we respond to these calls for research by providing empirical insights on method usage in design.

Second, finding patterns in the idiosyncratic ways students experience the use of systematic and heuristic methods is an important next step in understanding method usage in design. In the literature on design, individual differences in how designers engage in the activity of design are related to educational background (Günther & Ehrlenspiel, 1999), differences in problem-solving style (Demirkan & Osman Demirbaş, 2008; Kvan & Jia, 2005; López-Mesa & Thompson, 2006a; Roberts, 2006) and differences in the way design is understood (Atman et al., 2007; Daly et al., 2012; Eastman & Newstetter, 2001). Andreasen (2003) suggested that 'proper' execution of a method is not straightforward and typically requires a 'proper' mindset from the individual designer who applies it. Roozenburg and Eekels (1995) argued that methods are valuable to a designer only when used with caution and sufficient prior knowledge. The results of the study support this idea by unveiling how individual differences potentially shape method usage in design. The following research questions guided the inquiry:

- How do the design process experiences of students compare to one another when using systematic or heuristic methods?
- How do individual differences in method usage shape the design process experience of students when designing?

§ 5.1 *Research method*

In answering the research questions, we studied how design students experienced their design process when using systematic and heuristic methods during a design exercise. The design exercise constituted a mandatory course assignment and was carried out electronically. From an educational perspective, the purpose of the assignment was to stimulate discussion on the role of methods in design and to help the students to critically reflect on their own method usage when designing. In targeting these learning objectives, we devised the design exercise in such a way that the students could compare their own process experiences in using different types of methods. The exercise was divided into three parts. In each part the students were given a different design brief and a different set of method instructions. Students were instructed to tackle the brief by developing their ideas into a tangible product concept. For our study, we focused on the students' design process experiences when designing a 'key manager for the elderly'.

Sample

Our data on method usage and design process experiences comprise self-reports by 213 students (40% women). The students participating in our study were all taking part in a master-level course on design theory and methodology at the Faculty of Industrial

Design Engineering, Delft University of Technology. The course is mandatory for all design students pursuing master degree studies at the same faculty (97% of the sample). It is also open as an elective course for students from other faculties of the university (3% of the sample). The reported age of the students ranged from 20 to 32 with a mean age of 23.3. The reported work experience in practice of the students ranged from zero to seven years with a mean work experience of 0.9 years. 64 per cent of the students had earlier pursued bachelor degree studies in industrial design engineering at the Faculty of Industrial Design Engineering. The other students had pursued bachelor degree studies in design, engineering and other closely related academic disciplines at the Delft University of Technology or elsewhere.

Participation in the design exercise was mandatory in order to pass the course. However, the students had the possibility to opt out from having their answers included in the study. The background information about the participants was collected in a preparatory lecture assignment where the students reflected on their current work practices with the aim of stimulating discussion in the classroom. As anonymity was guaranteed when participating in the study, it was optional to report on gender, age, prior design experience and educational background. No student requested to have his/her answers excluded from the study. A total of 196 students reported their gender and age. A total of 191 students reported their past work experience. A total of 200 students reported their educational background.

Design brief

In developing the three briefs for the exercise, we sought briefs that were comparable in complexity, clarity and stimulated interest. To this end, we relied on the advice of academic colleagues who commented on the relative complexity, clarity and feasibility of the briefs. We also performed two rounds of pre-tests with students, who assessed the briefs in terms of complexity, raised interest and feasibility on 7-point scales (1: Low to 7: High), as we iteratively refined the briefs. Participants indicated their agreement/disagreement with several statements for each of the constructs. For ease of reporting, the extent of their agreement/disagreement is expressed in terms of 'low' vs. 'high'. All the briefs asked the student to design a product concept for a tangible device and suggested a user-centred approach. As such, they represented a common design problem. In order to stimulate the students' interest in the exercise, the briefs asked the students to empathize with a specific user group and to develop a product specifically for the needs of this group. They were also asked to imagine themselves as a designer working for a small company. For the sake of simplicity, only the first brief was used for the present study (between-subjects design) which is included in Appendix D. In the final pre-test, ten design students gave the first brief a low score in terms of the complexity of the brief (M = 1.87) and a moderate to high score in terms of complexity of the design task (M = 2.73), triggered interest (M = 4.87) and feasibility (M = 4.95).

Method instructions

In designing a product concept for the brief, the students were instructed to follow one out of three design approaches (conditions): the first one required the students to follow a systematic method approach by using a predefined method, the second one required them to follow a heuristic approach by using a set of predefined heuristics and the third one required them to follow the approach they normally would follow when designing. In this chapter, we focus on the design process experiences with respect to the first brief for the students that followed either a systematic (N = 118) or heuristic approach (N = 95). We note that the third design approach was incorporated as a comparison for the students and served only educational purposes.

With respect to the systematic approach, the students were asked to follow a highly systematic method by employing the principles of morphological analysis in their design task. Morphological analysis was originally introduced as a broadly applicable method for studying the interrelations between objects, phenomena and concepts (Zwicky, 1969) and is a subject of sustained interest in the field of product design. In short, the underlying idea of the method is to refrain from 'prejudice' and 'pre-evaluations' in order to overcome some of the limitations of the human mind with respect to problem solving and, in doing so, produce innovative solutions. When applied to design, the method prescribes that a design problem is formulated in such a way that it can be decomposed into sub-functions. For each sub-function, alternative solutions are generated and structured in a morphological chart from which different concepts are created to solve the original design problem in an innovative way. The goal of the decomposition (and composition) is to acquire as much information as possible within a given problem/solution space before combining the different sub-solutions into overall concepts from which to make an informed choice.

With respect to the heuristic approach, the students were instructed to deliberately avoid/neglect certain information by adhering to four common heuristics in design. The first heuristic was the 'primary generator' (Darke, 1979). This heuristic advises that the most salient sub-problem should be taken as a starting point for the design activity. The second heuristic was 'conjecture-analysis' (Hillier, Musgrove, & O'Sullivan, 1972). This heuristic suggests reducing the solution space by proposing the initial solution that comes to mind and that is worthwhile exploring. The third heuristic was 'iteration'. Adams (2001) identified four types of iteration cycles related to problem scoping, solution revision, coupled problem scoping and solution revision and self-monitoring. For this study, the students were instructed to employ iterations that were aimed at solution revision, as the task provided to the participants was characterized by concept development. Thus the students were asked to develop an initial idea and to revise it continuously until it fulfilled the design objectives. Last, the fourth heuristic was 'satisficing' (Simon, 1996). This heuristic suggests that work on the solution should be stopped as soon as it meets the design objectives in order to avoid unnecessary optimization. The method instructions that the students received are included in Appendix E.

Data collection

We collected data on the students' method usage at two occasions. First, before engaging in the design exercise (i.e. prior to having received the method instructions), the students were asked to assess the design brief they were assigned. As in the pre-test, the students rated the briefs with respect to several statements (items) covering (1) the complexity of the design brief, (2) the complexity of the design task, (3) the interest triggered and (4) the feasibility of solving the brief within a two-hour time limit. Exploratory factor analyses were conducted separately for each area (construct). Factor analyses led to the extraction of reliable one-component solutions for each construct. In some cases, based on the results of the factor analyses, we excluded a few single statements (items) in order to improve the reliability of the scales measuring the complexity of the brief and complexity of the task. For each construct, only one component was extracted based on Kaiser's criterion of Eigenvalues > 1. All scales showed high reliability with Cronbach's alphas exceeding .85 and Pearson correlations above .4. We therefore derived separate index scores (scales) by averaging across the items for each construct.

Second, directly after completing the design exercise, the students were asked to reflect on their process experiences when following the different methods by indicating their agreement/disagreement with a number of statements on a 7-point Likert scale. To acquire a broad understanding of their experiences, they were asked to assess their design process experiences in several areas. The areas covered (1) how pressed for time they had felt, (2) how self-confident they had felt, (3) how motivated they had been, (4) how conscientious they had been and (5) the effort they had put into doing the exercise. In acquiring an overall performance assessment regarding the work, they were asked to provide (1) an overall evaluation of their final design concept and (2) an assessment of the effectiveness of the taken approach. In assessing their method mindsets, we also asked them to indicate their experience with the specific approach taken in terms of prior exposure and preference. As a control, the mindset reported by the students who had been instructed to follow a systematic method was comparable to that reported by those who had been instructed to follow a heuristic approach. The mean prior exposure to the used methods was not significantly different for the students who had been instructed to follow a systematic approach ($M = 3.61$, $SD = 1.53$, $n = 118$) and those instructed to follow a heuristic approach ($M = 3.87$, $SD = 1.45$, $n = 95$), $t(211) = -1.20$, $p = .23$. Moreover, we only found a marginally significant difference for the mean preferences of the students who had been instructed to follow a systematic approach (M

= 4.75, SD = 1.22, n = 118) compared to those instructed to follow a heuristic approach (M = 5.04, SD = 1.10, n = 95), $t(211) = -1.76$, $p = .08$.

As for earlier areas of interest, each area was covered by multiple statements. In developing the statements, we once again relied on the advice of academic colleagues who commented on the comprehensiveness, clarity and suitability of the different statements as well as pre-tested them with students. In analysing the students' answers in the main study, we performed exploratory factor analyses prior to averaging the scores to produce separate index scores for each construct. Again, in some cases, based on the results of the factor analyses, we excluded single statements in order to improve the reliability of the scales. For each construct, only one component was extracted based on Kaiser's criterion of Eigenvalues > 1. Both the feedback we received from academic colleagues and the results obtained from the explanatory factor analyses provide evidence for the construct validity of the scales used in the measurement of students' method mindsets (cf. Messick, 1980). All scales further showed sufficient reliability with Cronbach's alphas exceeding .6. An overview of all the scales and items for the different constructs addressed in the study is provided in Appendix F.

§ 5.2 *Results*

The analyses of the students' design process experiences are split into two parts. In investigating our first research question, which was focused on the potential effect of systematic and heuristic method usage on the design process experience of design students, we compared the design process experience scores (see Section 2.3) of the students who were instructed to follow a systematic approach to those of the students who were instructed to follow a heuristic approach. Next, in investigating our second research question, which focused on individual differences in how design students deal with methods, we took a more holistic view on design process experience. We did this through a cluster analysis, which allowed us to look for patterns in the process experiences arising from individual differences among the students that are independent of the method that they followed.

Comparing systematic and heuristic method usage

With respect to how pressed for time they had felt in doing the exercise, the students who followed the systematic approach scored significantly higher in terms of reported time pressure ($M = 4.03$, $SD = 1.33$) than the students who followed a heuristic approach ($M = 3.23$, $SD = 1.40$), $t(211) = 4.27$, $p < .001$. The effect size ($d = .59$) exceeded Cohen's (1988) convention for a medium effect ($d = .50$). With respect to how motivated they had been, the students who followed the systematic approach reported significantly lower motivation ($M = 4.43$, $SD = 1.03$) than the students who followed the heuristic approach ($M = 4.73$, $SD = 1.02$), $t(211) = -2.14$, $p < .05$. The effect size ($d = .29$) exceeded Cohen's convention for a small effect ($d = .20$). With respect to how much effort they felt they had put into the work, the students who followed the systematic approach reported significantly higher effort ($M = 4.77$, $SD = 0.97$) than the students who followed the heuristic approach ($M = 4.49$, $SD = 0.99$), $t(211) = 2.07$, $p < .05$. The effect size ($d = .29$) indicated a small effect size. With respect to how confident they had felt and how conscientious they had been in doing the exercise, the results show no significant differences. Next, we compared the performance assessment between the two groups of students. The results showed no significant differences between the students with respect to the overall evaluation of their final design. However, the students who followed the heuristic approach reported significantly higher effectiveness of the approach taken (M = 5.09, SD = 0.72) than the students who followed the systematic approach (M = 4.44, SD = 1.03), t(211)= −5.23, p < .001. The effect size for this analysis (d = .72) indicated a medium to large effect. An overview of the results is presented in Table 5.1.

Table 5.1 Descriptive statistics for comparing between systematic and heuristic method usage.

	Systematic Mean (SD)	**Heuristic** Mean (SD)
Time pressure**	4.03 (1.33)	3.23 (1.40)
Self-confidence	3.92 (0.50)	4.06 (0.50)
Motivation*	4.43 (1.03)	4.73 (1.02)
Conscientiousness	3.29 (0.99)	3.26 (1.00)
Effort*	4.77 (0.97)	4.50 (0.99)
Overall evaluation of the final design	4.86 (0.97)	5.02 (0.83)
Effectiveness of the used method**	4.44 (1.03)	5.10 (0.72)

* t-test was significant at the p < .05 level

** t-test was significant at the p < .001 level

Beyond methods in themselves: searching for individual differences

The results above show that the choice of using a systematic or a heuristic method is not straightforward. Based on the students' own experiences, neither of the two types of methods led to a significantly higher-quality end result than the other. Rather, differences were found in the way that the students experienced the design process. Following a systematic approach induced more time pressure and lowered motivation

slightly. It was also deemed to be less effective than following a heuristic approach. However, the students also indicated that they put somewhat greater effort into doing the exercise when following a systematic approach. Further, there were no significant differences between the two groups in terms of confidence, conscientiousness or overall evaluation of the final design. As noted in the literature, method usage is no straightforward matter, in the sense of following instructions – like one would follow a road, leading to a predetermined destination. Rather, it is a more ambiguous matter, where experiences may differ greatly among designers, as became clear when comparing the use of the two types of methods. Indeed, our results underscore this ambiguity.
To some extent, different types of methods – in this case the systematic method of morphological analysis and the set of heuristics including primary generator, conjecture analysis, iteration and satisficing – led to differences in the way the students experienced the whole exercise. It is expected that other factors are at play as well, of which method mindset is a crucial one.
In order to investigate individual differences in method usage, we conducted a cluster analysis of the students' design process experience scores. By means of this analysis we were able to identify the underlying process experience types typical of certain individuals. Before subjecting the scores to cluster analysis, the design process experience scores were standardized. We used a SPSS-based K-means clustering procedure to group the process experience scores in terms of time pressure, self-confidence, motivation, conscientiousness and effort. K-means clustering does not provide any information on the number of meaningful cluster solutions. Therefore, following the recommendations of Burns and Burns (2008), we first used a hierarchical

clustering procedure to determine the number of meaningful clusters to explore with the K-means procedure. A hierarchical cluster analysis using Ward's Method and Squared Euclidean Distance suggested four meaningful main clusters within the students' process experience scores. As shown in Table 5.2, the four clusters produced by the K-means procedure consisted of 31 (14.55%), 70 (32.86%), 64 (30.04%) and 48 (22.54%) students, respectively.

In assessing the relevance of the different clusters, we compared the performance assessments of the students in each cluster. An analysis of variance showed that the overall evaluations of the final designs were significantly different for the four clusters, $F(3, 209) = 24.02$, $p < .001$. The same analysis of variance for the dependent variable perceived effectiveness of the used method also revealed a significant difference for the four clusters, $F(3, 209) = 11.28$, $p < .001$.

Further, in understanding the potential origin of the mapped design process experience in each cluster, we compared the two methods the students had been instructed to follow in doing the exercise. The types of methods used were distributed unevenly in the four clusters. With respect to having followed a systematic approach, the largest percentage of students (39.0%) was found in the second cluster 'swamped, yet striving', and the smallest percentage of students (11.0%) was found in the first cluster, 'on top of things'. With respect to having followed a heuristic approach, the largest percentage of students (37.9%) was found in the third cluster, 'Indifferent and disconnected', and the smallest percentage of students was found in the first (18.9%) and fourth (17.9%) clusters. The fourth cluster consisted of students that seemed to have 'lost faith'. Next, we compared the design brief assessments of the students in the different clusters. With respect to

the complexity of the design brief, an analysis of variance did not reveal any significant difference for the students in the four clusters, $F(3, 209) = 1.75$, $p =.16$. With respect to the complexity of the design task, an analysis of variance revealed a significant difference for the students in the four clusters, $F(3, 209) = 5.11$, $p < .01$. With respect to the interest triggered by the brief, an analysis of variance showed a significant difference for the students in the four clusters, $F(3, 209) = 5.83$, $p < .01$. With respect to the feasibility of solving the brief within the given time frame, an analysis of variance showed a significant difference for the students in the four clusters, $F(3, 209) = 4.82$, $p < .01$. Next, we compared the reported method mindset for the students in each cluster. With respect to their prior exposure to the used method, an analysis of variance showed a significant difference for the students in the four clusters, $F(3, 209) = 2.69$, $p < .05$. With respect to their preference for the used method, an analysis of variance showed a significant difference for the students in the four clusters, $F(3, 209) = 3.73$, $p < .05$.
Below, we elaborate on the specifics of the results above per cluster. In Table 5.2 we also report all the post-hoc tests that were carried out for the individual analyses above. In all multiple comparisons in the table we controlled for the family-wise error rate (alpha-inflation) by applying a Bonferroni correction.

Table 5.2 Cluster solutions.

	Overall	Cluster 1 'On top of things'	Cluster 2 ´Swamped, yet striving´	Cluster 3 ´Indifferent and Disconnected´	Cluster 4 ´Lost faith´	Post-hoc comparison (Bonferroni)
	N = 213 (100%)	N = 31 (14.55%)	N = 70 (32.86%)	N = 64 (30.04%)	N = 48 (22.54%)	
Design process experience (Z-scores)						
Time pressure	0.00	– 0.83	0.93	– 0.71	0.12	
Self-confidence	0.00	0.66	– 0.56	0.62	– 0.44	
Motivation	0.00	1.25	0.33	– 0.17	– 1.06	
Conscientiousness	0.00	0.78	0.46	– 0.59	– 0.40	
Effort	0.00	1.03	0.54	– 0.33	– 1.01	
Performance assessment (1:Low to 7:High)						
Overall evaluation of the final design**	4.93 (0.91)	5.73 (0.80)	4.85 (0.86)	5.15 (0.66)	4.25 (0.86)	C1 > C2, C1 > C3, C1 > C4, C2 > C4, C3 > C4
Effectiveness of the used method**	4.73 (0.96)	5.23 (0.96)	4.57 (0.94)	5.02 (0.82)	4.24 (0.90)	C1 > C2, C1 > C4, C3 > C2, C3 > C4
Design brief assessment (1:Low to 7:High)						
Complexity of design brief (comprehension)	2.08 (0.98)	1.91 (0.89)	2.29 (1.06)	1.95 (0.90)	2.06 (0.99)	
Complexity of design task**	3.35 (1.06)	3.32 (1.22)	3.78 (0.99)	3.18 (1.00)	3.77 (0.99)	C2 > C3, C4 > C3
Interest**	4.30 (1.31)	5.06 (1.33)	4.37 (1.30)	4.16 (1.22)	3.88 (1.27)	C1 > C3, C1 > C4
Feasibility**	5.12 (0.95)	5.52 (0.79)	4.94 (1.00)	5.31 (0.93)	4.86 (0.89)	C1 > C2, C1 > C4
Method mindset (1: Low to 7:High)						
Prior exposure with the used method (approach)*	3.73 (1.50)	4.34 (1.70)	3.45 (1.64)	3.67 (1.32)	3.82 (1.28)	C1 > C2
Preference for the used method (approach)*	4.88 (1.18)	5.27 (1.39)	5.05 (0.92)	4.82 (1.22)	4.47 (1.20)	C1 > C4, C2 > C4
Design approach (Condition)						
Instructed to follow a systematic method	118 (100%)	13 (11,0%)	46 (39,0%)	28 (23,7%)	31 (26,3&)	
Instructed to follow a heuristic method	95 (100%)	18 (18,9%)	24 (25,3%)	36 (37,9%)	17 (17,9%)	

* Separate one-way ANOVA test on the average scores over the four clusters was significant at $p < 0.05$

** Separate one-way ANOVA test on the average score over the four clusters was significant at $p < 0.01$

Cluster 1: 'on top of things'

Students in this cluster were generally ambitious. They were highly motivated, highly conscientious and put high effort into the exercise while feeling little time pressure and being generally self-confident. The very positive overall process experience suggests that this group of students felt 'on top of things' – well equipped for the task and eager to do well. They also showed the highest scores of all in assessing their own performance, for both their evaluation of their final design and the effectiveness of the design process. The positive process experience seems to have shaped their performance assessment. Students in this cluster rated the design brief as low in complexity and expected the task itself to be both rather feasible and interesting, and not too complex. In terms of method mindset, students reported a relatively bigger exposure to the method that they used in the exercise, also preferring it slightly more compared to the students in the other groups. Within this cluster, a slight majority of people had followed the heuristic approach in the design exercise.

Cluster 2: 'swamped, yet striving'

Students in this cluster could be described as ambitious. They put a considerable amount of effort into the exercise and worked conscientiously. At the same time, however, they experienced high time pressure and low self-confidence. This seemed to come at the expense of motivation: students in this cluster felt motivated but considerably less than students in cluster 1. However, they were much more motivated than students in clusters 3 and 4. This mixed overall process experience suggests that this group of students felt 'swamped' (high time pressure, low self-confidence) and had doubts about their own performance. That said, they continued to 'strive' to master the design challenge at hand (still motivated and conscientious). Further, in assessing their own performance, they showed much lower evaluations of their final design and the effectiveness of the design process compared to cluster 1, probably owing to the high uncertainty experienced in the process. Students in this cluster rated the design brief as low in complexity; however, in relative terms, the rating was higher than in all the other clusters. Furthermore, they expected the task itself to be feasible, showing slightly above average interest in it. They judged the task to be of average complexity, finding it considerably more complex than clusters 1 and 3. In terms of past method mindset, students reported the lowest prior exposure to the used methods, but a rather high preference for using them. Within this cluster, a majority of people followed the systematic approach in the design exercise.

Cluster 3: 'indifferent and disconnected'

Students in this cluster could be described as rather unambitious. They scored low on conscientiousness and on the effort they put into the exercise. This in turn might also explain why they felt little time pressure and were generally self-confident with scores comparable to those of cluster 1. In terms of motivation they seemed indifferent to the task, as supported by a slightly below average score in motivation. In assessing their own performance, they scored high on the evaluation of their final design and the effectiveness of the design process with scores only slightly lower than cluster 1. Due to the fact that they gave themselves high values in performance, despite their modest investments in the design task, they might best be described as being 'indifferent and disconnected'. Put more bluntly, students in this cluster could be characterized as underachievers with unrealistic expectations concerning their performance. Students in this cluster rated the design brief as low in complexity, comparable to the rating in cluster 1. They expected the task to be rather feasible, considerably more so than students in clusters 2 and 4, while showing average interest in it. They judged the complexity of the task to be below average, the lowest of all clusters. In terms of method mindset, students reported relatively low prior exposure to the used methods. Within this cluster, a slight majority of people followed the heuristic approach in the design exercise.

Cluster 4: 'lost faith'

Students in this cluster were generally unambitious. They showed very low scores in motivation and effort, and fairly low scores in conscientiousness and self-confidence. The students in this group might have started out with ambitious intentions, but seemed to have been 'caught up' by the reality of doing the exercise according to the instructions given. Together with the low scores in assessing their own performance, both in the evaluation of their final design and the effectiveness of the design process, this group of students could best be characterized as 'having lost faith'. In other words, they no longer had sufficient faith in themselves to master the design task. In comparison, more students in this group were asked to use a systematic approach. Students in this cluster rated the design brief as low in complexity. Furthermore, they expected the task itself to be feasible; however, of all the clusters, they gave it the lowest feasibility rating. They also showed slightly below average interest in it, again the lowest of all clusters. They judged the task to be of average complexity, finding it considerably more complex than the students in clusters 1 and 3. In terms of method mindset, students reported a considerably lower preference for the used method. Within this cluster, a majority of people followed the systematic approach in the design exercise.

§ 5.3 *Discussion*

Although learning to use different types of methods forms an integral part of training students to become designers, there are few empirical studies on the functioning of methods. Prior research in design has been devoted primarily to the development of methods and their importance for reaching quality design outcomes (for support of this argument, see e.g. Adams, Turns, & Atman, 2003b; Gerber & Carroll, 2012), whereas method usage itself has been of little interest. To fill this important gap in knowledge, our study draws on a rich set of quantitative material to offer insight into the use of systematic and heuristic methods.

In comparing how students used the two main types of methods – systematic and heuristic – during a design task, we uncovered that the use of a systematic method resulted in significantly higher perceived time pressure, lower motivation and higher effort spent than the use of a set of heuristics. Moreover, we found that the students who were instructed to use the systematic method felt significantly less effective compared to those who used heuristics. These results underscore the ambiguity surrounding method usage in design – the students felt that they put in great effort, yet felt pressed for time and their motivation suffered – providing inconclusive proof for or against using systematic and/or heuristic methods in the conceptual phase of design. But why do some methods help students to produce good results, whereas they merely frustrate others? And, in the long run, why are some methods adopted by certain students and not others?

Individual differences in method usage

In exploring individual differences in the use of methods, we subjected the students' design process experience scores to a cluster analysis. The goal of the cluster analysis was to reveal similarities and differences in the design process experiences of the students. We distinguished four distinct ways in which students experienced their design process. The first group of students seemed to be on top of things during the design exercise. The second group of students seemed swamped, yet striving to succeed. The third group seemed indifferent and disconnected from the task at hand. The last group seemed to have lost faith in themselves during the exercise. Together, the different process experiences suggest that the use of different types of methods is not connected to performance in a straightforward manner. For instance, the use of certain types of methods is more common for different process experiences. Moreover, they also suggest that students' initial assessment of the task at hand and their method mindset play a key role in the way they experience methods. As a result, the four clusters provide a more nuanced – and more actionable – view on the use of design methods in design education than typically provided in the literature.

In an educational setting, educators might want to account for these different types of experiences by more actively addressing the effects of method usage. In doing so, students are empowered to develop a richer methodological background, preparing them for their future careers. Furthermore, we suggest that by discussing students' personal experiences with method usage in relation to method mindset and performance assessments, more valuable learning experiences can be offered. We therefore present our results with the hope of stimulating further empirical work on method usage in design.

Quantitative studies on method usage in design

We devised a quantitative study on investigating method usage and design process experiences of design students. There are comparatively fewer quantitative studies than qualitative studies in design literature. This situation is slowly changing with an increasing number of design scholars adding quantitative methods to their skill set. For example, in the case of studies on method usage, Bender and Blessing (2004) investigated opportunistic design behavior in embodiment design in a quantitative manner. Another example is the study of Adams et al. (2003a) in which they investigated a number of factors influencing the design process of design students in the light of Schon's reflective practitioner theory. Although experimental and quantitative observational studies have become more important in design research in the last decades (Cross, 2007), the design research community still faces the challenge of improving the quality of such studies (Blessing & Chakrabarti, 2009). Increasing sample sizes is an important – yet challenging – step. Yet design researchers typically employ a small-scale set-up (Cash, Elias, Dekoninck, & Culley, 2012). Although these studies often result in valuable insights, scholars have also emphasized the importance of following up such research with larger sample sizes and quantitative approaches. This is also the case when studying the use of methods in design. For example, when discussing the results of a small-scale study of method usage, Gunther and Ehrlenspiel (1999) emphasized the importance of a large-scale approach to improve the reliability of results. Bender and Blessing (2004) answered to that call with their study on the use of methods in design, yielding more reliable results. With our study we answer that call as well. Further, given that empirical studies in design typically employ a small-scale set-up, we go beyond common design research practices by describing how a large-scale study can be employed in a design context. For this reason – and to support future research in design – we offer a detailed account of the research set-up, procedure for data collection, data collection instrument and statistical methods for data analysis.

Limitations & suggestions for future research

The limitations we faced in devising a study on method usage in design suggest a number of interesting areas for future research. First, the reliability of an empirical study such as ours is highly dependent on how well the measurement instruments capture the constructs of interest. Our study is a pioneering effort in understanding method usage in design quantitatively. Past studies on design did not provide any tested scales that we could adopt. As a result, we had to develop new scales for all the constructs addressed in the study. This was done over a period of several weeks involving feedback from academic colleagues and several rounds of pre-testing with students. In preparing the study, we covered each area of interest with multiple statements in order to cover their main facets. In analyzing the data, all scales also demonstrated high reliability. We therefore hope that the scales can benefit other researchers in design. That said, scale development is a complicated task. It typically involves several iterations before a reliable scale can be established (see DeVilles, 2011). Hence, in bringing empirical work on method usage forward in design, research efforts must be directed towards scale development in order to raise the overall quality of future studies.

Second, assessing the performance of a method is a complicated task. As noted earlier, in assessing the performance of a method, it is usually not the direct effect on the outcome that can be assessed, but rather the effect a method has on the individual using it. Given that individual method usage yields quite different experiences, not only is the outcome of method usage interesting, but so is the relation between the method and the method user who tries to reach that outcome. This is perhaps particularly so in design education where it is of great importance to know how students experience the process of a method in order to teach and promote the benefits of adhering to specific ways of designing. As a result, in taking a broad view on performance, we asked the students to provide both (1) an overall evaluation of their final design and (2) an overall evaluation of the effectiveness of the used method. However, indirect and subjective measures of performance only provide a partial account of performance. Future studies could therefore fruitfully be directed towards replicating our study, incorporating other perhaps more objective measures of performance.

Third, individual differences in method usage can be assessed in multiple ways. In this chapter, building on the importance of a method mindset when using a method (see e.g. Andreasen, 2003), we focused on the students' prior exposure to and preference for different methods. We also had the students provide an initial assessment of the brief to account for how their perception of the task at hand potentially affects their design process experience. However, from an educational perspective, individual differences can also be assessed in other ways. In particular, a student's learning style, cultural background or personality traits are likely to affect method usage in design as well, and future studies should therefore be directed towards exploring such effects. For example, in a recent study, Kvan and Jia (2005) studied the relation between learning style and the curricula design in architecture, noting that different learning styles profited from different forms of teaching. However, their study did not address the effects of method teaching. In carrying out a study on this topic, it would be important to take a longitudinal view on method usage in order to address how individual differences among students compare to those of practicing designers, and how such differences develop over time and in different contexts for different types of designers.

Implications for design education

The effect of method usage on the outcome of design activities is commonly mediated by many factors, many of which are hard to assess. The situation is further complicated by the fact that methods affect students' experiences and their ways of working. In aiding method teaching in design, we propose a number of themes based on our study to guide discussions between students and design educators. In probing a student's method mindset, we suggest that a student's own view of his or her process is of central importance. In facilitating discussions, students and educators can share their process through diagrams and sketches. In probing a student's method mindset further, the discussion can then be directed towards what methods a student commonly uses. In doing so, a teacher can inquire about the training a student has received in using those methods as well as the student's preferences regarding the use of specific methods. These questions can address the different dimensions of process experience by comparing the student's own experiences with the different profiles described in this chapter: Did the student feel on top of things? Or did the student feel swamped, even though he or she strived to succeed? Did the student feel indifferent to the project? Or did he or she lose faith in a good outcome altogether? Besides stimulating reflection on the way students and design educators go about learning and teaching design with the help of methods, we hope our study will stimulate more in-depth discussions on method usage in design across communities of educators, practitioners and researchers.

•6
Conclusions

Methods are important means that we use to teach, execute, manage, facilitate and reflect on design. In particular, methods help us to develop, enhance and communicate the mindsets and skillsets that are necessary for professional design. The main contribution of this thesis lies in an analysis of method usage in design and in providing empirical evidence for key phenomena that were related to the need for methods in non-routine situations, the relation between method usage and design expertise and the relation between methods, method mindset and process experience. Understanding method usage as a phenomenon in itself comprises a key question for the field of design methodology, for design researchers that aim to develop methods to support design education and practice and for the teachers, design managers and policymakers that aim to teach, implement and manage the use of methods in design.

In chapter 2 of the thesis I presented a theoretical analysis of method usage in design. I argued that understanding the designer is pivotal in understanding method usage and that method usage is a situated phenomenon in which the designer is the central actor. From this perspective, it was argued that the need for a method emerges from the subjective feeling of uncertainty that arises in non-routine situations. This viewpoint underlies the observation that methods function as flexible resources for designers to deal with non-routine situations (see e.g. Bender & Blessing, 2004). In addition, It was argued that methods can function along three dimensions: they can help to enhance design capabilities by extending a designer's capabilities (e.g. allowing the designer to grasp more complex problems), they can aid in reflection on design activities and contribute to the reinforced practice that is necessary for the development of expertise (e.g. providing a frame of reference through which structured reflection or feedback is made possible) and they can aid in learning to design by helping to make students of design aware of specific design capabilities and to strengthen them (e.g. by providing ways to deal with uncertainty in design). In analyzing method usage in-depth, I elaborated how methods function as mental tools for designers which can assist in initiating critical thought, framing perception, cognitive decoupling, mental simulation, belief-formation and, over time, in skill development through aiding in the reinforced practice that is necessary to develop intuitive expertise. Last, I argued that efficient and effective method usage requires a proper mindset from the one using a method and that a designer' method mindset is a central concept in understanding (individual differences in) method usage and their role in skill development.

In chapter 3, I reported on interviews with practicing designers about the non-routine situations they encounter in their practices and the strategies they employ to deal with those situations. In doing so, 9 different types of non-routine situations were revealed that could be attributed to the design task, the (social) context and the designer. In addition, 9 different strategies were revealed that together are a subset of the strategies and behaviors that form the arena in which methods 'compete' for attention of their potential users.

In chapter 4, I reported on a quasi-experiment involving practicing designers of different levels of expertise. First, in comparing the participants' method usage, a marginally significant association was found between level of expertise and the tendency to use one or more methods. However, it was also found that the odds of using one or more methods is *9 times* higher for advanced beginners than for experts. Second, in comparing the participant's performance, no significant difference was found on average.

However, a number of meaningful effect sizes were obtained, with the work of the advanced beginners receiving higher scores on average than the experts. That is, the experts did not rank higher than the advanced beginners, rather the advanced beginners had a higher mean rank (M = 8.11) than the experts (M = 10.00). The same pattern was true for all performance scores and this finding seems to go against the general expectation that experts do better than novices. Third, in going beyond differences between level of expertise, and in relating method usage directly to performance, a more ambiguous picture of the role methods play was found. In acquiring a comprehensive measure of performance of the participants, it was assessed in two ways. For the first performance measure (based on scoring of the participants' work on predefined criteria, no significant correlation was found. However, the second overall performance measure (based on overall ranking of the participants' work) the data revealed a different picture. A medium to strong positive correlation was found between method usage and the performance of the participants.

In chapter 5, I reported on a large-scale experiment involving 213 industrial design engineering students that focused on the impact of methods on design student's experiences. In comparing the use of systematic and heuristic methods it was found that they affect design students differently in terms of how they experience a design process. It was found that the use of a systematic method lead to a significantly higher perceived time pressure, lower motivation and higher effort spent when designing. The students also reported to feel significantly less effective when using the systematic method as compared to those that used the heuristic method. Furthermore, it was shown that method usage is tied up with designer's method mindset and perception of design task and that individual differences associated with mindset correlate with method usage. The results underscore the ambiguity surrounding method usage in design. In addition, four distinct ways in which students experience their design process were found, ranging from feeling 'on top of things' to feeling 'swamped, yet striving to succeed' to feeling 'indifferent and disconnected', to having 'lost faith' in being able to achieve a good outcome. Together, the process experiences uncovered in these groups suggest that students' perception of the task at hand and their method mindset play a role in the way they experience methods when designing.

§ 6.1 *Theoretical contributions for design methodology*

The results of the research presented in this thesis are interesting for the field of design methodology for several reasons.

First, following a theoretical inquiry into the phenomenon of method usage in design I have proposed that methods should be regarded as mental tools that designers can use to aid them in their reasoning. They can be used to do so on the short term: to aid in dealing or learning to deal with non-routine situations. Or they can be used to do so on the long term: to facilitate the reinforced practice that is needed for skill development and acquiring design expertise. In contrast, method usage is currently often seen as a matter of 'following' certain (systematic) instructions, leading to certain results. I argue that method usage is a much more complicated phenomenon than often implied, involving the designer as a main actor in determining whether and with what effect methods are used in a certain context for a certain task. This means that in general, method usage involves at least the following elements: (1) the designer with a goal and specific experience, method mindset, motivation, and personality, (2) the context in which a designer is acting, including the design team, the organizational culture and infrastructure, set of methods and project stakeholders, and (3) the design task including the project/design briefing, the resources available and the problem stakeholders. In any given project, these elements come together and influence if methods are used, when they are used, how they are used and what effects can be attributed to their usage. These elements should be taken into account when a method developer or researcher wants to make claims about the appropriateness of a method. More importantly, these elements should infuse research and method development efforts in design methodology.

Second, design methodology is typically focused on the design process. In the interview study with design practitioners reported in chapter 3, a wide variety of non-routine situations was found, going beyond the process of producing an 'object of design' alone. Particularly the social context was found to be an important source of non-routine situations. Therefore, I argue that the potential application area of methods (i.e. types of situations in which methods can be beneficial) should be extended beyond dealing with the process of developing a design object alone. Particularly the potential role of methods in social settings – as a 'boundary object'– is deemed to be an important subject of future study.

Third, (the development of) design expertise is a crucial determinant of design performance but has not been explicitly linked to method usage. To date, two opposing positions can typically be distinguished in the literature. The first position can be summarized by the statement: the development of expertise of design practitioners should be leading in teaching and nurturing design skill and is the best path to optimal performance in design; methods can sometimes be used to support skill development.

The 'expertise'-position is commonly associated with Schön's ideas on reflective practice. The second position can be summarized by the statement: practice should accept the ideals (norms) of systematic design and design science and make deliberate efforts to use its methods systematically to reach optimal performance in design. The latter 'rationality'-position is commonly associated with Simon's ideas on a 'science of the artificial'. Based on dual-processing theory, a model has been presented in which intuition and reasoning are reconciled and in which the roles of methods as mental tools have been elaborated. Based on the model, we identified fundamental roles of methods that 'speak' to different faculties of the human mind and that go beyond the dialectic positions described above.

Fourth, in choosing to study method usage as a phenomenon in itself, we end up with studying the human being that is at the center of that phenomenon: the designer. This perspective allows us to see that methods first and foremost have an impact on the ones using them. In other words: methods only have an impact on the design outcome through their users. This is a fact that is often implicitly ignored in studies that evaluate design methods. The evaluation of a method's impact is typically based on the outcome of a design process (e.g. measuring the creativity of ideas, the time that it took to finish, the level of detailing in a design concept). In some cases, such studies do not even include a base for comparison (e.g. a control group that does not use the method, or uses another, comparable method) while still drawing conclusions about a method's (universal) impact. When comparing methods, the distinction between systematic and heuristic methods comes into play, and shall be taken into account as well. As was discussed in chapter 2, the current debate on systematic and heuristic methods is rather polarized. It is expected that comparative studies like in chapter 5 will bring clarity to the matter and provide empirical evidence to move the debate forward in a productive manner.

In addition, I argue that studies which are aimed to evaluate a method's efficiency or effectiveness should take into account the competitive arena of alternative strategies and methods with which they 'compete' for attention and potential for enhancing performance. That is, methods are part of designers' repertoire of responses to deal with a wide variety of situations. Such responses include a number of cognitive strategies that assist the designer in dealing with uncertainty. Many of these strategies are normally not perceived as being within the scope of design methodology. One example that has been the topic of empirical research is the strategy to 'keep going' by using prototypes in the face of uncertainty (Gerber and Carrol, 2012). This strategy was also mentioned by a number of design practitioners that participated in the interview study in chapter 3. When studied and assessed in terms of performance, method usage should be carefully compared to such strategies. I argue that there is an urgent need to reconsider the way that we study method usage in design. This means that we need to reconsider how and where the impact of a method is to be expected and measured. It also means that we need to consider carefully how to set up studies that aim to measure impact of a method. Based on the work in this thesis, I argue that such considerations need to start with method users.

§ 6.2 *Limitations & further research*

In addition to the specific limitations that were reported separately in each empirical chapter, there are three main limitations to this thesis that provide fruitful avenues for further research.

First, given the focus in this thesis on the individual designer's method usage, the role of methods in a social context have been largely left untouched. Only a brief note in chapter 2 and some concluding remarks in chapter three referred to this topic. However, most design activity has a social nature (Bucciarelli, 1988; Bucciarelli, 1996) and much research has focused on team processes in design (see e,g, Dong, 2007; M. S. Kleinsmann, 2006; M. Kleinsmann & Valkenburg, 2008; Stempfle & Badke-Schaub, 2002; Valkenburg & Dorst, 1998), collaboration across company borders under the label of open innovation (Chesbrough, 2003) and more recently in terms of 'networked innovation' (Bergema, Valkenburg, Kleinsmann, & de Bont, 2010). In the thesis, I elaborated how methods aid individual designers in their thinking and conceptualized the roles that methods can play as well as some of the prerequisites for appropriate method usage. Underlying this conceptualization is the idea that methods function as mental tools, which fits well with the growing body of research into design thinking (amongst many others see e.g. Adams, 2001; Badke-Schaub, Roozenburg, & Cardoso, 2010; Brown, 2009; Cross, 2011; Dorst, 2011; Dym et al., 2005; Lawson, 2006; Rowe, 1987). Although the choice for the individual designer as unit of analysis remains valid – after all, design thinking ultimately happens at the level of the individual designer – individual designers typically work together in teams with other designers, other professionals, clients and sometimes end-users. Methods can aid in facilitating collaborative work, as was suggested in chapter 3, yet few methods are specifically designed or adapted for that purpose. More conceptual and empirical work needs to be carried out to understand the way methods can aid collaborative work.

Second, the research in this thesis mainly focused on design work at the level of the design project (project planning in chapter 4, conceptual design in chapter 5) and only briefly touched upon the potential broader application of methods in chapter 3. However, design happens at different levels of practice (Dorst, 2011) and methods have a role to play at those different levels. For example, decisions to adopt new methods are often made on the level of the organization but these decisions are not without problems (Araujo, 2001). Furthermore, experienced designers sometimes make efforts to evolve the way an organization works, i.e. they think about design at the 'process level' (Dorst, 2011). At this level, the organizational culture shapes the way designers work and think about design, and which methods they (are supposed to) use (see Eris & Leifer, 2003 for an analysis of how methods are used to facilitate knowledge acquisition in an organization). That said, the relation between method transfer and usage on the one hand and organizational culture and practices on the other is still largely left untouched in the literature and a fruitful avenue for future studies.

Third, there is a growing interest in individual differences and commonalities between designers in terms of learning style and personality (see e.g. Durling, Cross, & Johnson, 1996) problem solving style (see e.g. Kruger & Cross, 2006; López-Mesa & Thompson, 2006b) and confidence (Gerber & Carroll, 2012; Kelley & Kelley, 2012; Kelley & Kelley, 2013). With the study reported in chapter 5, I contribute to furthering the understanding of the link between individual differences and the use of methods in design by focusing on students' method mindset. The results suggest that individual differences in mindset have a significant influence on whether or not a method is used to a student's benefit, or even used at all. Yet in general, the literature is rather silent on the relation between methods and individual differences in design. Future studies should therefore be directed at the influence of factors related to the individual like learning style, cognitive style, motivation and personality on the use of different types of methods.

§ 6.3 *Implications for design practice & education*

Many design organizations use design methods in their practices and claim their key role in creating added value for clients, stakeholders and end-users. Yet how methods contribute to successful design and what constitutes appropriate method usage is often blurred by an oversimplified view of methods and a poor understanding of the role that methods can play for the individual designer. For design organizations, the simplified understanding of methods is problematic. This is because as design organizations mature, they typically rely more and more on formalized methods to strengthen their organizational capabilities and culture, and to increase the reliability of their design processes. Interaction between such formalized knowledge and the individuals working in an organization are crucial for the proper synthesis of methods into an organization's design processes (Eris & Leifer, 2003). Organizations that develop and/or implement methods thus need to be aware of how methods are used and the roles they can play if they seek to enhance the capabilities of their employees. This thesis offers a detailed analysis of method usage in design that aims to assist organizations in effective implementation of methods.

In chapter 2, and later in chapter 5, I identify and investigate the link between method usage and a designer's method mindset. A method mindset is specific to an individual designer and constitutes at least a designer's knowledge about a method and its use, belief in a method's added value, trust in a method's applicability and a designer's ability to apply it and preference for using it over other methods. A method mindset determines to a large extend whether a method will benefit a designer's work (see chapter 5). Designers or design organizations that want to utilize a specific method are well advised to be aware of the importance to develop a proper method mindset. That is, in many cases, an organization's efforts to implement a specific method should rather be seen as an effort to develop a specific mindset in individual employees in the organization. From this perspective, method implementation should be seen as a learning process that includes belief-formation, trust-building and development of preference for new ways of working besides more traditional transfer of knowledge about the method itself.[1] Dedicated training programs, case material and master-apprentice systems can be powerful ways of truly implementing design practices in an organization with the help of methods.

For design practitioners, the development of expertise in design is seen as a key path to success (e.g. Dorst & Lawson, 2009). Expertise is based on intuitive skill, and true intuitive skill is shaped by reinforced practice (Kahneman & Klein, 2009). Reinforced practice entails paying attention to decisions or actions that lead to mistakes or unexpected outcomes in order to learn from them, a process known as reflection-on-action in design literature (Schön, 1983). In the thesis, I argue that methods can provide 'scaffolding' for reflection-on-action by providing a frame of reference when looking back at past activities to identify and/or explain when and why certain actions might have led to success or failure.

1 The way that the authors of the vision in Product design method (Hekkert & van Dijk, 2011) have paid attention to mindset building is an excellent example of a mindset approach to teaching the use of a method.

Design organizations know that in general, designers aim for change (Brown, 2009; Simon, 1996) and good design practitioners should be, as a consequence, goal-oriented in their way of working. This means that the ways of working of the past do not necessarily work to achieve new goals in the future, or at least not always in exactly the same way. As methods are formalized description of designer's work they are virtually always based on past ways of working. This poses a risk for method adoption in design and might explain the frustrations (Alexander, 1971; see e.g. Araujo, 2001; Dorst, 2008; Jones, 1977) with some of the expectations that have been implied in the agenda of systematic design methodology (see e.g. Eder, 1998; Hubka, 1982; Pahl et al., 2007). In contrast, the conceptualization of methods as mental tools that should be utilized in a flexible, goal-oriented manner will have a better fit with the mindset of practicing designers. Following this view on methods, they are more likely to be perceived as means to grasp complexity, help carry on in the face of doubt and uncertainty and give confidence to designers to make an innovative leap while operating outside of their comfort-zone. This is expected to be true for both an individual designer as well as teams. Moreover, articulating and adopting this view of methods in design education is expected to help students to advance from novice (rule-based mode of learning and working) to more advanced levels of expertise more easily. It should be noted however, that the development of design expertise happens in leaps and bounds (Lawson and Dorst, 2009). Although methods can provide scaffolding for reinforced practice that takes students through these phases it will by no means take away the anxiety that often accompanies the process of becoming expert designer and helping students to deal with that remains a key role for design educators.

In addition, design managers and policy makers that are involved in shaping and fostering best practices might consider to take into account the individual differences that can exist between designers. Particularly in the multifaceted practice of today, it is suggested that organizations foster the use of 'repertoires' of methods allowing employees to be flexible in their choices for an approach (Kyffin & Gardien, 2009). Again, this is also relevant for design education: in helping students to develop a repertoire of methods, students are empowered to develop a richer methodological background, preparing them for their future careers.

For designers and design teams, the complexity of the stakeholder-landscape of their projects is increasing dramatically with the advance of design into a more strategic role (Verganti, 2009) into the domain of business and ICT (Brooks Jr, 2010; Brown, 2009; Martin, 2009) and into more open forms of design innovation (Chesbrough, 2003; Van Abel, 2011). Managing design collaboration in such complex networks of stakeholders is a huge challenge. For example, designers in Philips Design use methods to "demystify the design process" and "create buy-in from stakeholders" (Timmer, personal communication, September 24th, 2010). In this context, the value of methods increases. They can help to create shared beliefs and understanding about design, discuss, plan and coordinate appropriate action and justify and account for design work.

In many projects, the level of experience and design mindset will vary between stakeholders. For example, projects might involve novice designers, clients, interns, external stakeholders, end-users, etc. These stakeholders might be uncertain about the (status of the) project, and about how they can contribute to it. Methods can help to create a shared mental model of what needs to be done, what the current status is and how one might contribute to the project. That is, methods can help to create a 'shared agenda' for design work.

For design educators, methods are still commonly seen as instructions that need to be followed to reach certain results. Yet from a didactic perspective, methods are better seen as mental tools that can help to develop student's ability to reason about design and that shape their beliefs and perception of design situations and tasks. Learning to design with the help of methods requires the development of a proper mindset that takes effort and time. In an educational setting, educators might consider to shape student's learning experiences by prescribing different types of methods and by employing a 'mindset approach' to teaching design. A mindset approach entails having attention for student's need to understand the beliefs and theory that underlie a method in order for the student to be able to believe in the method's value, to develop trust in the method's applicability and to develop confidence in their ability to use it effectively . It also entails helping them to recognize and articulate the specific roles methods can have in developing design capabilities and to recognize the situation-dependent nature of method usage. By discussing student's personal experiences with method usage in relation to method mindset and performance assessments, more valuable learning experiences can be offered (see e.g. Gerber & Carroll, 2012 for an in-depth study of the way early prototyping practices can help designers to deal with uncertainty). In probing a student's method mindset, teachers can discuss a student's own view of his or her process. For example, students might be asked to make diagrams of their design process in order to facilitate discussion (by allowing pointing, annotating and reflecting) and to surface a student's beliefs and attitude towards design. In probing a student's method mindset further, a teacher might go into more detail by asking about methods that are commonly used by the student and comparing them to established reference works. Following empirical work in this thesis and work on opportunistic behavior of designers in practice, method teaching should incorporate the development of capabilities to select and adapt methods to specific circumstances. It should also incorporate method teaching that highlights the ways in which designers generally use methods. That is, to communicate that designers typically do not use them as formal mechanisms/ instructions that are followed throughout, but as an aid in reasoning and/or reflection used in between more opportunistic episodes: good designers find a balance between relying on their intuition whenever possible, and to grasp for a method when a situation calls for it. Helping students to develop their ability to determine when to switch between modes of thinking should be a key learning goal for design education.

Designer-centered methodology: a way forward

With the results presented in this thesis, I contribute to a more detailed understanding of method usage in design, from the perspective of its central actor: the designer. I hope to have laid a foundation for a more designer-centered methodology (Badke-Schaub et al., 2011) that inspires researchers to deliver more valuable and useful methods to the design community and that inspires designers, design educators, design managers and design policy makers to re-think the way they employ and promote design methods in their practices. And to realize that the value of methods goes beyond contributing to a designer's execution of a task; methods can assist in staging, coordinating, managing, justifying and communicating design as well. In the spirit of a discipline that highly values the user of its products a designer-centered methodology should be grounded in a sound *understanding of why designers need methods and how they use them – both now and in the future. This is important because in spite of the criticism it often receives, design methodology is part of the fabric of design and methods constitute an important catalyst in advancing both design education and design practice. Yet at present, it is safe to assume that methods are frustrating students and practitioners as often as they benefit them. And just as worse: many methods that have taken a lot of effort to develop – and for which substantial research funding has been used – never reach practice on a broad scale. The research community should move away from the simplistic view of methods as 'instruction to be followed' as it obstructs methods' full potential. Conceptualizing methods as mental tools offers an avenue towards a more designer-centered methodology that will produces powerful means to assist designers in learning and doing design and extent their mental capabilities to help change our increasingly complex world into a better one.*

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Summary

Methods are means to help designers achieve desired change as efficiently and effectively as possible. Methods can be used to do so in the context of learning - to help teach students how to design on a professional level. Methods can also be used in the context of performance - to help designers perform better at what they already do (well). Methods should be seen as mental tools that influence the thinking patterns and mental models of designers. If we accept that methods function via a designer's mind, we can see that method usage is a human activity in which the designer is the user. This seems to be an obvious fact to be aware of for a discipline that is characterized by its focus on the user of the products and services they design; yet, quite remarkably, many design researchers have paid little attention to the users of their methods. Instead, most design research is aimed at 'directly' improving the design process through methods, often ignoring differences between designers, design contexts and design objects (Dorst, 2008). In this way, many method makers bypass the role of designers as central actors in method usage. When they do so, they seem to assume that designers follow their method almost "like a road" (Jensen & Andreasen, 2010, p. 3).

Aim of the thesis

In this thesis, I argue that an important reason for the current state of design methodology is our marginal understanding of the phenomenon of method usage. The thesis aims to contribute to a more detailed understanding of method usage in design, from the perspective of its central actor: the designer. With that, I hope to lay a foundation for a more designer-centered methodology that inspires researchers to deliver more valuable and useful methods to the design community and that inspires designers, design educators, design managers and design policy makers to re-think the

way they employ and promote design methods in their practices.

A theoretical inquiry into method usage in design

In chapter 2, a theoretical analysis of method usage in design is presented. I argued that the need for a method emerges from the subjective feeling of uncertainty that arises in non-routine situations. This viewpoint underlies the observation that methods function as flexible resources for designers to deal with non-routine situations (see e.g. Bender & Blessing, 2004). In addition, I argued that methods can function along three dimensions: they can help to extend design capabilities (e.g. by allowing the designer to grasp more complex problems than was possible without the method); they can aid in reflection on design activities and contribute to the reinforced practice that is necessary for the development of expertise (e.g. by providing a frame of reference through which structured reflection or feedback is made possible); and they can aid in learning to design by helping to make students aware of specific design capabilities and how to strengthen them (e.g. by providing ways to structure the design process). In analyzing method usage in-depth, I elaborated how methods function as mental tools for designers. Building on dual-processing theory from the field of cognitive science, we describe a model that outlines the fundamental roles of methods. In bridging the gap between the analysis of different fundamental roles that methods can have and the individual prerequisites for a person's proper use of a method (i.e. a person's ability to purposefully use a method to his or her benefit), the concept of method mindset is introduced. Method mindset refers to a person's mental equipment that is necessary for the purposeful use of a method.

Uncertainty & non-routine situations in design practice

In chapter 3, an interview study on non-routine situations with design practitioners is offered. With the focus on non-routine situations, the chapter takes a somewhat wider scope than in the previous chapter in order to study the arena in which methods are used. The study reveals a variety of non-routine situations that go beyond the design task and reach into the personal realm of the designer and (social) context of design. The study results in a variety of responses to the non-routine situations that were found. Although the list of non-routine situations and responses is not claimed to be complete, they do extend the basis for design methodology as a field of study, and as the body of design methods and tools. The results form an argument to consider contextual and personal factors in design methodology.

Method usage & expertise

In chapter 4, the relation between method usage and level of expertise is studied in a quasi-experimental setting. The study compared design practitioners with different levels of expertise – advanced, beginner and expert design practitioners – and offers three main insights.

First, in comparing the participants' method usage, a marginally significant association was found between level of expertise and the tendency to use one or more methods. As revealed by the odds ratio (a measure of effect size), the odds of using one or more methods were 9 times higher for advanced beginners than for experts.

Second, in comparing the participants' performances for a planning task the work of the advanced beginners received higher scores on average than the work of the experts. Although none of the differences were significant, a number of meaningful effect sizes were obtained that allow for some tentative conclusions. The finding that advanced beginners received higher scores on average seems to go against the general expectation that experts do better than novices.

Third, in going beyond differences between level of expertise, and in relating method usage directly to performance, a more ambiguous picture of the role methods play was found. Participants' performance was measured in two ways: for the first performance measure (based on scoring of the participants' work on predefined criteria) no significant correlation was found. However, for the second performance measure (based on overall ranking of the participants' work) the data revealed a different picture. A medium to strong positive correlation was found between method usage and the performance of the participants.

Taken together, the findings offer a somewhat ambiguous picture of method usage and design planning performance. It seems that methods correlate to better performance in planning for design projects and that experts tend to use fewer methods than advanced beginners. Most of the participants whose performances were ranked at the top also used methods from the database during the execution of the task, mostly more than one method. We note that the results should be interpreted with caution due to the lack of significances.

Individual differences in method usage

In chapter 5, the relation between the use of systematic and heuristic methods on design students' process experience is studied in a large-scale, experimental setting. The study compared the use of systematic and heuristic methods for a conceptual design task. The study also offers insight into the idiosyncratic ways in which students experience the use of systematic and heuristic methods in design, specifically in relation to the concept of method mindset that was described in chapter 2. First, in comparing how students used the two types of methods during a design task, it was found that the use of a systematic method resulted in significantly higher perceived time pressure, lower motivation and higher effort spent than the use of a set of heuristics. Moreover, we found that the students who were instructed to use the systematic method felt significantly less effective compared to those who used heuristics. These results underscore the ambiguity surrounding method usage in design, providing inconclusive proof for or against using systematic and/or heuristic methods in the conceptual phase of design. Second, in exploring individual differences in the use of methods we identified four distinct ways in which students experienced their design process: students felt (1) on top of things, (2) swamped, yet striving to succeed, (3) indifferent and disconnected, (4) seemed to have lost faith in themselves. Together, the results suggest that the use of methods in design is not connected to performance in a straightforward manner: their use depends at least on a student's method mindset and interpretation of the task.

Conclusions

The four main chapters in this thesis contribute to design methodology, design education and design practice in a number of ways.

Contribution to design methodology

First, following a theoretical inquiry into the phenomenon of method usage in design, it is proposed that methods should be regarded as mental tools that designers can use to aid them in their reasoning. They can be used to do so on the short term: to aid in dealing or learning to deal with non-routine situations. They can also be used to do so on the long term: to facilitate the reinforced practice that is needed for skill development and acquiring design expertise.

Second, it is argued that the potential application area of methods (i.e. types of situations in which methods can be beneficial) should be extended beyond dealing with the process of developing a design object alone. Particularly the potential role of methods in social settings – as a 'boundary object'– is deemed to be an important subject of future study.

Third, based on dual-processing theory, a model has been presented in which intuition and reasoning are reconciled and in which the roles of methods as mental tools have been elaborated. Based on the model, we identified fundamental roles of methods that 'speak' to different faculties of the human mind.

Fourth, when comparing methods, the distinction between systematic and heuristic methods often comes into play, and shall be taken into account as well. As was discussed in chapter 2, the current debate on systematic and heuristic methods is rather polarized. It is expected that comparative studies like in chapter 5 will bring clarity to the matter and provide empirical evidence to move the debate forward in a productive manner.

Fifth, it is argued that studies that aim to evaluate a method's added value should take into account alternative strategies and methods with which they will 'compete' for attention. Many of these strategies are normally not perceived as being within the scope of design methodology.

Contribution to design practice

First, it is proposed that the effort of design organizations to implement a specific method should be seen as an effort to develop a specific mindset in individual employees in the organization. From this perspective, method implementation is a learning process that includes belief-formation, trust-building and development of preference for new ways of working besides more traditional transfer of knowledge about the method itself. In addition, it is proposed that a conceptualization of methods as mental tools (that should be utilized in a flexible, goal-oriented manner) will have a better fit with the mindset of practicing designers and improve acceptance.

Second, it is proposed that methods can provide 'scaffolding' for skill development in individual employees by providing a frame of reference when looking back at past activities to identify and/or explain when and why certain actions might have led to success or failure.

Third, design managers and policy makers that are involved in shaping and fostering best practices are advised to take into account the individual differences that can exist between employees. Particularly in the multifaceted practice of today, it is suggested that organizations foster the use of 'repertoires' of methods allowing employees to be flexible in their choices for an approach (see also Kyffin & Gardien, 2009).

Fourth, for designers and design teams, the complexity of the stakeholder-landscape of their projects is increasing dramatically. Managing design collaboration in such complex networks of stakeholders is a huge challenge. In this context, the value of methods increases. For instance, methods can help to create understanding about design work, to discuss, plan and coordinate appropriate action and to justify and account for design work.

Contribution to design education

First, it is proposed that from a didactic perspective, methods are better seen as mental tools that can help to develop a student's ability to reason about design and shape their beliefs and perception of design situations and tasks. Learning to design with the help of methods requires the development of a proper mindset that takes effort and time. In an educational setting, educators might consider to shape a student's learning experiences by prescribing different types of methods and by employing a 'mindset approach' to teaching design. A mindset approach entails having attention for student's need to understand the beliefs and theory that underlie a method in order for the student to be able to believe in the method's value, to develop trust in the method's applicability and to develop confidence in their ability to use it effectively. It also entails helping them to recognize and articulate the specific roles methods can have in developing design capabilities and to recognize the situation-dependent nature of method usage. Second, in helping students to develop a repertoire of methods, they are empowered to develop a richer methodological background, preparing them for their future careers. Third, following empirical work in this thesis and work on opportunistic behavior of designers in practice, method teaching should incorporate the development of capabilities to select and adapt methods to specific circumstances.

Methoden zijn middelen om ontwerpers te helpen om gewenste verandering op een zo efficiënt en effectief mogelijke manier te bewerkstelligen. Methoden kunnen hiervoor gebruikt worden tijdens het leren – om studenten te helpen een professioneel niveau te bereiken. Methoden kunnen ook gebruikt worden tijdens het presteren –om professionele ontwerpers te helpen om nog beter te laten presteren dan ze al deden. Methoden dienen te worden gezien als mentaal gereedschap welk het denken en de mentale modellen van ontwerpers beïnvloeden. Als we accepteren dat methoden functioneren via het denken van de ontwerper, dan kunnen we zien dat methodegebruik een menselijke activeit is met de ontwerper als gebruiker. Dat men zich hier bewust van is lijkt voor de hand te liggen voor een discipline die wordt gekenmerkt door zijn focus op de gebruiker van de producten en diensten die zij ontwerpt; het is echter opmerkelijk dat veel onderzoekers in het ontwerpen slechts weinig aandacht schenken aan de gebruikers van hun methoden. In plaats daarvan is het meeste ontwerponderzoek gericht op het 'direct' verbeteren van het ontwerpproces door middel van methoden, waarbij verschillen tussen ontwerpers, ontwerpomgevingen en ontwerpobjecten worden genegeerd (Dorst, 2008). Op deze manier wordt de ontwerper als gebruiker van methoden door veel ontwerponderzoekers over het hoofd gezien. En wanneer ze dit doen lijken ze vaak aan te nemen dat ontwerpers hun methoden wel zullen volgen alsof 'het een weg is' (Jensen & Andreasen, 2010, p. 3).

Doel van het proefschrift

In dit proefschrift stel ik dat de huidige staat van de ontwerpmethodologie voor een belangrijk deel verklaard kan worden door ons gebrekkige begrip van het gebruik van methoden. Het proefschrift heeft als doel om bij te dragen aan een gedetailleerder begrip van methodegebruik in het ontwerpen, vanuit het perspectief van zijn belangrijkste actor: de ontwerper. Hiermee hoop ik een basis te leggen voor een meer ontwerpergerichte ontwerpmethodologie die onderzoekers inspireert om waardevolle en bruikbare methoden aan de ontwerpgemeenschap te leveren, en die ontwerpers, onderwijzers, managers en beleidsmakers inspireert om de manier waarop ze ontwerpmethoden inzetten en aanbieden opnieuw uit te vinden.

Een theoretische study van methodegebruik in het ontwerpen

In hoofdstuk 2 presenteer ik een theoretrische analyse van methodegebruik. Ik stel dat de behoefte aan een methode voortkomt uit de subjectieve ervaring van onzekerheid die ontstaat in non-routineuze situaties. Deze zienswijze ligt ten grondslag aan de observatie dat methoden functioneren als flexibele hulpbron voor ontwerpers die ze helpt om te gaan met non-routineuze situaties (see e.g. Bender & Blessing, 2004). Daarbij stel ik dat methoden kunnen functioneren langs drie verschillende dimensies: ze kunnen helpen om het ontwerpvermogen te vergroten (bv. door de ontwerper in staat te stellen een grotere complexiteit aan te kunnen dan mogelijk zou zijn zonder de methode); ze kunnen helpen om reflectie op ontwerpactiviteiten te verbeteren om zo bij te dragen aan gerichte oefening (reinforced practice) die nodig is voor de ontwikkeling van expertise (bv. door een referentiekader aan te bieden waarmee gestructureerde feedback en reflectie mogelijk wordt); en ze kunnen bijdragen aan het leren ontwerpen door studenten te helpen om zich bewust te worden van specifieke ontwerpvermogens en hoe deze te versterken. Middels een diepe analyse van methodegebruik weid ik uit over hoe methoden functioneren als mentaal gereedschap voor ontwerpers. Bouwende op ‘dual-processing’ theorie vanuit de cognitieve psychologie, beschrijf ik een model waarmee fundamentele rollen van methoden uiteen worden gezet. Dan, om een brug te bouwen tussen de analyse van de rollen die methoden kunnen hebben en de individuele voorwaarden voor iemands goede methodegebruik (d.w.z. iemands vermogen om doelgericht, en tot zijn of haar voordeel een methode te gebruiken) introduceer ik het begrip 'methode mindset'. Een methode mindset refereert aan iemands 'mentale uitrusting' die nodig is voor het doelgericht gebruik van een methode.

Onzekerheid & non-routineuze situaties in de ontwerppraktijk

In hoofdstuk 3 presenteer ik een interviewstudie met praktijkontwerpers over non-routineuze situaties. Met de focus op non-routineuze situaties neemt het hoofdstuk een wat ruimere blik dan het voorgaande hoofdstuk, om zo de arena waarin methoden worden gebruikt te bestuderen. De studie onthult een variëteit aan non-routineuze situaties die voorbijgaan aan de ontwerptaak en reiken tot in het persoonlijke domein van de ontwerper en de (sociale) context van het ontwerpen. De studie resulteert in een variëteit aan reacties op de non-routineuze situaties die gevonden zijn. Hoewel ik niet pretendeer dat de lijst met non-routineuze situaties en reacties compleet is, vergroot zij wel de basis voor de ontwerpmethodologie als onderzoeksgebied. De resultaten vormen een argument om persoonlijke en contextfactoren in acht te nemen binnen de ontwerpmethodologie.

Methodegebruik & expertise

In hoofdstuk 4 presenteer ik een quasi-experimentele studie naar de relatie tussen methodegebruik en expertise. De studie vergelijkt praktijkontwerpers met verschillend ervaringsniveau –gevorderden, beginners en experts– en levert drie inzichten.
Ten eerste, na vergelijking van het methodegebruik van de deelnemers vinden we een

marginaal significante associatie tussen expertiseniveau en het gebruik van een of meer methoden. De 'odds-ratio' (een maat voor effectgrootte) laat zien dat de kans dat een geavanceerde beginner methoden gebruikt 9 keer groter is dan bij experts.

Ten tweede, na verglijken van de prestaties van de deelnemers voor een planningtaak vinden we dat het werk van de geavanceerde beginners een gemiddeld hogere score ontvangt dan het werk van de experts. Hoewel geen van de verschillen significant zijn vinden we wel een aantal betekenisvolle effectgroottes die wat tentatieve conclusies toelaten. De bevinding dat geavanceerde beginners gemiddeld hogere scores ontvangen lijkt in te gaan tegen de algemene verwachting dat experts beter presteren dan beginners.

Ten derde, als we voorbij de verschillen tussen expertiseniveau kijken, en we methodegebruik direct aan prestatie relateren, vinden we een meer ambigu beeld van de rol van methoden. De prestaties van de deelnemers is gemeten op twee manieren: voor de eerste manier (gebaseerd op de beoordeling van het werk van de deelnemers aan de hand van vantevoren gedefinieerde criteria) is geen significante correlatie gevonden. Echter, voor de tweede manier (gebaseerd op de globale ranking van het werk van de deelnemers) liet de data een ander beeld zien. Een middel tot sterke correlatie is gevonden tussen methodegebruik en prestatie van de deelnemers.

Samengenomen leveren de bevindingen een enigszins ambigu beeld op van methodegebruik en prestatie voor een planningtaak binnen het ontwerpen. Het lijkt erop dat methodegebruik samenhangt met betere prestaties in het plannen van ontwerpprojecten en dat experts geneigd zijn minder methoden te gebruiken dan geavanceerde beginners. De meeste deelnemers wiens prestatie hoog werd gerankt genbruikten ook meer methoden uit de database tijdens het uitvoeren van de taak, en meestal meer dan één methode. Ik merk op dat de resultaten met voorzichtigheid dienen te worden geïnterpreteerd vanwege het gebrek aan significantie.

Individuele verschillen in methodegebruik

In hoofdstuk 5 presenteer ik een grote, experimentele studie naar de relatie tussen het gebruik van systematische en heuristische methoden en de proceservaringen van ontwerpstudenten. De studie vergelijkt het gebruik van systematische en heuristische methoden voor een conceptuele ontwerptaak. De studie biedt ook inzicht in de karakteristieke manieren waarop studenten het gebruik van systematische en heuristische methoden ervaren, in het bijzonder in relatie tot het concept van 'methode mindset' dat in hoofdstuk 2 is beschreven.

Ten eerste, na vergelijking van het gebruik van de twee verschillende typen methoden door studenten tijdens een ontwerptaak, vinden we dat het gebruik van een systematische methode leidt tot ervaring van een significant hogere tijdsdruk, lagere motivatie en hogere inzet dan voor het gebruik van een set heuristieken. Bovendien vinden we dat studenten die gevraagd waren een systematische methode te gebruiken zich significant minder effectief voelden in vergelijking met degenen die heuristieken gebruikten. Deze resultaten benadrukken de ambiguïteit rondom methodegebruik in het ontwerpen.

Ten tweede, na verkennen van individuele verschillen in het gebruik van methoden vinden we 4 verschillende manieren waarop studenten het ontwerpproces ervaren: studenten voelden zich (1) op en top, (2) overweldigd maar strevend naar succes, (3) onverschillig en losgekoppeld, (4) alsof ze het geloof in zichzelf verloren waren. Samengenomen suggereren deze resultaten dat methodegebruik in het ontwerpen niet aan prestatie is gekoppeld op een eenduidige manier: het gebruik hangt tenminste af van de mindset van een student en zijn of haar interpretatie van de taak.

Conclusies

De vier kernhoofdstukken in dit proefschrift dragen bij aan ontwerpmethodologie, ontwerponderwijs en de ontwerppraktijk op een aantal manieren.

Bijdrage aan ontwerpmethodologie

Ten eerste, op basis van een theoretische analyse van het fenomeen methodegebruik in het ontwerpen, stel ik voor dat methoden dienen te worden gezien als mentaal gereedschap dat ontwerpers kunnen gebruiken om hun redeneren te ondersteunen. Dat kan op de korte termijn: door bij te dragen aan het omgaan, of leren omgaan, met non-routineuze situaties. Dat kan ook op de lange termijn: door de gerichte oefening te faciliteren die nodig is voor de ontwikkeling van expertise.

Ten tweede, ik stel dat wat we zien als de potentiële toepassingsgebieden van methoden (d.w.z. de verschillende typen situaties waarin methoden nuttig kunnen zijn) uitgebreid dient te worden buiten het productontwikkelingsproces op zich. De potentiële rol van methoden in sociale situaties – als een 'boundary object'– wordt als belangrijk toekomstig studieonderwerp voorgesteld.

Ten derde, op basis van 'dual processing' theorie stel ik een model voor waarin intuïtie and ratio worden verenigd and waarin de rol van methoden als mentaal gereedschap uiteen wordt gezet. Op basis van het model identificeer ik fundamentele rollen van methoden die spreken tot verschillende delen van het menselijke denkvermogen.

Ten vierde, wanneer methoden worden vergeleken komt vaak het verschil tussen systematische en heuristische methoden aan de orde. Zoals ook al besproken in hoofdstuk 2, is dat debat behoorlijk gepolariseerd. Ik verwacht dat vergelijkende studies zoals genoemd in hoofdstuk 5, helderheid over het onderwerp zullen brengen en empirisch bewijs leveren dat het debat voorwaarts kan brengen op een productieve manier.

Ten vijfde, ik stel dat studies ter beoordeling van de toegevoegde waarde van een methode zouden moeten refereren naar concurrerende strategiën en methoden. Veel van deze strategiën worden normaal gesproken niet gezien als onderdeel van de set methoden die onder ontwerpmethodologie vallen.

Bijdrage aan de ontwerppraktijk

Ten eerste stel ik dat de moeite die ontwerporganisaties doen om specifieke methoden te implementeren gezien dient te worden als een streven om een specifieke mindset te ontwikkelen bij individuele werknemers binnen de organisatie. Vanuit dit perspectief gezien is methode-implementatie een leerproces waarin het vormen van overtuigingen, het bouwen van vertrouwen en het ontwikkelen van een voorkeur voor nieuwe manieren van werken onderdeel zijn, naast de meer traditionele overdracht van kennis over de methode zelf. Daarbij stel ik dat de zienswijze dat een methode mentaal gereedschap is (welke gebruikt dient te worden op een flexibele, doelgerichte manier) beter zal aansluiten bij de mindset van ontwerpers en de acceptatie van methoden zal bevorderen.

Ten tweede stel ik dat methoden als 'steiger' kunnen dienen voor de ontwikkeling van expertise, doordat ze een referentiekader bieden voor reflectie op activiteiten in het verleden, om te identificeren en/of te verklaren wanneer en waarom bepaalde handelingen tot succes of mislukking hebben geleid.

Ten derde, ontwerpmanagers en beleidsmakers die betrokken zijn bij het vormgeven en aanmoedigen van 'best practices' worden geadviseerd om de individuele verschillen die bestaan tussen werknemers serieus te nemen. Met name in de veelzijdige praktijk van vandaag wordt aangeraden dat organisaties het hebben van 'repertoires' van methoden aanmoedigen zodat werknemers in staat worden gesteld om flexibel te zijn in hun keuze voor een aanpak (zie ook Kyffin & Gardien, 2009).
Ten vierde, het landschap van belanghebbenden wordt steeds complexer. Het managen van samenwerking in zulke complexe netwerken van belanghebbenden is een enorme uitdaging. In deze context wordt de waarde van methoden groter. Methoden kunnen bijvoorbeeld helpen om gedeeld begrip te creëren over werk dat gedaan moet worden, om activiteiten te bediscussiëren, plannen te coördineren en om werk te verantwoorden en uit te leggen.

Bijdrage aan het ontwerponderwijs

Ten eerste stel ik dat vanuit didactisch perspectief methoden beter kunnen worden gezien als mentaal gereedschap dat kan helpen om het vermogen van studenten om te redeneren over het ontwerpen te ontwikkelen en om hun overtuigingen en perceptie van situaties en taken vorm te geven. Leren ontwerpen met behulp van methoden vereist de ontwikkeling van een geschikte mindset en dat kost moeite en tijd. Docenten kunnen in een onderwijssituatie overwegen om de leerervaringen van studenten vorm te geven door verschillende methoden aan te bieden en door een 'mindset' aanpak aan te nemen. Een 'mindset' aanpak houdt in dat een docent aandacht heeft voor de behoefte van een student om de overtuigingen en theorie die aan een methode ten grondslag liggen te begrijpen en om zodoende te kunnen geloven in de toegevoegde waarde van een methode, te vertrouwen in de toepasbaarheid van de methode en het vertrouwen te kweken in het effectief kunnen toepassen van de methode. De mindset aanpak houdt ook in dat studenten worden geholpen met het herkennen en articuleren van specifieke rollen die methoden kunnen hebben in het ontwikkelen van hun ontwerpvermogen en de situatie-afhankelijke aard van methoden.

Ten tweede, door studenten te helpen met het ontwikkelen van een repertoire aan methoden worden ze in staat gesteld om een rijkere methodologische achtergrond te ontwikkelen ter voorbereiding op hun toekomstige carière.

Ten derde, op basis van het empirische werk in dit proefschrift en ander werk waaruit blijkt dat een bepaalde mate van opportunistisch gedrag gewenst is stel ik dat ontwerponderwijs aandacht dient te hebben voor het vermogen van studenten om methoden te kiezen en aan te passen aan specifieke omstandigheden.

Appendix A - interview guidelines

An important aspect of designing in the context of an organization is to do projects (more) efficiently and effectively. Designers, and organizations as well, have ways of working that are familiar to them and which are known to lead to a satisfying result and process. However, there are always situations when things do not go as expected or desired for whatever reason or situations where a different approach is needed. We are looking for those kinds of situations, and your ideas about these situations.

What are typical situations in design projects that result in outcomes that are not efficient or effective?
What are situations where you feel you are not being efficient or effective?
What are the characteristics of these situations?
What personal aspects/issues/characteristics induce these situations?
What characteristics of the project induce these situations
What characteristics of the team induce these situations?

Appendix B - influencing factors to non-routine situations

Influencing factor	f	Description	example quote
		A designer's perception of a specific situation and his response to it is influenced by:	
Factors related to the task			
Time pressure	10	Limitations in amount of time that is available	Mechanical engineer: "But, the trouble is, in these design processes that there isn't the time to bring in a vendor."
Complexity of task	5	A high amount of interrelated factors related to the design problem	Mechanical engineer: "How you're going to tackle problems it depends on the external circumstances, and the timeline and the complexity"
Fuzziness of task	1	A highly abstract and open design task	Interaction designer: "I think it also has to do with the type of assignments we get, for which companies come to us, [they] are very open-ended and very abstract."
Phase of project	2	The current phase in which a project is	Mechanical engineer: "If you make an error at the conceptual level you have a big problem if you get downstream with it. And so there tends to be a lot of evaluating of the concepts early on; prototyping"
Newness of domain	2	The degree to which a task-domain is new to the designer/organization	Interaction designer: "often the case that very few assignments, attention is paid to the proper framing of the assignment and the sort of defining of the domain"
Budget limitations	1	Limitations in the budget that is available	Experienced design manager: "we tend to look deeper and sometimes there is not budget for that"
Factors related to the individual			
Level of experience	6	His or her level of experience	Experienced product designer: "and so we create a tool for that, to gather the input, to combine and filter it in a way that we get a quick and effective result. But I think that's kind of experience"
Design principles	5	His or her design principles or personal design philosophy	Experienced product designer: "my philosophy is about really focusing on the experience of use."

Influencing factor	f	Description	example quote
		A designer's perception of a specific situation and his response to it is influenced by:	
Methodological background	5	His or her methodological background	Experienced design consultant: "the design thinking we talk about, that was sort of invocated at school, they did a good job at that."
Perfectionism	4	His or her perfectionism	Interaction designer: "in part this is in the character of designers [laughs] because we are the type of designers who demand from our first ideas to be good, or we are not very eager to try. (…) That means that you first have to have thought of everything before you go on."
Curiosity	3	His or her curiosity to learn new things	Experienced design engineer: "so you come up with something that your intuition tells you and then you actually go and try and prove it, and something doesn't pan out. And I think there is where the greatest learnings occur, because now you have to shift your mental model. And so, you know, from just an intellectual delight standpoint you know, when I run across those, I like to dig into those."
Educational background	1	His or her educational background	Experienced product designer: "I am educated as a mechanical engineer, so I am bale to translate abstract ideas into working objects. And I think this relationship between idea and object is the most important thing you can imagine."
Innate abilities	1	His or her innate abilities	Mechanical engineer: "it was already in my nature when I got here: how to approach a problem"
Factors related to the (social) context			
Company culture	15	An organization's culture	Design engineer: "so in the corporate setting there was much less of a design process to say. I was a design engineer for a number of years. And there it was much more iterative very low risk changes."
Team culture	3	A team's culture	Design manager: "So setting up a good team that inspire each other and can grow their creativity together. That's always, that can either go very fast and feel very easy. And sometimes it just doesn't work. And then you need creative facilitation or other tools to support that."

Influencing factor	**f**	**Description**	**example quote**
		A designer's perception of a specific situation and his response to it is influenced by:	
User involvement	3	The (need to) involve users in the process	Design engineer: "especially for projects where I know that the end-users will actually be interacting with them [products], as opposed to part of a component or a process. I feel more of an emotional connection to the product I am working on."
Client demands	1	The demands that are expressed by a client	Design manager: "so the client comes with requirements that are not relevant in the early stage for example, and they will bombard you with a whole list of requirements that kind of holds your - I would say almost breaks down - your creativity. That is always an issue."
Client relationship	3	The kind of relationship that exists between client and organization	Design manager: "we do have some return clients, quite a few now and we have some clients we are the brand custodian for (…) so taking care of all their design activities. So there is quite a range in what we do externally, now. From one-off jobs to, you know, taking care of a company's brand.in total, so you see the scope of the challenge is quite broad."

Introduction to assigment

De Koning is a reasonably large Dutch company (approximately 1500 employees) that produces consumer products for the US and European market. The division 'personal care' creates products like shavers, massage chairs, solariums, etc. In the last 10 years they have specialized in products for independent living elderly. Through this De Koning has gained a large market share in the first years after initial market launch of these products.

Your agency is hired to develop the packaging of their best selling product, the Swing self-care. First a project proposal is expected, in which the general approach, subtasks and activities for the project are specified. Your team member, Mrs. Kinkel will present the project proposal tomorrow to the management of De Koning.

You are asked to make a detailed planning and a short PowerPoint presentation for this project in the next 2 hours. The project team consists of 6 people including you. (see "team members"). Your design agency is located both in The Netherlands as well as in the US, and part of your project team is located in the USA which makes a clear process planning necessary for communication.

Make a detailed planning for the project, with sub-processes stated and justified. The planning has to meet the following requirements:

- A clear general approach, distinguishing phases and specified main activities
- Specification of the relation between tasks and the total process.
- Include a short presentation that shows the main approach and most important subtasks and allows Mrs. Kinkel to present and justify the approach to the

management of de Koning tomorrow.

- A vizualization of the approach on paper
- To be eligible for certification of the product in the US, the project structure must be usable for documenting the processes during and after the project.

The product manager of De Koning has provided a design briefing that contains the goals and context of the project (see 'project briefing').

Composition of the team

Marieke Kinkel (45) - Marketing manager, project leader

- 21 years of experience, has been employed by your office for 10 years.
- She has experience with project management and market implementation of complex products

Jolanda Dal (34) - Creative director

- 10 years of experience, has been working for your office for 2 years. Before that she worked at Philips design.
- She has been educated at the Willem de Koning Academy.

Team members in the USA

Sonia Smith (26) – Marketing manager North-America

- MBA from Haas school of business, UC Berkeley
- Various marketing functions in the domain of medical product development in the US.
- Has been working at the US location of your office since 5 years

Erik Scherp (28 jaar) – Graphic designer

- Graduated at the Delft University of Technology in 2004
- He has been working at IDEO for a number of years, first in the London office, then in Palo Alto.
- He has been employed by your office since 2 years.

Project briefing "Packaging for the Swing Selfcare"

De Koning is a reasonably large Dutch Company (about 1500 employees) creating consumer products for the US and European market. The division 'personal care' produces shavers, massage chairs, solariums, etc. We have been focusing on products for independently living elderly for the last 10 years, By doing this we have gained a large market share since the launch of these products.

Figure 1. A number of the products of De koning. From left to right: product for measurement of the glucose levels in the blood, massage chair, product for measuring bloodpressure, and an alarmsystem for independtly living elderly.

Our best selling product, the Swing selfcare, enables our users to measure blood pressure, ocular pressure and glucose levels with one integrated product. The product is aimed at frequently occurring symptoms in the target group. The product transmits data to a central server that can be used by general practitioners to monitor patients' health

status as well as for accurate measurements of long term trends in patients' health status. Unfortunately, our market share is shrinking lately. More competitors have entered the market and have gained market share. From a market research report, we found out that our target group is not familiar with our company. Moreover, their adult children, who are often involved in purchasing decisions for our products do not know us as well.
As a product manager I want to create a clear and coherent image into our products in the next couple of years. As a starting point for this project, I want to create a new packaging concept for our best-selling product the Swing selfcare. The current brief needs to be a stepping stone for a more coherent and clear communication of what we strand for as a company. The new packaging also needs to enable to create a broader market for the Swing. Some of my ideas are to widen our retail channels to include also major drugstores in the Us and Europe.
I want to focus on clear communication of our values, on easy-to-use products for the target group, creating the opportunity to sell our product though broader retailing channels. (for example the ETOS in the Netherlands), creating the opportunity to apply the new packaging concept to the whole product portfolio and on the technical and manufacturing feasibility of the packaging.
Our target group typically consists of people aged between 60 and 85, living independently in suburban areas. They are usually retired and have a limited action-radius. I am very enthousiastic about creating an exciting new packaging concept that both increases our presence amongst our target group and allows us to sell the product to a broader group. Below I have indicated a number of critical issues for the project, as well as a specification of the Swing selfcare.

General project information:

- Since the project is a model for future development of packaging concepts and products, process and rationale behind it need to be documented.
- The first meeting between Mrs. Kinkel and the management team is tomorrow.
- In 4 weeks the first concepts need to be presented to the management team.
- The final presentation to the board of management takes place in 2 months. By that time there needs to be a fully detailed packaging proposal for the Swing selfcare.
- In order to be eligible for certification in the US; the development process of the product – including the packaging - needs to be documented. The management team of de Koning has specifically indicated that a detailed and justifiable process specification is needed for the meeting tomorrow.
- Production takes place at our partner in Szuhai, China.

Product specificaties "Swing selfcare"

Model: "Swing Selfcare"

Price: € 249 in most European countries, $ 299 in the US.

Materials exterior: ABS and silicon

Manufacturing: 2K injection moulding, outsourced to a preferred supplier in Germany.

Primairy functions:

- Self measurement of ocular (eye) pressure
- Self measurement of bloodpressure
- Self measurement of glucoselevels

Secundairy functions:

Transmitting of data to a central

User can view datatrends via a TV connection

De Swing can be used singlehanded for measurement of ocular pressure, glucoselevels and bloodpressure. The user can do these measurements by himself which allows for an accurate overview of relevant indicators for illnesses that are common for elderly. General practitioners can make more reliable and accurate diagnosis from the data.

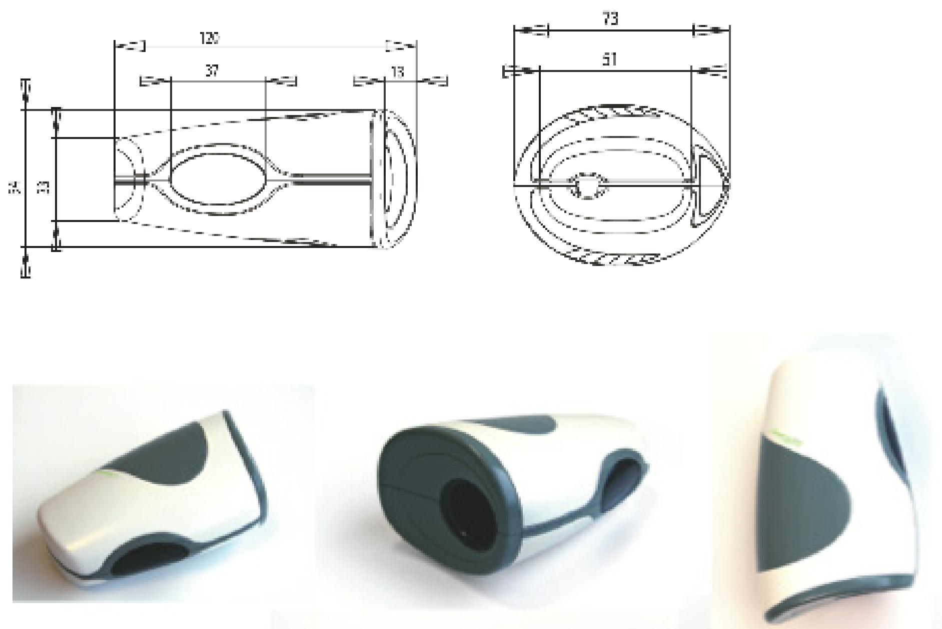

Figure 2. The Swing selfcare

Key manager for the elderly

In an aging society, more and more people are able to live at home until a later age. At the same time, with age, many people experience reduced physical capabilities (such as their eyesight becoming worse), which can result in day-to-day problems. A seemingly simple problem is the handling or management of keys. With reduced sight, very often elderly face difficulties in locating their keys or finding the right key for each lock. In addition, many elderly struggle with locking and unlocking doors because of physical impairment (e.g. they lack the necessary strength and fine motoric skills). Most keys are too small and do not provide enough grip to be handled with ease. As a consequence, many elderly leave doors unlocked during the night or when leaving the house. This can make elderly feel unsafe at home.

The Danish company GEMO has decided to address this problem. GEMO is a medium-sized company producing a variety of household products for the Danish market. Their portfolio is diverse and characterized by simplicity in form and function, often favouring low-tech designs. In providing a solution to the problem above, the company has asked you to design a product that will help elderly people manage their keys. Your assignment is:
Come up with a concept for a tangible product that helps elderly in handling and managing their keys. Make sure your design accounts for the special needs of your target group, which are mentioned above. The product should fit the company's portfolio. Try to keep within two hours for designing the concept.

Instructions for using the systematic method

In coming up with a solution to the design brief, we want you to design with the help of a morphological chart (see below). With the help of a morphological chart, a design problem is decomposed to sub-problems, which can be solved individually. The solutions to the sub-problems are then combined to possible solutions to the original design problem from which the most promising solution is selected.

An A3 template for doing a morphological chart is available to you (a hyperlink to the document was provided). If you cannot print the template, you can also draw your own chart on a larger sheet of paper.

Please fill in the chart as you design a solution to the brief by following the instructions on next pages. Next to the morphological chart, you will need paper to sketch on.

After having completed the exercise, you will be asked to place a copy of your morphological chart together with your sketches and final solution in the PowerPoint template (provided on Blackboard) in preparation for the tutorial.

Step 1.

Please formulate your interpretation of the design problem in the brief as accurately as possible below [a textbox was provided] and on top of the morphological chart in front of you.

Step 2.

Please identify the sub-functions that the product concept needs to fulfill in order to solve the design problem. Next, list them below [a textbox was provided] as well as in the left column of your morphological chart.

Step 3.

Please think about possible ways of solving the different sub-functions and draw the different solutions next to each function in the morphological chart. Try to think about at least four different ways of solving each sub-function.

Step 4.

Analyze the rows and group the components. Create principal solutions by combining at least one component from each sub-function.

Step 5.

Carefully analyze and evaluate all principal solutions with regard to the objectives

Step 6.

Please generate possible design concepts by integrating at least one solution to each sub-function (integrating sub-solutions vertically across the morphological chart) in rough sketches.

Step 7.

Please select the most promising solution (sketch) and work it out in a presentation sketch. Add explanatory (textual) notes to the presentation sketch so that it becomes self-explanatory.

Instructions for using the heuristic method:

In coming up with a solution to the design brief, we would like you to design with the help of a number of heuristics (rules of thumb). Specifically, we want you to start with the most prominent problem in the brief and begin designing by taking the first solution idea that comes to mind to this problem (and is worthwhile exploring). Next, we want you to develop the solution further by continuously adapting until it meets the objectives in the design brief. You should stop designing as soon as you have a solution that meets the requirements in the brief.

A summary of the heuristics are listed below:

- Primary generator: take the sub-problem that seems most prominent to you and start solving it.
- Conjecture-analysis: take the first solution idea that comes to mind (and is worthwhile exploring) to your design problem and start developing it further.
- Iterate: develop an idea and adapt it continuously to get closer and closer to the design objectives
- Satisfice: stop designing as soon as your concept meets the design objectives.

Please adhere to these heuristics when you follow the instructions on the next pages. You will need a paper to sketch on. After have completed the exercise, you will be asked to place scans of your sketches and final solution in the PowerPoint template (provided on Blackboard) in preparation for the tutorial.

Step 1.

When thinking about the design brief, you probably have an intuitive idea about which problem is most challenging to solve. Please formulate below the (sub) problem [a textbox was provided] that seems most prominent to you.

Step 2.

When thinking about the design brief, you will probably have an intuitive idea for a solution in mind. Please formulate below [a textbox was provided] the initial solution idea that you will work with.

Step 3.

Please develop your idea and adapt it to get closer and closer to the design objectives. If you are not satisfied with your concept either choose to:

- Go back and pick another sub-problem,
- Go back and develop another solution idea,
- Or, if you think your solution satisfies the objectives, please click this link. [hyperlink was provided]

The complexity of the design brief ($r = .64$, $p < .01$)

1. The brief is difficult to read.
2. The brief is difficult to understand.
3. The brief's design objectives are clear. (excluded)

The complexity of the design task ($r = .42$, $p < .01$)

1. A suitable solution to the brief will be difficult to design.
2. Working out solutions to the brief will be easy. (reversed)
3. I expect to feel overwhelmed at certain stages of the design process. (excluded)

The interest triggered by the brief ($\alpha = .87$)

1. The topic of the design brief triggers my interest.
2. The design challenge posed in the design brief is interesting to me.
3. I find the design brief inspiring.

Feasibility of solving the brief ($r = .43$, $p < .01$)

1. I expect to be able to work out appropriate solutions within 2 hours.
2. he objectives of the design brief can be feasibly met.

Time pressure ($\alpha = .80$).

1. I felt pressed for time when doing this exercise.
2. I had plenty of time in coming up with a design for the brief. (reversed)
3. I worried a lot about not finishing on time during the exercise.

Self-confidence (α = .69).

1. Throughout this exercise, I felt confident that I would be able to solve the design problem. (reversed)
2. I sometimes felt overwhelmed by the complexity of the design problem in doing the exercise.
3. I doubted myself a lot during this design exercise.

Motivation (α = .75)

1. I felt highly motivated to do this design exercise.
2. I wanted to do well in this design exercise.
3. I worked eagerly on this design exercise.

Conscientiousness (α =.63)

1. I tried to design with great attention to detail.
2. I was too perfectionist during this exercise.
3. I was somewhat careless in my detailing. (reversed)

Effort (α = .72)

1. I put a lot of effort into this design exercise.
2. I took this design exercise seriously.
3. I took this design exercise too lightly. (reversed)

Prior exposure to the used method (α = .86).

1. In my training to become a designer, I have learnt a lot about [morphological charts/ the four heuristics].
2. Using [morphological charts/the four heuristics] has been an important part of my education so far.
3. In the past, I have worked a lot with [morphological charts/the four heuristics].

Preference for the used method (approach) (α=.89)

1. I like to work with [morphological charts/the four heuristics].
2. I find [morphological charts/the four heuristics] useful.
3. I think [morphological charts/the four heuristics] are helpful to me when designing.

Overall evaluation of the final concept (α=.93)

1. I am happy with my design.
2. I like what I have produced.
3. I am content with my solution.
4. I feel I have produced a good design.

Effectiveness of the used method (α=.60)

1. I solved the design brief effectively with the suggested approach.
2. The suggested approach was very effective.
3. The suggested approach took a lot of unnecessary time. (reversed)

Petra, our journey began many years ago when I was still a student and you had recently arrived at the faculty as professor in design theory and methodology. I came to you with a proposal to start a research internship that included (perhaps slightly naïve) plans for a follow-up during my graduation project, and then a PhD project. With your openness to my ideas, encouragement and with the many good discussions we had, I ended up with a thesis that I am proud of. I am impressed with your broad and detailed knowledge (of both psychology and design) and ability to stay positive even when times are tough. Thank you for your support in the past years.

Norbert, in the past years your critical mind – in the good sense of the word – kind choice of words and drive (read: patience) to have detailed discussions with me on design methodology and many other good things have opened my mind many times and have allowed me to sharpen my thinking. I am amazed by your ability to reason through complex and abstract matters with clarity and precision – and while leaving room for doubt. This, to me, makes you an example of a true scholar. I am grateful that you agreed to become my co-promotor at a later stage in the project.

Pieter Jan and Joris, I am grateful for your support in the first year of my PhD. You have helped me to get started and to choose direction (even though that perhaps resulted in an unexpected path).

Govert & Nynke, you both inspire me in many ways and I am proud to have you as my paranymphs. Nynke, thank you in return for walking this road together. You are one of the most talented and passionate people I know. Your unrivaled ability to be honest to yourself and to others has taught me much. Govert, I am still utterly amazed by your ability to live such a rich life, to have such a down-to-earth attitude and to be so

empathic to the people around you. I enjoy those (and other) qualities every time we meet. Nynke and Goof, I am looking forward to walk many roads together in the future.
Oscar, Valentin, Fernando and Milene, our extended office spans the globe by now, I hope we will use that as an excuse for having a beer together in exotic places outside of Delft as well. Oscar and Val, you deserve a special thank you. I enjoy the fantastic collaboration that we have going on. I hope we will keep doing funky work.
Annemiek, our 'hobby project' has kept us busy over the past years and resulted in the Delft Design Guide. I am very proud of our book and the impact it has. I enjoy working with you, which is good, because I am afraid the book will keep us busy in the years to come...
I believe that discussion is an invaluable research method. Yet for a good discussion one needs good discussion partners. I have had the pleasure of discussing my research (and many other good things) with many people throughout my PhD project. In particular, I would like to thank Stephen Batill, Mogens Myrup Andreasen, Remco Timmer, Jacco Lammers and Paul Hekkert for being great discussion partners throughout my PhD project. Many people have contributed to parts of my research or have inspired me in my work. I would like to thank in particular Ton Borsboom (the Vibiemme is still going strong!), Floris (thanks for the illustrations!), Matthijs van Dijk (I am looking forward to continue our discussion), Dirk Snelders (I never expected to find another enthousiast for the combination of monkeys and methods), Andre Rotte, Rene Bubberman, Boudewijn Soetens and Maaike Kleinsmann. Lucienne, Mogens and Christian, thank you for a very inspiring summer school experience. I hope you will keep putting young PhD students on the right track.

I have had very good years at the faculty of Industrial Design Engineering that included german beer & ‘Weisswurst’ before eleven in the morning, a PhD dinner with waterpipe and Jarmila’s unrivaled door-lock beer opening skills, being part of a circus act, karoake-parties, endless discussions on healthy food at the lunch table that could only be ended by a sharp comment of Jan S., dancing with professors at our two-day PhD event, excluding professors from our debating series (no better way to get their attention!) and also countless invaluable discussions around the coffee machine or on studiolab’s bright cushions. For that I have to thank many colleagues. First, the PIM crowd that was there during my time at the department: Jan, Jan, Petra, Carlos, Jarmila, Oscar, Fernando, Christine, Andre, Joost, Ellis, Janneke, Milene, Valentin, Ana, Sicco, Erik-Jan, Marielle, Fleur, Katinka, Agnes, Dirk, Silje, Jan Willem, Leo, Job, Kristina, Linda, Giulia, Lianne, Frido, Marc, Han, Kasia, Pinar, Nik, Sonia, Maaike, Erik, Sylvia, Gerda, Ruth, Sijia, Norbert, Ozgur, Lisanne, Maria, Danielle, Leandra, Sandra and Wil, thank you for the good times and for offering such a great research culture to work in.

Of course, there is a world beyond PIM (really? yes really) and many people have made my time at at the faculty of IDE enjoyable as well (or in some cases, in politically correct phrasing, they have made it ‘a great learning experience’). I would like to mention Thomas, Miguel, Andre, Daniel (guys, I miss the climbing!), Jasper (the only researcher-cabaretier I know), Ana, Annemarie, Ingrid (thanks for your enthousiasm for my research), Elmer, Lenneke, Nazli, Stella, Helma, Imre, Ellen, Hugo, Ena and Cees. I am probably forgetting people here, and I am terribly sorry if I do.

Daan thank you for inviting me into the usability community, participating in your events provided me with the opportunity to receive excellent feedback on my work-

in-progress. Jaap, Corrie, Norbert, Pieter Jan, Angeline, Carlos and Christine de Lille, thanks for the good times while organizing the IASDR conference in Delft.
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Copenhagen, Januari 2014,
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Curriculum vitae

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Jaap Daalhuizen is a post-doctoral researcher at the Product Development and Engineering Design group, Technical University of Denmark and a part-time assistant professor at the Department of Product Innovation Management, Delft University of Technology. Jaap holds a Master of Science in Integrated Product Design from the faculty of Industrial Design Engineering (IDE) at the Delft University of Technology. He does research in the field of design theory and methodology with a focus on understanding the act of designing from a designer's point of view and the aim to support the designer in context. Jaap has published on this topic in Design Studies and the International Journal of Product Development, he has contributed to a book on the Future of Design Methodology, edited by professor Herbert Birkhofer and his work has been presented at a number of international, peer-reviewed conferences on engineering design, product development and design education, such as: the International Conference on Engineering Design, the conference on Tools and Methods for Competitive Engineering, the world conference of the International Association of Societies of Design Research, the international DESIGN conference and the international conference on Engineering and Product Design Education. Jaap is co-editor of the Delft Design Guide, a collection of models, approaches and methods for design that are used in the Delft design curriculum. In 2010, the Delft Design Guide was published as open courseware and has since then been nominated for a global People's Choice award and has received an Award for Best Text Book during the Open CourseWare

Global conference. In 2013, the Delft Design guide was published as a book and has sold over 3000 copies in the first 6 months after its launch. Jaap has more than 5 years of experience in teaching design in various courses on the bachelor and master level, such as Business, Culture & Technology, Fuzzy Front End, Bachelor end-project, Graduation project and Design Theory & Methodology. He served on the board of Promood-IDE, an organization that represents the interests of more than 100 PhD candidates at the faculty of Industrial Design Engineering, co-organizing a faculty-wide PhD event and an event for PhD candidates of the three technical universities in the Netherlands. He was part of the local organizing committee for the Summer School on Engineering Design Research and part of the organizing committee of the IASDR2011, 4th World Conference on Design Research.