UNDERSTANDING THE FRONT END OF DESIGN

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ABSTRACT
What do we really know about design expertise during the front end of design and which personal characteristics assist designers? This paper reports literature and empirical research to understand the knowledge, skills and characteristics that designers require during the early part of new product development (NPD). A literature review of papers that refers to knowledge, skills and characteristics is presented. Semi-structured interviews are used to understand the knowledge, skills and characteristics that designers working in the front end of design have. The research provides a categorisation of these elements and highlights possible relationships between them.

Keywords: Front End of Design, Design Context, Design Experience, Knowledge, Skills, Personal Characteristics

1 INTRODUCTION
In design research there is increasing evidence that contextual factors play an important role in the design process [1]. Analysis of design has shown that design activities are characterised by ambiguity [2], uncertainty [3] and complexity [4]. These characteristics refer to design information having multiple meanings, being incomplete and tangled. It is also known that in the front end of design these characteristics are more evident than in the later phases. In this research all these elements are considered forming the *environment external to designers*. Design is, however, undertaken by individuals who generally have different level of success in design practice. Design expertise and personal characteristics are, therefore, recognised as having a fundamental role in the design process. In this research design expertise and personal characteristics are considered defining the *environment internal to designers*. Expertise has already received substantial attention in design research. It is commonly seen as including various types of knowledge and skills. Lateral thinking, systemic view and domain knowledge are examples of elements that are considered critical in design. Various models of expertise have been proposed [5]. These often involve a hierarchical structure of expertise with a variable number of levels from novice to master. The personal characteristics of designers have also been studied and researchers argue different roles for elements such as attitude to taking risk and openness to innovation.
The aim of this research is to explore and understand front end design activities focusing on the designer. The specific objectives of the work are to: 1) understand the characteristics of the environment external to designers working in the front end of design; 2) identify the principal elements of the environment internal to designers; and 3) to investigate the relationships between the two environments. These objectives are researched through a mix of literature review and empirical research with designers in industry.

2 BACKGROUND
This section starts by reviewing past work on the front end of design. It then covers the topic of the design environment exploring aspects external and internal to designers. Finally, it reviews types of design experience and personal characteristics possessed by designers.

2.1 Front end design
The term front end of design was popularised by Smith and Reinertsen in their book on reducing time to market [6] and today there are several concurrent definitions of the front end of design. Murphy and Kumar's definition proposes that it is the phase from `the generation of an idea to its approval for development' [7]. The front end of design is often described as 'fuzzy', and is seen as an imprecise process that includes ad hoc decisions [8]. Other research has described it as dynamic, unstructured

and characterised by low levels of formalisation [7]. Within the literature there are those who attempted to formalise the front end of design and others who have simply accepted it as it is.
Murphy and Kumar refer to the front end of design as a `neglected topic' due to an apparent lack of research into this phase [7]. Backman reported that 'the greatest opportunities for improving the overall innovation process lie in the very early phases of NPD' [9]. Even with the importance of this phase continuing to be reinforced within the literature there appears still to be little holistic understanding. The reader may note that this work avoids using the term 'fuzzy' in connection with the front end because of the belief that, although fuzziness is one characteristic of the front end of design, it is misleading to believe that it is the only one. This may limit the perception of others as to the full depth of what happens within this phase and also implies that there is little fuzziness in the unfuzzy back end.

2.2 Design environment

Designers operate within an external environment that can be characterised through elements such as ambiguity, uncertainty and complexity. The internal environment can, instead, be considered consisting of the expertise and personal characteristics of the designers.

2.2.1 External environment

A review of design research has indicated that there are three main factors relevant to the external environment in the front end of design: ambiguity, uncertainty and complexity.

Ambiguity

Within the literature, several definitions of ambiguity have been attempted. Ambiguity has been interpreted as the relationships between the factors in the design environment, and how they remain unclear to the designer [10]. Other work to characterise ambiguity has broken it down into equivocality and lack of clarity [11]. Equivocality can be considered as the presence of two or more meanings for the same cue or the existence of multiple and conflicting interpretations of a situation, typically leading to confusion [12]. Lack of clarity stems from ignorance and can be reduced by increasing the amount of information available to the designer [2, 11]. These definitions suggest that there are two possible meanings for ambiguity. One is concerning not being able to clearly understand the relationship between elements, and the other is concerning the elements themselves having multiple meanings as well as having little overall information.
High levels of ambiguity can lead to a state of confusion and lack of understanding [12] as well as to some frustration [13]. However, ambiguity can be 'intriguing, mysterious, and delightful' [13]. This shows that there are possible positive and negative aspects of ambiguity.
In considering the *causes* of ambiguity, it has been proposed that ambiguity, as a lack of clarity, stems from lack of information and can be reduced by information gathering [2, 11]. Ambiguity, as equivocality, can be instead reduced by organisation, and it is often the main reason for adding structure into businesses [11]. Other researchers have identified four causes of ambiguity, namely multiplicity, novelty, validity of information, and reliability of information [2].

Uncertainty

Within the uncertainty literature there appears to be a general consensus on its definition. Design and non-design literature sources alike define it as an information deficiency [14]. Leifer's epistemological perspective is that uncertainty refers to the state of not knowing or a lack of knowledge [15]. The meaning of these definitions is that not only uncertainty involves a lack of information, but also a lack of knowledge and possibly of understanding. Whichever of these definitions are used, it is not likely that having a lack of knowledge is a positive thing that will assist in the design process.
When considering the causes of uncertainty, Brun [2] proposes a relationship between uncertainty and information in so much as when information increases the other decreases. This clearly outlines that one cause of uncertainty is simply a decrease in the amount of information available. This is supported by Klir [14] who calls it 'a manifestation of some information deficiency', which in some part explains why designers search for information in order to manage this effectively. Haimes [16] builds upon this by suggesting that uncertainty is caused by incomplete knowledge or stochastic variability and surrounds all aspects of decision making.

Complexity

Complexity has been defined as the inability to evaluate the effects of actions because too many variables interact [10]. Erdi outlines how complexity has several aspects [17]. The first of these relates to the *structure* of a system, such as the interaction between different atoms or the neurological

connections in the brain. Complexity has also a *dynamic* aspect, which relates to the temporal relationships and processes taking place within the system. The third aspect is the *algorithmic* one, which refers to the ability to make computations about the movement and structure as they change. Finally, the *cognitive* aspects of complexity refer to people's ability to create mental models of the systems.

The causes of complexity have been under-researched within design [18]. Kim and Wilemon propose that six causes of complexity exist, namely technological complexity, market-environmental complexity, development complexity, marketing complexity, organisational complexity, and inter-organisational complexity [18]. Technological complexity stems from the types of technology that are being used and the integration of these in potentially new ways. Market complexity is based around users and how they understand the products. Development complexity is based around the multidisciplinary nature of design. Marketing complexity concerns itself with the way the product will be sold. Organisational complexity consists of how the development process and organisation sit within the business and are sponsored by individuals. Finally, inter-organisational complexity exists when the supply chain is considered from source materials through the end product.

2.2.2 Internal environment

In this research the knowledge, skills and personal characteristics of designers define the internal environment. Knowledge has been defined as 'innovation that is relevant, actionable and based at least partially on experience' [19]. Knowledge is seen as existing in the spectrum from tacit through to explicit. Tacit knowledge cannot be elicited by an individual, whereas explicit knowledge can be elicited [19]. Expertise is commonly associated with knowledge and is described as 'the repertoire of knowledge used to solve problems' [20]. Expertise has been defined as consisting of declarative and procedural knowledge [21]. Declarative knowledge consists of the designer's information, beliefs and orientations, whereas procedural knowledge is composed of strategies, rules and skills for managing the former [22].

The definitions of skill vary in their agreement on whether to include skills which are only cognitive in nature or whether there has to be a visible and observable outcome. One definition proposes skills to be the ability to demonstrate a system and sequence of behaviour that are functionally related to attaining a performance goal [23].

Personal characteristics in the context of this research are the internal components that make up not just our personality but also other internal factors such as affect and motivation. For the purposes of this research these were grouped in order to both provide clarity but also to align with the concept of the internal environment. A review of knowledge, skill and personal characteristic types is presented in the next section.

2.3 Design knowledge, skills and characteristics

The results of an extensive literature research to identify and understand the different types of knowledge, skills and characteristics of designers are now presented. Despite our research interest being in investigating these elements as part of the front end of design, the literature available was limited and therefore the review was extended to other research areas including new product development, architecture, creative psychology, philosophy and business. Publications presenting and discussing the knowledge, skills and personal characteristics of designers were collated, analysed and categorised. The literature analysed comes under themes such as 'design cognition' or 'design expertise' and it was not explicitly separated into knowledge, skills and characteristics. Table 1 presents the outcomes of this inquiry outlining types of knowledge, skill and characteristic respectively. The elements marked with an asterisk (*) were identified from literature directly related to the front end of design.

Table 1: Knowledge, Skill and Characteristic types

	KNOWLEDGE and sample reference		SKILLS and sample reference		PERSONAL CHARACTERISTICS and sample reference
Knowledge	Domain knowledge [24]*	Creative thinking skills	Divergent thinking [25]*	Emotional characteristics	Positive affect [26]
	Case-based knowledge [27]*		Lateral thinking [25]*		Negative affect [28]
	Knowledge of users [29]*		Ideation [30]*	Personality characteristics	Attitude to innovation [31]
	Technology knowledge [32]*	Problem resolution skills	Problem finding [33]		Openness to experience [34]
			Problem framing [35]*		Abstractedness [33]
			Systemic view [31]		Risk taking [36]
			Reflection in action [33]		Accepting mistakes [37]*
			Reflection on action [33]		Aesthetic sensitivity [33]
			Convergent thinking [25]*		Motivation [30]*
			Case association [38]		
			Designing from first principles [31]		
		Representation skills	Sketching and spatial modelling [39]*		
		Environment management skills	Managing ambiguity (Ext.) [2]		
			Managing uncertainty (Ext.) [40]*		
			Managing complexity (Ext.) [18]*		
			Questioning (Ext.) [41]*		
			Learning (Ext.) [25]*		
			Networking (Ext.) [42]*		
			Observing (Ext.) [29]*		
			Planning (Ext.) [3]*		
			Emotional differentiation (Int.) [26]		

Four types of knowledge were identified namely domain knowledge, case-based knowledge, user knowledge and technology knowledge, see Table 1. Domain knowledge is specific to the domain in which a designer is working, e.g. the mobile phone industry [24]. Case-based knowledge relates to knowledge of specific design situations acquired by designers through experience, stored in memory and recalled when needed [27]. Knowledge of users refers to understanding users and ways of using a product or a class of products [29]. Technology knowledge relates to knowing the tools, techniques, crafts, systems or methods of organisation in order to solve a problem, e.g. wireless communication [32]. Case-based knowledge, technology knowledge, and knowledge of users can be considered as parts of domain knowledge.

Four groups of skills were identified, namely creative thinking skills, problem resolution skills, representation skills and environment management skills, see Table 1. Creative thinking skills include three elements, see Table 1. The dominant ways of thinking for the generation of new ideas are divergent and lateral thinking. Divergent thinking is a thought process that typically occurs in a spontaneous and free flowing manner [25]. Lateral thinking is used to solve problems through an indirect and creative approach using reasoning that is not immediately obvious [43]. There are skills also in the volume, uniqueness, and variety of ideas that a designer is able to generate. These are seen as part of ideation and referred to as fluency, originality and flexibility [30].

Problem resolution skills include eight elements, see Table 1. Problem finding and problem framing are key skills required in the investigation of design problems. The first refers to finding and stating problems as well as to understanding and exploring them [35]. Often design problems are not a given and it is increasingly acknowledged that designers create problems [44]. The second is associated with framing problems [44]. This includes selectively viewing the design situation in a particular way for a period of time during the design activity. It also includes creating and manipulating frames. This skill enables the redefinition of the problem in order to generate a different problem space and possibly a more appropriate solution space. In line with the importance of viewing the design problem discussed earlier, another skill that designers require is a systemic view [31]. This refers to the ability of maintaining sight of the big picture and viewing the solution and the context of its use as a whole. It may include systems thinking and systems design. The ability of systemic view seems to be closely associated to reflection-in-action defined as the ability to keep a perspective view on the current understanding, emergent problem and solution [31]. A different viewing skill is reflection-on-action defined as the ability to keep a view as to the success of the process in achieving the outcomes [33]. Generating large sets of ideas is important but it comes a moment in the design process in which these have to be filtered. The skill needed in this context is convergent thinking or critical thinking. This involves the ability to analyse, synthesise, reorganise or redefine, evaluate, see relationships. In this process it is also important to have a desire to resolve ambiguity or bring order to disorder, and a preference for understanding complexity. The last two elements of the set are case association and designing from first principles. The first refers to the ability of seeing associations between problem spaces where a similar solution has been used before [38]. This skill is closely linked to analogical thinking. The second refers to the ability of understanding and manipulating the underlying physical or aesthetic principles in order to create the most suitable outcome [45].

Representation skills including sketching and drawing are fundamental in design, see Table 1. They allow the portrayal of an idea outside the mind. This is important because the designer is often having a conversation with the drawing. These skills allow more refined mental functions.

The next group of skills is related to the management of both the external and the internal environment, see Table 1. These skills deserve a special note as they differ from the others we have reviewed so far. Three of them focus directly on the management of ambiguity, uncertainty and complexity. The management of uncertainty is seen by several authors as dependent on skills like questioning, learning and networking. The first is related to the ability to develop a line of inquiry by asking appropriate questions. For example, asking ‘Why’ and ‘Why not’ questions can help facilitate the discovery of certain types of information. The second is related to the acquisition of new or modification of existing knowledge, behaviours, skills, values or preferences and may involve synthesising different types of information. The third is associated with the ability to create social networks.

The skill of observing is associated with looking and storing relevant aspects of solutions or possibilities gained from experimentation. This is a prerequisite for the case association skill as without a large knowledgebase of solutions it becomes hard to make analogies. The skill of emotional

differentiation involves the ability to separate one's own emotion or intellect from those of a family, society or other organisational units. This includes dependence on the opinions and support of others. It appears that this skill is used for the management of the internal environment. Finally, planning is similar to reflection on action except that it relates to the organisation of activities, rather than reflecting on them after the event.

Two groups of personal characteristics were identified, namely emotional characteristics and personality characteristics, see Table 1. Emotional characteristics include positive and negative affect. They are associated with positive or negative mood, feeling or emotions that designers may have. The personality characteristics are a set of seven elements. Attitude to innovation has been described as a sense of creativity, inspiration and persistence despite adversity [46]. This attitude is widely seen as a key characteristic to start the innovation journey and to survive throughout it. However, it is not sufficient on its own. Designers are often described as having characteristics like openness to experience, abstractedness, risk taking and accepting mistakes. The first is associated with the characteristic of being inquisitive and showing a desire to learn something new. This characteristic is also referred to as curiosity. The second is associated with the abstractedness of the individual. Being imaginative is often seen as more important than being idea-orientated. The third relates to risk-appetite and the level of risk that a designer is willing to engage in with regards to performing the role. The fourth concerns itself with how being a good designer is about accepting mistakes and being wrong. Finally, two additional characteristics that are seen as important for designers are aesthetic sensitivity and motivation. The first is associated with the sensitivity of the individual including his or her tender mindedness. The second is concerned with the energy driving the activities within the front end. This represents both internal drivers and external incentives but little has been found within the literature to separate these two concepts and so these are presented as one category.

3. RESEARCH METHOD

The literature review has shown that designers rely on several types of knowledge, skills and characteristics that have been referred to as the *environment internal to designers*. In addition, it was found that the *environment external to designers* can be characterised through elements such as ambiguity, uncertainty and complexity. The aim of this project is to research these elements as part of the front end of design. In this initial part of the research the intent was to gain a holistic view of these elements through literature review and empirical research. Interviews were identified as the best method of gaining this understanding.

Six semi-structured interviews were conducted with practising designers working within the front end of design representing different levels of experience and areas within the field. These designers came from a range of different industries, e.g. telecommunication devices design and exhibit design. The companies in which these practitioners worked included large multinational organisations as well as small to medium sized enterprises. The designers represented both American and European viewpoints and their level of experience varied from novice through to expert.

Table 2: Details of Interviewees

Participant	Area	Gender	Age Range	Experience Range	Company size	Design Industry
A	Industrial Design	M	45-60	20 + years	1-10	Furniture
B	Industrial Design	F	30-44	5-10 years	1-10	Landscape
C	Interaction Design	M	30-44	5-10 years	1-10	Exhibit
D	Interaction Design	F	30-44	5-10 years	20,000 +	Musical Instruments
E	Industrial Design	M	30-44	5-10 years	100,000 +	Telecoms Devices
F	Industrial Design	M	20-30	0-5 years	1-10	Furniture

A protocol was created consisting of questions relating to different aspects of the front end. The themes included understanding of the context of front end design based on the experience of the participants as well as on their opinions on other successful designers. The flexible nature of the interview was to allow specific focus into areas of interest when required [47]. Each interview was kept to approximately one hour in length.

The audio data and notes from the interviews were collected over three months and the recordings were fully transcribed. In order to assist in analysing the text a basic theme analysis was utilised that applied keywords to sections of text in order to keep track of common threads. This allowed specific cues to be identified based upon the topic. Specific sections of text were then captured which related to

the overall research aims and fed into the results. Full qualitative coding was not required for this exploratory study. In order to address the biases affecting this research, some preventative methods were used. For self-reporting bias, the participants were asked questions from their own perspective and then a similar sub-question asked about other designers. For consistency bias, there were limited ways to reduce the effects. However, the participants had all expressed recent experience working in the front end of design.

4. RESULTS

The outcomes of this research included several interesting themes relating to the main aim, which was to develop a greater understanding of how designers operate during the front end of design. The paper will now look at those themes in order, starting with knowledge, skill and then finishing with personal characteristics. These groups were chosen in order to facilitate the comparison with data from the literature review.

4.1 Knowledge

The themes presented here describe relationships between types of knowledge and skills. All of the participants associated the use of domain knowledge with managing uncertainty. This is especially true for Participant E who worked in the design of high-tech consumer goods. He expressed how his industry is functionally driven and only by understanding users and the underlying technology relevant additional functionality can be introduced.

A theme identified during the interviews was the need to create interdisciplinary teams in order to combine knowledge to resolve complexity. Participant A suggested that businesses now 'understand that they need to form interdisciplinary teams to face complex problems'.

4.2 Skills

The themes covered in this section show examples of skills as well as relationships between different types of skills. A distinction between the skill of 'creative' thought and that of 'logical' thought was identified by Participant A, who advised that design uses a third skill consisting in the ability to use and balance the creative and the rational sides at the same time. More so, he said that many new designers struggle to do this during the outset of their career as a designer. Participant B expressed that designers often have a bias either towards creativity or rationality. The more junior designer, Participant F, expressed how he was unable to rely effectively on the rational side. He found this to be 'frustrating' and could only be balanced by working with another designer who had the opposite issue. It was also inferred that either skills to deal with 'balancing' are developed to cope with this frustration, or the character somehow adapts.

It became clear from the interviews that visualisation skills are an important part of dealing with complexity. Several interviewees expressed how complexity was an issue, particularly in relation to the requirements and constraints of the design context. Participant A expressed that visualising the requirements was a much more effective method of dealing with complexity. Referring to tutorials with junior designers, he said: 'I often suggest to print it [the list of requirements] and put it on the wall'. Visualising the requirements, either textually or graphically, can assist in the management of complexity by representing them outside of the brain. The less experienced designer, Participant F, admitted to struggle with the conflict between requirements and did not appear to employ any specific supportive skill.

4.3 Personal characteristics

The themes presented below shows examples of relationships between personal characteristics and skills. The characteristic of being exploratory or an explorer came out as a strong theme with most of the participants. Referring to past work participant F reported: 'We were kind of given a brief, we went out there, started looking at lots of different products out there, looking for inspiration and then from that we started to explore some different concepts'. Other participants suggested that an inquisitive character is important to manage situations such as an open brief. This need to learn, inquire and explore was expressed commonly among the interviewees.

The characteristic of being youthful apparently has a deep effect on knowledge acquisition. This effect was expressed by participants A and C. Participant A expressed: 'I have 57 years, but sometimes I feel like a 10 year old. This is a big secret to be creative, because if you work and you say about yourself I am mature, I know a lot of things (then) I know that you cannot learn'. Participant C felt that 'childlike

learning' is better than being taught in order to assist in design, and that conventional 'teaching methods' are not useful in design. It was also expressed by the participants how knowledge is required in the management of uncertainty, and the acquisition of this knowledge would, therefore, be dependent on an internal mode or characteristic. This was an example of a personal characteristic assisting in the acquisition of knowledge, exposing a possibly complex relationship between the two.
Participant D expressed how her ability to deal with uncertainty and complexity came from her positive personality. During the interview she said: 'I am personally very positive and not very critical, I am sorry to say. I try to find the good things in everything'. This use of positive psychology was common to several of the designers and seemed to lead to retain their motivation during the front end. Yet again, a question remained over whether this was a use of a positive character trait or the skill of emotional regulation.
The next set of themes illustrates specific personal characteristics that the interviews pointed out as important. Motivation was a key theme within the interviews. Participant A expressed: 'I am thinking (about) twenty things, different things. And if one day I have only two things then I am bored. So this is the reason why I wish to always have new contacts, new things to do and because the creative mind needs to eat'. In his case motivation was apparently provided by complexity. Complexity was being used as a driver in order to keep the feeling of boredom, and consequently de-motivation at bay.
The characteristic of being a focused individual was one personality factor that was commonly discussed when speaking about the front end of design. Participant B stated: 'I think that it [designers' ability to focus on a specific task] is a lot more [than normal people], they [designers] are extremely focussed'. Whether this characteristic was generally used for the management of the whole context or just individual parts was not elicited. Participant C discussed stubbornness and it appeared it was used as a motivational factor. Supporting this, he said: 'I think you need stubbornness to continue to explore, don't you? Like to continue to look for new books in the world, you know, some sort of grit and determination. You cannot just do it because you love it, that doesn't take you far enough'.

5. DISCUSSION

This article has presented initial work to understand the front end of design by characterising the environment within which designers operate. The external environment was found to have characteristics like ambiguity, uncertainty and complexity. The internal environment was described through elements like knowledge, skills and personal characteristics. These were researched through literature review and empirical investigation. The review of literature showed that several models of design experience have been developed but no attempt has been made to develop a holistic view on the knowledge, skills and personal characteristics of designers. Research work to synthesise the findings from previous investigations has led to a categorisation of knowledge, skills and personal characteristics.
Not surprisingly designers were found to need domain knowledge to operate effectively. The skills required to practice design were found to fall under four groups, namely creative thinking skills, problem resolution skills, representation skills and environment management skills. It is noteworthy that these skills are all seen playing an equally important role in the design process. Without underestimating the value of creative thinking skills and that of representation skills we believe that the most interesting groups are problem resolution skills and environment management skills. The first group brings together a set of skills involving problem discovery, design process view, solution analysis, case association and manipulation of fundamental principles. The second group, instead, refers to skills to manage characteristics of the environment. These skills show how being effective in design requires not only design thinking but also management and control of the design situation. Little is known about the ways of thinking employed and the actions taken by designers to manage ambiguity, uncertainty and complexity. Questioning, learning and networking have been suggested as skills required for the management of uncertainty. It is worth mentioning that although these skills are very basic we believe that they take different forms in design. For example, questioning skills acquired during higher engineering education would not be the same as those acquired during higher design education.
This research has identified by literature review a set of personal characteristics that are expected to have influence on the design process. It is our view that the role of personal characteristics in the design process is still under researched. Aspects such as the effects of positive psychology on cognitive functions and motivation are covered within psychology research, but they have received

little interest within design research. Cross during his summary of design cognition discusses the skills required to perform design tasks, but rarely touches on the concept of personal characteristics and how they affect the design process [31]. Newer texts, such as those of Lawson and Dorst, still retain relatively little discussion of the personality traits of designers, other than to look at expertise as a type of intelligence [33].

This research has shown that approximately half of the knowledge, skill and characteristic types identified during the literature review were mentioned in past work to understand the front end of design. However, there are as many types that were identified as part of investigations related to design but not strictly linked to the front end of design, e.g. creativity. This leads to questioning whether these types are relevant to the front end of design. Many are in the groups termed problem resolution skills and personal characteristics. It is difficult to think that elements like problem finding, and reflection are not relevant to the front end of design. Overall, this finding shows that more research is needed to understand the importance of these elements.

The types of knowledge, skill and personal characteristics presented in the review are by no means definitive. This article reports work in progress and more research is required to understand the elements presented in Table 1. This further work would include analysis of any overlap that may exist in the current classification, e.g. the distinction between having a systemic view of the problem-solution and reflection in action. Another piece of work would involve aligning the personality categories to models already present within psychology.

The empirical research showed that some of the elements identified during the literature review where brought up also by the six designers interviewed. The results also show a range of relationships between knowledge and skills, skills and skills, and personal characteristics and skills. Among these it is worth mentioning the role of knowledge in the management of uncertainty and complexity as well as that of exploratory character in the management of open briefs. The interviews also showed awareness by designers of what elements make their internal environment. The results presented in section 4 are just a selection of themes identified during the interviews. More research is needed to understand the variance between different designers.

Further research will focus on understanding: how designers overcome a deficiency in knowledge, skill or personal characteristic, e.g. the skill of balancing creative and logical thought appeared to be overcome by group-work; and the relationships between knowledge, skills and personal characteristics.

6. CONCLUSIONS

Work in the front end of design presents designers with situations that are commonly described as ambiguous, uncertain and complex. Previous research on the competencies required by designers operating in this context has not contributed to the development of a holistic view on the knowledge, skills and personal characteristics needed. This research was undertaken with the aim to fill this gap. An extensive review of the literature in design, creativity, new product development and other fields has led to the identification of four types of knowledge, twenty-one types of skills and nine types of personal characteristics. Interviews with designers of varying level of expertise were carried out to understand from an empirical perspective how they work and what knowledge, skills and personal characteristics they deem important. The results from the literature review have shown that knowledge and skills are important in design but personal characteristics also have a prominent role. The skills required by designers are not just about effective creative thinking and problem resolution. There is also a need for designers to develop skills to manage the environment in which they operate. The results from the interviews showed that some of the elements identified in the literature were confirmed and new ones were discovered. The skill of balancing between divergent and convergent thinking emerged as an interesting new element not seen in previous literature. The work presented in this article is the outcome of an exploratory study and it presents preliminary results. More research is needed to confirm these results and carry out further analysis of the data set.

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