Influence of cultural characteristics on designers' approaches – an empirical study

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Abstract

In globally operating companies, designers with different cultural backgrounds work together, normally not co-located, to develop products. Literature shows that so far the influences of the designers' cultural background on the design approaches have not been investigated. As a consequence, there is a lack of support for design processes which are performed in intercultural teams. This dissertation intends to address this deficit by presenting the results of a study into the influence of cultural characteristics on designers' approaches. The focus was on designers in Germany, India and China. In a detailed literature study six cultural characteristics were identified, which could be expected to influence the design approach depending on the cultural background of the designers. To investigate how the design processes of designers from different cultures differ, an empirical study was conducted under participation of designers drawn from industrial practice in Germany (four cases), India (four cases) and China (six cases). The designers were observed while solving a given design problem in a laboratory setting. All design processes were recorded on video, transcribed, analysed and compared.

The findings present a mixed picture. The influence of the cultural characteristics, which were derived from the literature, on the design approaches varies clearly. The influence of the characteristic "paying attention either to objects or to relationships when deriving selection criteria" was observed for each cultural group. The influence of further three characteristics was observed, however, not for each cultural group. These are: "addressing or not addressing situational influences in predicting user needs when analysing problem and requirements", "treating functions analytically or holistically when finding solutions" and "giving formal or intuitive reasoning when evaluating solutions". The influence of two of the characteristics was observed to deviate from that what was expected based on the literature. These are: "avoiding or accepting a contradiction when improving solutions and embodiments" and "working on functions in a monochronic or polychronic way". Despite the limitations, the first three mentioned cultural characteristics had clear or at least some influence on the design approaches. A comparison of the order in which design activities were performed showed different tendencies – the designers from China worked 'from the outside inwards', from Germany worked 'from the inside outwards' and from India shared both tendencies. The findings show that the cultural characteristics have a significant influence on the designers' approaches. Based on the findings, initial suggestions for design in multi-cultural teams were derived.

Zusammenfassung

In der Produktentwicklung global agierender Unternehmen arbeiten Konstrukteure mit unterschiedlichen kulturellen Hintergründen, in der Regel örtlich verteilt, zusammen. Eine Literaturrecherche hat gezeigt, dass die Einflüsse kultureller Hintergründe auf das Vorgehen von Konstrukteuren bisher nicht untersucht worden sind. Folglich fehlt eine Unterstützung für Konstruktionsprozesse mit interkulturellen Entwicklungsteams. Diese Dissertation befasst sich mit diesem Defizit und präsentiert die Forschungsergebnisse zum Thema Einflüsse kultureller Eigenschaften auf das Vorgehen von Konstrukteuren. Im Fokus der Studie standen Konstrukteure aus Deutschland, Indien und China. Anhand einer ausführlichen Literaturrecherche wurden sechs kulturelle Eigenschaften ermittelt, die in Abhängigkeit vom kulturellen Hintergrund der Konstrukteure Einfluss auf das Vorgehen beim Konstruieren ausüben könnten. Um zu untersuchen, wie sich die Konstruktionsprozesse von Konstrukteuren aus verschiedenen Kulturen unterscheiden, wurden in einer empirischen Studie unter Beteiligung von Konstrukteuren aus der Industrie in Deutschland und Indien je vier, und in China sechs Untersuchungen durchgeführt. Die Konstrukteure wurden beim Lösen einer vorgegebenen Konstruktionsaufgabe in einer Laborsituation beobachtet. Die per Video aufgenommen Prozesse wurden transkribiert, analysiert und verglichen.

Die Ergebnisse zeigen ein gemischtes Bild. Der Einfluss der anhand der Literatur ermittelten kulturellen Eigenschaften auf das Vorgehen von Konstrukteuren variiert deutlich. Der Einfluss der Eigenschaft „Richten der Aufmerksamkeit entweder auf Objekte oder auf Zusammenhänge beim Ableiten von Bewertungskriterien“ wurde in jeder Kulturgruppe beobachtet. Der Einfluss von drei weiteren Eigenschaften wurde jedoch nicht in jeder Kulturgruppe beobachtet. Diese sind: „Berücksichtigung oder Nichtberücksichtigung situativer Einflüsse bei der Erfassung von Benutzererwartungen in der Problem- und Anforderungsanalyse“, „analytisches oder holistisches Arbeiten an Funktionen bei der Lösungsfindung“ und „formales oder intuitives Argumentieren bei der Lösungsbewertung“. Der beobachtete Einfluss zweier folgender Eigenschaften wich von dem gemäß der Literatur erwarteten Einfluss ab: „Ablehnen oder Akzeptieren eines Widerspruches bei der Lösungsverbesserung“ und „Arbeiten an Funktionen in einer monochronischen oder polychronischen Weise“. Abgesehen von einigen Einschränkungen übten die ersten drei erwähnten Eigenschaften einen deutlichen oder zumindest gewissen Einfluss auf das Vorgehen beim Konstruieren aus. Ein Vergleich der Reihenfolge von durchgeführten Konstruktionstätigkeiten zeigte unterschiedliche Tendenzen – die Konstrukteure aus China haben ‚von außen nach innen‘ gearbeitet, die aus Deutschland ‚von innen nach außen‘ und die aus Indien verfolgten beide Tendenzen. Die Ergebnisse zeigen, dass die kulturellen Eigenschaften einen signifikanten Einfluss auf das Vorgehen der Konstrukteure haben. Basierend auf den Ergebnissen wurden erste Vorschläge für das Konstruieren in multi-kulturellen Teams abgeleitet.

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There is nothing so stable as change.
Bob Dylan

1 Introduction

This chapter presents the basic idea behind the research project described in this thesis. The fundamental issues of motivation, objective, research questions and scope are addressed and the research approach is presented.

1.1 Motivation

Companies operating worldwide work with partners from many countries. This cooperation is in a constant flux. Globalisation has a diversifying effect on companies. They need to rethink their strategies and reposition themselves in the world market. Many companies have already reorganised their production by relocating or outsourcing it to different countries, often involving local employees. Companies also try to be close to their markets by partly moving or outsourcing product development. As a consequence, cooperation between companies in different countries has extended from the field of product manufacturing to product development. In such cooperation, designers with different cultural backgrounds participate in product development, for instance, when a product is developed or adapted for a local market under contribution of local designers.

Cultural studies have shown that the cultural background of persons influences their thinking and behaviour (see Sections 2.1 and 2.4). Design studies have shown that the design approaches of designers differ, i.e., they are individual (see Section 2.7). The assumption is that the cultural background of designers influences their design approach and hence, having a team with designers of different cultural backgrounds might cause differences and possible misunderstanding in a design project.

For successful international collaboration, an understanding of the cultural backgrounds of involved partners is considered a key success factor (see Section 2.6.1). Culture as an influencing factor has drawn attention in many fields of research, e.g. in project management and usability engineering. In design research, however, cultural influences are sparsely investigated. Although the importance of social aspects is addressed in design research, cultural influences are still an open topic.

Fostering international cooperation calls for an understanding of different cultural influences. The understanding of how cultural influences come into effect in designing can contribute to improved cooperation between designers in multi-cultural teams. Currently, however, it is unclear how cultural influences affect designers' approaches. As a consequence, there is lack of know-how about how cultural influences should be taken into consideration in a design project in which designers with different cultural backgrounds are working together or how these backgrounds might possibly be exploited.

This research focuses on the effect of cultural influences on designers' approaches through an investigation of design processes in Germany, India and China.

1.2 Objective and research questions

The objective of this research is to support designers with different cultural backgrounds who are working together in design processes. To achieve this objective the following research questions are to be answered:

1. Which cultural characteristics could influence the approaches used by designers in designing?
2. How do the design processes of designers from different cultures differ?

Based on the answers initial suggestions for design in multi-cultural teams will be derived.

1.3 Scope of the research

Together, designing as an engineering discipline and culture as a social discipline covers a wide range of research topics. The scope of this research covers the design process and cultural influences on this process. In terms of the design process, the focus is on the following phases as defined by Pahl and Beitz [Pahl et al., 2007]: task clarification, conceptual design, and embodiment design. Regarding cultural influences, the focus is on those that can affect design activities in the aforementioned phases. The term 'culture' in this research denotes the culture of a country. It is not differentiated here at the level of regional cultures. Other existing forms, like corporate culture or project culture are not considered either.

The effect of cultural influences on designers' approaches are investigated through an analysis and comparison of design processes, which are recorded in an empirical study conducted in Germany, India and China under participation of designers drawn from industrial practice.

Only those cultural influences are investigated for which a theoretical ground for influencing can be derived based on literature from both disciplines (i.e. designing and culture).

The findings of the empirical study and the derived suggestions based on the findings can be useful for designers and project managers working in multi-cultural product development teams. A contribution to design research is the improved understanding of the effect of cultural influences on designers' approaches.

1.4 Research approach

The research approach presented in this section addresses, how the research questions will be answered and suggestions will be derived based on the answers. The research is structured in three parts – a theoretical part pertaining to the literature review, an empirical part pertaining to the empirical study and its findings, and a prescriptive part pertaining to the derivation of suggestions.

The research approach is based on the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti [Blessing, 1994; Blessing & Chakrabarti, 2009]. Figure 1 shows the DRM framework.

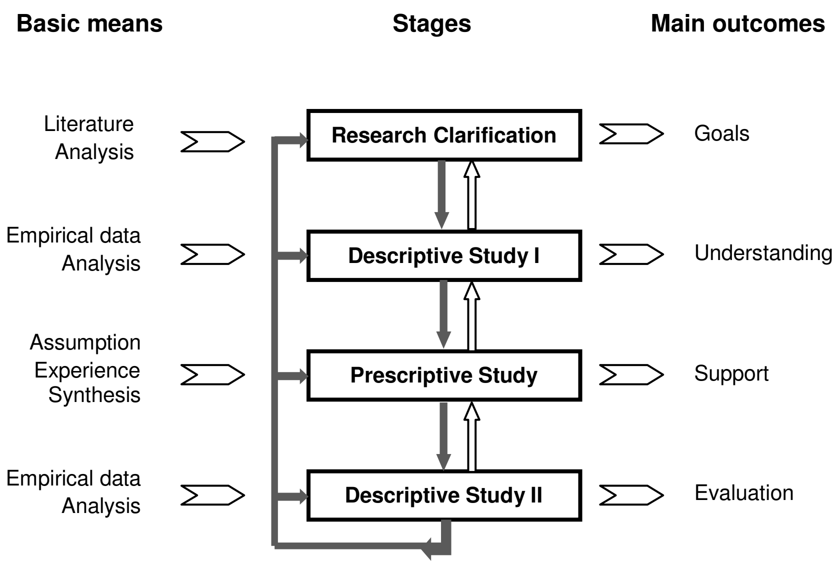


Figure 1: DRM framework [Blessing & Chakrabarti, 2009, p. 15]

The DRM framework structures design research and allows it to be positioned in comparison to other design research, in particular by indicating the stages on which a particular research project focuses. The research presented in this thesis covers the following phases – Research Clarification is performed by a comprehensive review of the literature, Descriptive Study I is performed by conducting a comprehensive empirical study, and the Prescriptive Study is performed by deriving initial suggestions on the basis of the findings of the empirical study. The three parts of the research mentioned earlier in this section thus map onto the first three stages of the DRM framework. The details of each part, how they are linked and how they are related to both research questions and to the derivation of suggestions are given below.

To answer the first research question, i.e. which cultural characteristics could influence the approaches used by designers in designing, the characteristics of culture and of design approaches will be presented and compared resulting in characteristics that require investigation (Chapter 2).

To answer the second research question, i.e. how the design processes of designers from different cultures differ, an empirical study was carried out in Germany, India and China under participation of designers who were drawn from industrial practice in these countries. The focus was on determining, whether and how the cultural characteristics derived from literature influence these designers' approaches, and to identify any differences in the design processes. The empirical part is described in Chapters 3, 4 and 5.

The findings of the empirical study should reveal culturally influenced approaches and differences in design processes. An initial support is derived on the basis of the findings (Chapter 6) in form of suggestions.

The research approach is shown in Figure 2.

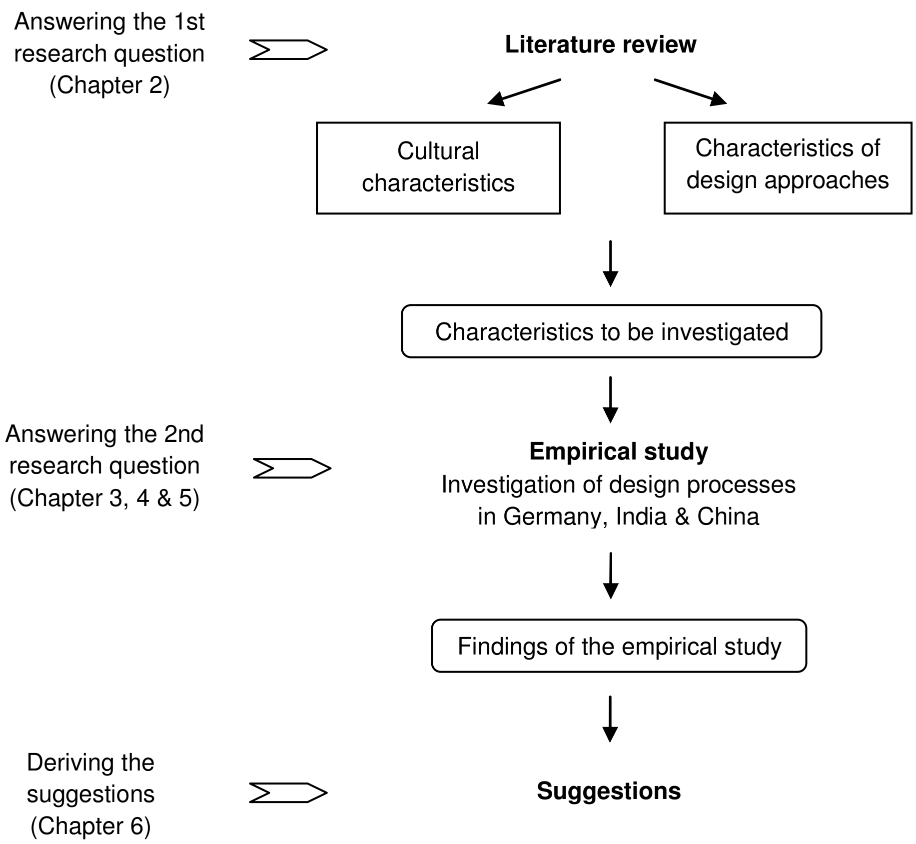


Figure 2: Research approach

1.5 Overview of the thesis

Chapter 2 forms the theoretical part of the dissertation, addressing the first research question. This chapter presents the state of the art based on a literature review on culture, design and some related fields, and provides the theoretical base for the research. Various definitions of the term ‘culture’ are given and cultural differences are explained with the help of characteristics. Also characteristics of design approaches are presented. Finally the chapter describes, how certain cultural characteristics that are expected to influence design approaches are derived on the basis of the literature.

Chapters 3 to 5 address the second research question and constitute the empirical part of the dissertation.

Chapter 3 provides the details of the empirical study, designed to investigate design processes in the three countries involved in the study, and describes the data analysis methods employed.

The first part of the findings of the empirical study is presented in Chapter 4. These findings describe the influence of cultural characteristics on the designers’ approaches and the differences observed between the designers from Germany, India and China.

The second part of the findings of the empirical study, presented in Chapter 5, addresses tendencies for the cultural groups pertaining to the nature of the design processes, such as the order in which design activities are performed and how the knowledge of systematic design has affected the design processes. Further, the findings presented in this and the previous chapter are compared to derive their relation.

Chapter 6 summarises the findings. Based on the findings, initial suggestions for design in multi-cultural teams are derived. Possible limitations of the study are discussed. Statements on possible future research direction conclude the thesis.

People are strange when you're a stranger.
The Doors

2 Literature review – Definitions and characteristics

This chapter looks into literature with the aim to determine the state of the art and to provide a theoretical base for answering the first research question, i.e., which cultural characteristics could influence the approaches used by designers in designing. For establishing this base, definitions and characteristics of culture (Sections 2.1 – 2.4) and characteristics of design approaches (Section 2.7) are used. In Section 2.6 details of different fields in which culture is taken into consideration as an influencing factor are given and the need for this research is substantiated. The assumption upon which this research is based is presented in Section 2.8. Section 2.9 describes, how certain cultural characteristics that are expected to influence design approaches are derived on the basis of the literature. These characteristics are the focus of the study described in the subsequent chapters.

2.1 Definitions of culture

'Culture is to a human collectivity what personality is to an individual' [Hofstede, 2001a, p. 10].

'Culture is the human-made part of the environment' [after Herskovits, cited in Triandis, 1994, p. 1].

'Culture is the way in which a group of people solve problems and reconcile dilemmas' [Trompenaars & Hampden-Turner, 1998, p. 6].

'Culture is the means by which people communicate, perpetuate and develop their knowledge about attitudes towards life' [after Geertz, cited in Trompenaars & Hampden-Turner, 1998, p. 24].

The examples show that there are different ways of understanding culture. As a consequence, the definitions of culture given in literature vary widely. However, different definitions also complement each other, as they represent different points of view to look at culture. In this section various definitions of culture are discussed and differences in societies are explained with the help of cultural characteristics. The key statements to be used in this research are derived from the definitions and given in Section 2.1.6.

2.1.1 Hofstede's definition of culture

Hofstede [2001a, 2001b] differentiates between culture in a general and in a social sense. The first refers to culture defined as 'the refining of the mind', like arts and literature. The second, which is used here, refers to culture defined as a sort of 'software of the mind'. According to Hofstede, culture is the collective programming of the mind that distinguishes the members of one group or category of people from another. Every person carries patterned ways of thinking, feeling and acting. These are partly unique and partly shared with others. The unique part belongs to the individual's personality. The common part belongs to the collective level. Culture is a collective phenomenon and is shared at least partially with other people living in the same social group. The mental programs, Hofstede adds, predict merely how a person probably would react in a certain situation. Core element of culture is a system of values. A value is a broad tendency to prefer certain states of affairs over others. His findings are based on answers to a questionnaire involving 116.000 participants from 72 countries.

The differences in cultures are described with the help of 'dimensions'. According to Hofstede, all societies face the same fundamental problems, only their answers vary. Each fundamental problem can be represented by an independent dimension. A dimension is an aspect of a culture which can be measured in comparison to other cultures. Moreover, a dimension summarises a number of phenomenon in a society. Hofstede describes five independent dimensions of culture differences.

'Power distance' describes how human inequality is handled in a society. It is the extent to which the less powerful members of organisations and institutions accept and expect that power is distributed unequally. 'Uncertainty avoidance' describes how societies try to cope with stress in the face of an unknown future. It is the extent to which the members of a society feel uncomfortable in unstructured or unanticipated situations. 'Individualism versus collectivism' describes the relationship between the individual and the collectivity that prevails in a society. It is the degree to which individuals are supposed to look after themselves or remain integrated into groups, usually around the family. 'Masculinity versus femininity' describes how societies cope with duality of the genders. It refers to the distribution of emotional roles between men and women. 'Long-term versus short-term orientation' describes whether the focus of people's efforts is on the future or on the present. It is the extent to which members of a society accept delayed gratification of their material, social and emotional needs.

In addition to the society, Hofstede also addresses other fields like school and educational system, political system, consumer behaviour, workplace and organisational culture, and relates these fields to the dimensions by showing their influences.

2.1.2 Triandis's definition of culture

Triandis, based on his own data and that from earlier sources, acknowledges that there are many definitions of culture and they are all valid. According to the comprehensive definition he gives [Triandis, 1994, p. 22], 'Culture is a set of human-made objective and subjective elements that in the past have increased the probability of survival and resulted in satisfactions for the participants in an ecological niche, and thus became shared among those who could communicate with each other because they had a common language and they lived in the same time and place'. Triandis distinguishes between objective elements of culture, such as tools, and subjective elements of culture, such as norms, roles and values.

Cultural differences are described with 'cultural syndromes'; these are conceived as dimensions of cultural variation [Triandis, 1994; Triandis, 1996]. A cultural syndrome is a pattern of beliefs, attitudes, self-definitions, norms and values that can be identified in a society. Following cultural syndromes are identified – complexity, tightness, individualism and collectivism.

In 'complex cultures', people make large numbers of distinctions between objects and events in their environment. For example, the number of distinct occupations reflects complexity. Agricultural societies are less complex, industrial societies are more complex, information societies are most complex. In 'tight cultures', there are many rules, norms and ideas about what is correct behaviour in different kinds of situations; 'loose cultures' have fewer rules and norms. In 'individualism' the self is defined as independent and autonomous from collectives, and personal goals are given priority over the goals of collectives. In 'collectivism' the self is defined as an aspect of a collective (e.g. family) and personal goals are subordinated to the goals of this collective.

Triandis also proposes methods for intercultural training that can reduce culture shock and improve intercultural relations.

2.1.3 Trompenaars and Hampden-Turner's definition of culture

According to Trompenaars and Hampden-Turner [1998] culture is a shared system of meanings. It dictates what we pay attention to, how we act and what we value. Culture is the context in which things happen and the context denotes, what they mean to the people in each culture. Culture also involves values. A value serves as a criterion to determine a choice from existing alternatives. The authors add that people within a culture do not all have identical sets of norms and values. Individuals in the same culture do not necessarily behave according to the cultural norm; individual's personality mediates in each cultural system. Their findings are based on answers to a questionnaire involving 30000 participants from 55 countries.

The basis of cultural differences is described by these authors with seven fundamental dimensions of culture, which are summarised in three categories: relationships with people, attitudes to time and attitudes to the environment.

Five of the seven dimensions belong to the first category ‘relationships with people’ and cover the ways in which human beings deal with each other. ‘Universalism versus particularism’ defines how we judge other people’s behaviour. Universalism is rule-based, i.e. what is good and right can be defined and always applies. Particularism is relationship-based, i.e. far greater attention is given to the obligations of relationships and particular circumstances. ‘Individualism versus communitarianism’ defines whether people regard themselves primarily as individuals, i.e. a prime orientation to the self or regard themselves primarily as part of a group, i.e. a prime orientation to common goals and objectives. ‘Neutral versus affective’ defines the range of feelings expressed, i.e. the nature of interactions should be objective and controlled, or expressing emotion is acceptable. ‘Specific versus diffuse’ defines how far one gets involved, i.e. the involvement with others is direct and in specific areas of life, or it is diffuse and in multiple areas of life. ‘Achievement versus ascription’ defines whether status is accorded based on doing or being, i.e. one is judged on recent accomplishments or status is attributed by background.

The second category (and also the sixth dimension) is ‘attitudes to time’, which is about how we manage time. The ways in which societies look at time differ in how importance is given to the past, present and future. The emphasis varies between concern to maintain past achievements, extension of the present, and expectations of the future. This dimension also describes whether our view of time is sequential or synchronic, i.e. doing one activity at a time following an initial plan, or doing more than one activity at a time while remaining loosely structured (see Section 2.2).

The third category (and the last dimension) is ‘attitudes to the environment’, which is about how we relate to natural environment. ‘Inner-directed’ refers to motivations and values derived from within, i.e. assuming control based on one’s convictions; ‘outer-directed’ implies an external reference point, i.e. assuming control by adapting to an external force.

Trompenaars and Hampden-Turner have addressed cultural diversity in the context of doing global business. They also describe how cultural preferences prevailing in a society find their way into the corporate culture. With a notion on cultural diversity, the authors underline that there is no ‘one best way of managing’; there are several ways, which are culturally appropriate.

2.1.4 Hall and Hall’s definition of culture

According to Hall and Hall [1990] culture is, in the anthropological sense, a system for creating, sending, storing and processing information. Even though culture is experienced personally, it is nonetheless a shared system. Cultural differences are described with four categories, based on the authors' past research and 180 additional interviews. Their work provide insights into how cultural factors affect the way business is conducted in Germany, France and USA. The four categories are described below.

'Time' is perceived differently in different cultures – monochronic or polychronic (see Section 2.2). Monochronic time means doing only one thing at a time; polychronic time means being involved with many things at once. 'Context' refers to the availability of information that is taken for granted and to the transfer of information during communication. Low-context means people are not well informed outside their own area of expertise and require lots of background information. High-context means people are well informed, i.e. already 'contexted'. They maintain extensive information networks and require a minimum of background information. 'Space' refers to how one is surrounded by visible and invisible boundaries, such as one's territory and personal space. 'Information flow' refers to how information is handled – whether it flows slow or fast, and where it goes. In low-context countries information flows slowly, and is compartmentalised and controlled; in high-context countries information spreads rapidly and freely within the peer group.

2.1.5 Thomas's definition of culture

According to Thomas [1999; 2003] culture is a system of orientation to perception, thinking, judging and acting of persons belonging to a certain social group. Specific features of such a system of orientation are 'cultural standards'. Cultural standards are norms and points of reference and are seen as binding and normative by the majority of members belonging to a certain social group. The concept of cultural standards is used to develop training programme for many target groups.

2.1.6 Discussion

The definitions of culture given above have shown that there are many ways of understanding and describing what culture is. Differences between cultures are described with characteristics, such as dimensions.

The two key statements derived from the definitions given above are that culture affects the way people think and act and that culture is a shared system. Sharing common characteristics of a culture would mean that people belonging to a cultural group are likely to think and act in a similar way, but differently when compared to people belonging to another cultural group. This statement will be used in deriving the assumption for this research (see Section 2.8).

It should be noted, as pointed out by Hofstede, and Trompenaars and Hampden-Turner, that although norms and values are known points of references among members of a cultural group, in addition to this collective level there is a also a level of individual personality. It means that thoughts, actions and attitudes are results of interplay between common cultural assets (i.e. collectivity) and an individual's personality.

Also noteworthy is a point made by Trompenaars and Hampden-Turner, and Hall and Hall. They believe that reading about and getting engaged into cultural studies is not only about understanding others, but also about understanding one's own culture.

2.2 Definitions of 'time'

Section 2.1 introduced different understandings of 'time' in different cultures. To facilitate further use in this thesis the definitions of time are summarised and presented in this section.

Experiencing and managing time – Monochronic versus polychronic

Time is one of the fundamental bases around which all activities revolve. There are many kinds of time concepts in the world; the two most important according to Hall and Hall [1990] are 'monochronic' and 'polychronic'. Monochronic time means paying attention to and doing only one thing at a time. Monochronic time is experienced and used in a linear way; time is scheduled and divided into segments, making it possible for a person to concentrate on one thing at a time. Polychronic time means being involved with many things at once. Polychronic time is characterised by involvement with many people; time commitment is considered as an objective to be achieved and if deviated, plans can be changed.

Another similar pair of definitions, which is about managing time, is given by Trompenaars and Hampden-Turner [1998] and is called 'sequential' and 'synchronic'. Having a sequential view means time can be conceived of as a line of sequential events passing us. Events appear at regular intervals and have their time and place of occurring in a worked out plan. One activity is done at a time. Having a synchronic view means time can be conceived as cyclical and repetitive. Various activities run in parallel. On the way to the final target numerous routes can be taken.

The definitions given in both sources overlap to a great degree to denote the respective temporal mode. For further use in this thesis the terminology given by Hall and Hall is taken (i.e. monochronic and polychronic) and embraces the definitions given in both sources. The monochronic time concept is used in many European countries and the USA, whereas the polychronic time concept is used in France and in many Mediterranean, Latin American and Asian countries. As Hall and Hall state, generalisations based on the definitions given above do not apply, however, they help convey a pattern for cultures.

There are also other manifestations of time given in the literature, such as the orientation of a society (i.e. importance given) towards its past, present and future. However, the focus in this thesis is on monochronic and polychronic time in terms of the sequence of carrying out activities.

2.3 From social differences to cognitive differences

People's values and attitudes in a culture differ from those in another culture; these differences (i.e. social differences) between cultures were described in Sections 2.1 and 2.2. According to Nisbett et al. [2001, p. 291] social differences that exist between people from different cultures affect not only their beliefs about specific aspects of the world, but also the nature of their cognitive processes, i.e. the ways by which they know the world. The authors establish a link between social factors and cognition. For instance, they see a link between strong social networks (i.e. a social factor), which prevail in collectivism-oriented cultures, e.g. Chinese, and avoidance of debate (i.e. a cognitive factor; see Section 2.4.5), which is characteristic for Chinese culture as well. People who live in a collectivistic society would try to avoid debate, so as to maintain harmony.

Markus and Kitayama [1991] state in their significant contribution that the view one holds of the self, of others and of surrounding social context can influence cognition, emotion and motivation. According to them, the way people perceive and understand the world is rooted in their self-perceptions and self-understandings. "If one perceives oneself as embedded within a larger context of which one is an interdependent part, it is likely that other objects or events will be perceived in a similar way" [Markus & Kitayama, 1991, p. 246]. For instance, people who view themselves as a part of a larger whole, (i.e. living in a collectivistic culture; a social factor) are likely to be directed outside oneself and detect relationships between the object and the field (i.e. a cognitive factor, see Section 2.4.2).

The views of Nisbett et al., and Markus and Kitayama help to understand how social differences between cultures (those already described in Sections 2.1 & 2.2) can form cognitive differences between cultures (those to be described in Section 2.4).

2.4 Nisbett et al.'s definition of cultural characteristics

One of the major research paradigms in cultural psychology is 'analysis-holism'. The concept of analysis and holism is proposed by Nisbett and his colleagues [Nisbett et al., 2001; Nisbett, 2003] to describe different systems of thought in cultures. Analysis and holism represent the different ways in which we perceive the world and think about it. People in Western cultures tend to view the world analytically; people in East Asian cultures are likely to have a holistic view about the world. Nisbett and his colleagues have conducted a series of experimental studies and their research work also incorporates concepts and findings of other psychologists and sociologists of past decades.

Building on such theoretical accounts and empirical evidence they have offered a framework for understanding and representing analysis and holism.

The analytic and holistic stance finds expression in different ways of cognition. The cultural characteristics, which show cognitive differences between cultures, are:

- different ways of seeing the world;
- different foci of attention;
- different causal explanations of situations;
- different ways of giving a reason;
- different attitudes toward contradiction.

Nisbett and his colleagues explain how these cultural characteristics fit into the framework of analysis and holism. These characteristics are described in Sections 2.4.1 – 2.4.5. Analysis and holism as a paradigm is defined by the authors as follows [Nisbett et al., 2001, p. 293]:

> Analytic thought involves detachment of the object from its context, a tendency to focus on attributes of the object in order to assign it to categories, and a preference to use such attributes to predict object's behaviour. Analytic approaches prefer use of rules and formal logic, and avoidance of contradiction. Holistic thought involves an orientation to the context or field as a whole including attention to relationships between an object and the field, and a preference for explaining situations on the basis of such relationships. Holistic approaches rely on experience based knowledge rather than abstract logic and are dialectical (i.e. a recognition of contradiction).

'Analysis-holism' in this thesis is understood as a paradigm based on the above definition.

2.4.1 Ways of seeing the world – Analytic versus holistic

The focus in this section is not on analysis and holism as a paradigm, but on analytic and holistic tendency as a cultural characteristic itself. It is about the ways in which the world around us is seen as composed of – either of discrete objects or of continuous substances. Taking reference to past theories and research, Nisbett and his colleagues propose that people in Western cultures (analytically minded) and in East Asian cultures (holistically minded) literally see different worlds [Nisbett et al., 2001, p. 293; Nisbett & Norenzayan, 2002, p. 583]. Analytically minded people are inclined to see the world as a collection of single objects which are unconnected. For them, in order to understand the world around us, it should be merely dissected into components and the properties which characterise them discovered [Ehlers, 2004]. Holistically minded people are inclined to see the world as consisting of inter-connected objects. For them everything relates to everything else and parts exist only within wholes, to which they have inseparable relations. It is not individual object but continuous nature of substance that matters.

2.4.2 Focus of attention – Objects versus relationships

Cultural differences exist in how attention is allocated when perceiving the world [Ji et al., 2000; Masuda & Nisbett, 2001]. People in Western cultures are likely to pay attention to objects. In doing so they are inclined to separate objects from the field (i.e. environment) in which they are located, i.e. decontextualise them. Due to being more attentive to objects, they are likely to take notice of properties of the objects. People in East Asian cultures tend to focus on the field as a whole. They are likely to pay attention to the relationships between objects and the field (i.e. environment) in which the objects are located. In doing so they are likely to detect relationships in the field.

Having an analytic stance makes it likely to focus on objects. Having a holistic stance makes it likely to focus on the entire field, i.e. also on relationships. People thus tend to focus on objects or on relationships due to their analytic or holistic orientation.

2.4.3 Explanation and prediction – Addressing situational influences

Everyday social judgement involves explaining and predicting behaviour of other people. Addressing situational influences (i.e. influences which may arise out of a particular situation) may come into picture when an action or behaviour is analysed. According to Choi et al. [1999] and Nisbett et al. [2001] people from different cultures are likely to attribute an action or behaviour either to a person who carried it out, or to a situational context in which it took place. People in different cultures hold different theories to explain or predict what they believe caused behaviour in a given situation. People in Western cultures tend to consider primarily the disposition and inclination of the person involved. In their view a person has characteristics independent of a situation, hence they tend to attribute an action or behaviour to the actor and independent of the situation in which it is taking place. People in East Asian cultures share a different view regarding such cases. They are more aware of situational information and are likely to make more use of it. In their view, behaviour arises in a specific situation; hence they tend to attribute an action or behaviour to situational influences. According to the authors, such tendencies can be observed not only for social but also for non-social or other daily life events.

People in Western cultures, with their analytic stance, are likely to explain an event by taking reference to properties of the object. People in East Asian cultures, with their holistic stance, may explain the same event by taking reference to interactions between the object and the field. Since they attend to a broader field, it is likely that they may take notice of situational influences.

Another point worth mentioning is that the difference in explaining and attributing (i.e. owing to a person or owing to a situation) is a potential source of cultural misunderstandings, for instance, when debating [Choi et al., 1999].

2.4.4 Giving a reason – Formal versus intuitive

Reasoning denotes the ways in which people argue or come to make their judgements. In reasoning the thinking can be guided by two types of cognitive strategies – formal or intuitive [Norenzayan et al., 2002]. Formal reasoning is characterized by the use of rules and logic. People in Western cultures are likely to apply this type of reasoning. Intuitive reasoning is characterized by the use of similarity detection and experience. An association based on an already noticed similarity, or an association drawn from experience assists the reasoning. People in East Asian cultures are likely to apply this type of reasoning.

Both types of reasoning reflect analytic or holistic stances of people. In analytic thought, noticing properties of objects makes applying rules likely. In holistic thought, attending an entire field makes tracking associations likely.

2.4.5 Avoidance or acceptance – Dealing with contradictions

A contradiction may arise when two different propositions produce an unclear picture in terms of which one to prefer. The level of tolerance when facing such a contradiction can vary – from avoiding to accepting. Cultural differences exist in the way a contradiction is handled [Peng & Nisbett, 1999; Nisbett et al., 2001]. People in Western cultures tend to avoid a contradiction. When presented with a contradiction, they adhere to a logical analysis and try to decide which of the propositions is correct. The aim is to resolve the contradiction by choosing one of the two propositions. People in East Asian cultures tend to accept a contradiction. When presented with a contradiction, they use dialectic reasoning (cognitive tendency towards acceptance of contradiction). They try to find a compromise based on the assumption that both propositions can contain some truth.

The different ways of dealing with contradictions reflect the analytic or holistic stance of people. Contradictory propositions do not comply with the logical thinking of analytic thought; hence they are unacceptable. Acceptance of contradiction is related to the principle of change (i.e. because change is constant, contradiction is constant), which is a part of holistic thought; it is because of change that contradiction becomes inevitable.

2.5 Cultural emphases of the participating designers

As mentioned in Section 1.3, the participants in this research are practicing designers from Germany, India and China. This section addresses the cultural emphases of the participating designers for the cultural characteristics as described in the literature (Sections 2.1, 2.2 and 2.4).

In the cultural studies described in Sections 2.1 and 2.2, in particular those of Hofstede, Triandis, and Trompenaars and Hampden-Turner, many countries are covered including Germany, India and China. This means that the literature provides information about the cultural emphases of the participating designers for the cultural characteristics described in these sections (incl. monochronic and polychronic time concepts).

In the cultural studies described in Section 2.4 (of Nisbett et al.) the countries covered are mainly USA, China, Korea and Japan. The participating designers from China are, hence, assumed as having East Asian cultural emphases for the cultural characteristics described in this section.

Kühnen and Kitayama [2003] conducted a similar study in Germany and Japan to the one conducted earlier by Nisbett and his colleagues. They found that the cultural differences between participants from Germany and Japan were comparable to the cultural differences found between western and eastern participants by Nisbett et al. The participating designers from Germany are, hence, assumed as having the Western cultural emphases for the cultural characteristics described in Section 2.4.

Regarding Indian participants, literature suggests a holistic orientation. E.g. the study of Miller [1984] shows that participants from India took reference of situational and contextual factors in explaining events, in line with which was observed in people from East Asian cultures (see Section 2.4.3). Marriott [1990] and Shweder [1991] too observed the context-sensitiveness of Indians. However, the literature also suggests that the use of logic has a tradition in India [Nakamura, 1964/1974; Becker, 1986], a tendency which is observed in people from Western cultures (see Section 2.4.4). The application of logic suggests that, similar to people in Western cultures, Indians would avoid contradiction (see Section 2.4.5).

The participating designers from India are, hence, assumed as having East Asian cultural emphases for the cultural characteristics ‘analytic versus holistic’, ‘objects versus relationships’ and ‘addressing situational influences’ (see Sections 2.4.1, 2.4.2 and 2.4.3), whereas for the cultural characteristics ‘formal versus intuitive reasoning’ and ‘dealing with contradictions’ they are assumed as having Western cultural emphases (see Sections 2.4.4 and 2.4.5).

2.6 Intercultural design

2.6.1 Intercultural projects

Management of projects in an international context poses several challenges. Wiebusch and Dörrenburg investigated the characteristics of international projects. They identified that cultural characteristics, besides other characteristics, hallmark international projects; the cultural characteristics include intercultural communication, acceptance of authority and organising time [Wiebusch & Dörrenburg, 2005, p. 96]. Based on their analysis, measures are suggested and recommendations are given to support international projects. Nehlsen investigated changes of trend in project management and found that in managing global projects in the period from 1988 to 2000 the importance of communication between cultures has grown and leading multicultural teams will be one of the key skills of project managers [Nehlsen, 2005, p. 119].

More specifically in the area of design is a study conducted by Baumgärtner, in which collaborative projects between engineering consultants and their German, Italian and Indian clients in automotive industry were analysed. Besides other factors, cultural competence of participants, in particular of project leaders, was identified as important for the successful collaboration of internationally acting companies [Baumgärtner, 1999; Baumgärtner & Blessing, 1999]. An understanding of cultural backgrounds of project partners was also identified as important in a large international product development project involving a distributed project team in Germany, Spain, Turkey and Poland [Meyer-Eschenbach & Blessing, 2005].

In their studies and contractual work, Hales and Gooch identified various kind of influences on projects. They too found cultural influences, such as social issues [Hales & Gooch, 2004, p. 31]. Gausemeier et al. [2000, p. 69] identified the ability to work with people from other cultures as one of the competencies for cooperative product engineering.

Culture as an influencing factor in distributed product development was the subject of a colloquium [Lindemann, 2005], in which the speakers from internationally operating companies reported on their experience of how cultural diversity has become apparent in product development. They noticed differences between persons with different cultural backgrounds working together in product development, which are in communication, in decision-making, in organising work, in setting priorities, in working with subsuppliers and in understanding time. The statements, however, are anecdotical, and not the result of an investigation. Nevertheless, the statements support the basic assumption of this thesis that cultural differences are an issue in product development.

How cultural capital is used in designing was investigated in a study conducted by Strickfaden [2004]. In this study cultural capital is defined as information that relates directly to individual experiences and memories and those that relate to social and cultural situations. The base assumption made here is that each individual inherently gathers and retains cultural information, which is later utilised as inspiration and motivation during the designing. In a case study, industrial design students were observed using cultural capital, mainly in task clarification and concept generation. Strickfaden and Heylighen [2007] take the concept of cultural capital a step further and have analysed how values and beliefs of design educators (i.e. their cultural capital) can influence their design students. The participants were design educators in Belgium, Mexico, USA and UK and were teaching in different disciplines, such as in industrial design, furniture design and architecture. The study suggested that values and beliefs are passed consciously and unconsciously from design educators to design students.

2.6.2 Use of products

What a product is ‘meant to be’ in its use is also culture-related. As Press and Cooper [2003, p. 12 ff.] state, culture gives products meaning; values which prevail in a culture are often reflected in a product’s form and function. They also state that meanings and values play a role in shaping consumer culture; the term ‘consumer culture’ refers to how consumption has become a central focus of social life and cultural values. According to Michael Solomon, “culture is the lens through which people view products” [cited in Press & Cooper, 2003, p. 12].

Products developed in one country are sold worldwide and manufacturers try to capture expectations and using habits of users with different cultural backgrounds. A study conducted by Honold [2000] from the field of intercultural usability engineering investigated the use of a German washing machine by Indian and German users, and the use of a mobile phone by users in Germany, Italy, India and China. Based on the analysis, recommendations for intercultural usability engineering were derived.

Heterogeneity among worldwide users is an issue in the field of man-machine interaction. Culture-specific preferences of users as an influencing factor in interface design were the subject of the research conducted by Röse [2000]. A method for the design of intercultural man-machine systems was developed to support developers. A study was carried out in India, Indonesia, China, South Korea, USA and Germany to analyse and determine cultural differences in icon usage and colour coding. The results of the study were used to demonstrate the application of the developed method.

Usability of websites is another field which has come under scrutiny because websites can be visited by people from different countries. In a study conducted by Dong and Lee [2008] the webpage perception of Chinese, Korean and American users was investigated. The findings suggested that there are differences between users in viewing webpages and the differences are in line with their cultural thought patterns (see Section 2.4). Based on the findings, suggestions were made for webpage design targeting users from different countries.

Use of products and product design in a cross-cultural context were investigated in a research reported by Diehl and Christiaans [2006]. Several case studies were carried out to get an understanding of how users in culturally-different markets (within the European market itself and in European and Asian markets) experience and interact with products. Gomez and Pasa [2003] investigated the influence of culture in the implementation of product-service systems in Europe, Japan and Brazil. Cultural differences were analysed based on Hofstede's cultural dimensions (see Section 2.1.1) to discover possible drivers and obstacles in the acceptance of product-service systems.

2.6.3 Intercultural product development

Pauwels [2001] uses the term 'intercultural product development'. In his study, however, design processes are not investigated. Rather, a theoretical approach for intercultural product development is proposed based on *Value Analysis*. The approach treats aspects such as recognising functions for different markets, paying attention to product design for different markets, considering cultural values for different markets and working in intercultural teams. Further, the use of graphical symbols in embodiment is described.

In a workshop Felgen et al. [2004] investigated collaborative design in intercultural teams involving researchers from Germany and India. This workshop shed light on aspects pertaining to communication in teams (especially language), knowledge of cultural traditions of participating countries, product requirements for targeted markets, overall planning, knowledge of design methods and required media for communication and documentation. However, as the authors state, a more detailed analysis of cultural influences is necessary to understand these properly.

The study of Gaul [2001, p. 3, 108] recognises the different cultural emphases of participants as a chance to enhance creativity in a distributed product development environment. This study discusses the context of distributed product development, such as cooperation, flow of information and working in teams, but does not go deep into the influence of culture.

2.6.4 Discussion

This section contains a discussion of the reviewed literature. Based on the identified deficits, the need for this research is derived.

Sections 2.6.1 and 2.6.2 show that in the areas of project management, and product use and usability, cultural influences are gaining attention and have been subject of investigations. Cultural influences have been identified and various kinds of support have been developed to render assistance in a global environment.

Section 2.6.3 shows that things stand differently in product development. Although the relevance of cultural influences is realised, design processes of designers with a different cultural background have not been investigated and compared. This leads to a lack of know-how about the effect of cultural influences on designers' approaches. As a consequence, design support based on this know-how is also missing. Such support can be useful for internationally operating companies which develop or adapt products for different market under participation of local designers.

An investigation of the effect of cultural influences on designing will offer a twofold gain – a better understanding of approaches used by designers in designing and enhanced support for companies working with designers with different cultural backgrounds. The first gain will contribute to the understanding of human behaviour in design and the second gain will contribute to the global development of products.

2.7 Characteristics of design approaches

The first research question, i.e. which cultural characteristics could influence the approaches used by designers in designing, covers two topics – culture as an influence and approaches used by designers in designing. The first topic was treated in Sections 2.1 – 2.4. This section addresses what is characteristic in design approaches.

A review of literature revealed many studies in which approaches of designers or design students have been investigated. Such studies have described how design processes are actually performed and have identified the characteristics of the various design approaches. Findings from following studies are discussed: Stauffer et al. [Stauffer, Ullman & Dietterich, 1987; Stauffer & Ullman, 1988; Ullman, Dietterich & Stauffer, 1988], Dylla [Ehrlenspiel & Dylla, 1989; Dylla, 1990], Fricke [Fricke, 1993; Fricke, 1996], Blessing [Blessing, 1994], Günther [Günther, 1998; Günther & Ehrlenspiel, 1998] and Bender [Bender & Blessing, 2003; Bender, 2004]. In all these studies, except the one by Blessing, designers or design students were observed in a laboratory situation; Blessing's study was undertaken in a company. In all these studies, except the one by Bender, the participants were designers; in Bender's study the participants were design students. In all studies the participants came from one country. There are also variations within studies, such as in Günther's study – designers who had studied design methodology and designers who had not studied design methodology, but had acquired practical experience in designing. Such variations, however, are not treated here further.

The approaches observed in the mentioned studies are summarised and presented around design activities.

2.7.1 Characteristics of design approaches based on design activities

Analysing problem and requirements

Analysing problem and requirements deals with clarification of the problem, analysis of goals and requirements, and formulation of the problem.

Dylla observed that, while analysing requirements, the designers clarified boundary conditions and determined whether all necessary information regarding the problem was available. During problem-solving the designers frequently consulted the information contained in the requirements. Fricke observed that the designers clarified requirements, while keeping the goal in mind. They tried to understand the problem, e.g. which functions are to be fulfilled or which are the product characteristics. Sometimes they also went beyond the problem space and actively searched for requirements. In Blessing's study the designers who had received a set of requirements with the design problem were observed to reformulate and prioritise requirements while developing a solution.

Finding solutions for functions

Once the problem is analysed, solutions for identified functions need to be found. How designers were observed to treat functions in finding solutions, i.e. each function separately or many functions together, is described below. The focus in this section is on finding solutions for concept and embodiment.

Stauffer et al. observed that the designers considered functional aspects of the design throughout the process rather than performing a full functional analysis in the beginning. After performing a brief functional analysis they moved to fixing concept and form (embodiment) for a function. Then they shifted back to functional analysis and the cycle was repeated for another function.

Dylla found that solving the given design problem 'as a whole' hardly happens. He observed that the problem statement hinted at functions, for which solutions were to be found. Occasionally, two functions were elaborated together. Fricke describes the two observed approaches as 'stepwise process-oriented' and 'function-oriented'. In a 'stepwise process-oriented' approach the designers worked on many problem areas (i.e. functions) while staying at the same level of abstraction and then moved to the next level of abstraction. In a 'function-oriented' approach the designers worked on one problem area, i.e. on one function, from an abstract to a concrete level (i.e. performed many design activities for a function) and then moved to the next problem area, which was addressed in the same way.

In Blessing's study the relationships between product elements (i.e. parts) were observed to play an important role in finding solutions – how the solution for one product element would affect another. While finding a solution for a product element a jump was made to related product elements (i.e. parts) to verify the effects, and an alternative was suggested if necessary.

Günther observed that, similar to the ‘function-oriented’ approach observed by Fricke, the designers with practical experience stayed mainly with one sub-problem at a time (i.e. function), found its solution and then generated the embodiment. The designers educated in design methodology moved between sub-problems (i.e. functions) while staying with one design activity at a time (e.g. finding solutions for all functions) before moving to the next design activity, for instance, embodiment generation. This approach is similar to the ‘stepwise process-oriented’ approach observed by Fricke.

In Bender’s study, three main approaches were observed. The ‘hierarchically object-oriented’ approach contained a decomposition of the design object. Many design activities were performed, similar to the ‘function-oriented’ approach observed by Fricke, for a sub-system (i.e. function), before they were performed for the next sub-system. The ‘opportunistic and associative’ approach involved taking advantage of available and promising opportunities which arose during problem-solving. The same design activity was performed successively for many sub-systems. The ‘muddling through’ (or ‘trial and error’) approach involved more or less unsystematic attempt to cope with different sub-systems and design activities every time they come to conscious consideration.

Deriving selection criteria and evaluating solutions

The generated solutions have to be examined to determine whether they are worth pursuing. This requires a comparison with the problem and requirements and with alternative solutions [Blessing, 1994, p. 64].

Stauffer et al. observed that many decisions involved in evaluating solutions are based on qualitative, subjective reasoning rather than on quantitative criteria. Dylla observed that only a few selection criteria are used in evaluating solutions; many solutions are evaluated qualitatively, i.e. ‘it works’ or ‘it won’t work’. Fricke observed in his study that successful designers evaluated solutions frequently, whereas the level of abstraction of evaluation matched with the concreteness of the solution. In Günther’s study, an explicit evaluation of solutions was observed to be performed by the designers with an education in design methodology, whereas the designers with practical experience were not observed evaluating the solutions explicitly. Blessing observed that in evaluating solutions, the documented requirements were rarely consulted explicitly as a source from which to derive criteria. Instead, a variety of sources were drawn upon, such as past experience, and reference to other products and to the product being developed.

Improving solutions

Based on the results of an evaluation it might be necessary to generate other solutions, either by finding a new, alternative solution or by modifying the existing solution [Blessing, 1994, p. 68].

Stauffer et al. observed that the designers often pursued a single concept both at the level of the overall design problem and at the level of individual sub-problems. Dylla observed two ways of varying the generated solutions, which he called ‘generative variation’ and ‘corrective variation’. Generative variation refers to the situation in which multiple solutions are generated for different functions. From each set of solutions one or more are selected and combining these, a solution is generated, which is elaborated further. Corrective variation refers to the generation of a solution, its subsequent evaluation, and the generation of an improved solution based on this evaluation. The corrective way of varying solutions was found to be practiced more often. Both ways of varying solutions were also observed in the studies conducted by Fricke and Günther.

In Blessing's study, improving solutions for product elements was observed to be performed in different ways, such as by adding or deleting a part, by differentiating (i.e. introducing two or more elements to fulfil a function previously fulfilled by one element) or combining functions (i.e. introducing one elements to fulfil the functions previously fulfilled by two or more elements).

Switching between design activities

This section describes the sequence in which various design activities are performed.

Dylla observed that the designers switched frequently between finding solutions and fixing the found solutions (i.e. fixing the concept and drawing the layout). Fricke observed in his study that there is no approach which is completely without jumps between design activities. Günther observed in his study that the designers with practical experience switched frequently between finding solutions in the conceptual phase and generating the embodiment. In Bender's study, jumps between design activities were observed, while working on the same function or switching between functions.

2.7.2 Discussion

The findings presented in the previous section are based on observations of design processes. The description provides the characteristics of individual approaches taken by designers when they performed various design activities. The individual approaches were found to differ strongly. Individual, characteristic approaches of designers can influence their design processes and this is relevant in international cooperation when designers with different cultural backgrounds work together in product development. The cultural background is expected to influence the approach used by a designer and hence to influence intercultural collaboration. This scenario brings together both topics addressed in the first research question – culture as a possible influence on designers and characteristic approaches used by individual designers. Section 2.8 on 'Assumption' will follow up this notion.

2.8 Assumption

Culture affects the way people think and act, and culture is a shared system (see Section 2.1.6). Sharing characteristics of a culture would mean that people belonging to a cultural group are likely to think and act in a similar way, but differently when compared to people belonging to another cultural group. Further, as derived in Section 2.7.2, individual approaches of designers can strongly differ and significantly influence their design processes. An intercultural situation was defined as a situation in which designers with different cultural backgrounds work together in one design project.

The assumption underlying this research is that designers with a different cultural background differ in their design approach and hence show a different design process.

2.9 Characteristics to be investigated

The first research question, i.e., which cultural characteristics could influence the approaches used by designers in designing, is answered in part in this chapter by describing the characteristics of culture and of design approaches. Following on from the research approach described in Section 1.4 and from the characteristics described earlier in this chapter, this section addresses how the characteristics are analysed in further answering the first research question.

First, the characteristics of culture which could be relevant in the context of design approaches were determined. The characteristics of culture exert influence in various kinds of situations, for instance in daily life or at work. However, only some cultural characteristics are expected to influence design activities. Next, the cultural characteristics were compared with the characteristics of design approaches. The comparison suggested which cultural characteristic could have a strong effect on which characteristic of design approaches, i.e., could have a strong effect on which design activity. This is shown in Table 1. The empirical study will focus on these characteristics (see Figure 2, Section 1.4).

Literature on design, such as Dylla [1990] and Fricke [1993], has shown that the durations of design activities and the order in which they are performed differ between designers based on their individual design approach. Therefore, the investigated design processes will also be analysed based on design activities (i.e. not only from point of view of cultural characteristics) to find out differences and similarities between the investigated cultural groups and to derive tendencies for the groups. Literature on design, such as Günther [1998] and Bender [2004], has also shown that the knowledge of systematic design affects design processes. Therefore, how the knowledge of systematic design could have affected the design processes will also be investigated for the cultural groups. These aspects are included in Table 1.

Table 1: Characteristics to be investigated

Cultural characteristics which are expected to have an effect on a design activity	
Cultural characteristics	**Characteristics of design approaches based on design activities**
1. Addressing situational influences	Analysing problem and requirements
2. Analytic versus holistic	Finding solutions for functions
3. Objects versus relationships	Deriving selection criteria
4. Formal versus intuitive reasoning	Evaluating solutions and embodiments
5. Dealing with contradictions	Evaluating and improving solutions and embodiments
6. Monochronic versus polychronic	Various design activities while working on functions
Tendencies for the cultural groups pertaining to the nature of the design processes	
7. - Comparison of duration of performed design activities - Comparison of order of performed design activities - Effect of knowledge of systematic design	

The mapping of the emphasis of the cultural characteristics to the cultural groups is addressed when presenting the findings in Chapter 4.

Since Aristotle, man has organized his knowledge in separate and unrelated groups. The main emphasis has been on the identification of objects rather than on the relationships between objects.
The 13th Floor Elevators

3 Empirical study

To answer the second research question, i.e. how the design processes of designers from different cultures differ, an empirical study has been carried out in Germany, India and China under participation of designers drawn from industrial practice in these countries. Section 3.1 addresses the design of the empirical study. Section 3.2 addresses the data analysis methods used to identify differences between design processes. The results of the empirical study are presented in Chapters 4 and 5.

3.1 Design of the empirical study

3.1.1 Data collection method

In order to compare and determine differences between design processes, the empirical study is designed to take place in a laboratory setting. The same laboratory setting is used in each of the three countries involved – Germany, India and China. The empirical study was conducted in 2007 and 2008; one last case was recorded 2009 in Germany. 14 design processes (cases) were captured – four each in Germany and India, and six in China.

Data is collected by observing teams of two designers solving a given design task (simultaneous verbalisation) and by means of interviews. The design task is to develop a device for baking biscuits, which is suitable for household use. The participants are asked to develop the solution together, and to voice their thoughts and exchange these with their partner. The design process covers the phases from task clarification until a rough embodiment design. The participants developed their solution on paper. The interviews are held with the participants, after they have finalised the task, to capture their views on the aspects mentioned in Table 1 (Section 2.9), and on the set-up of the empirical study. All cases are recorded on video and subsequently transcribed for analysis. The total time of recorded design processes was 47 hours. The language used in Germany was German. In India and China English was used. The participants were given assurance of anonymous treatment of personal details and collected data.

A closer look is taken in the following at simultaneous verbalisation and using teams of two designers. Simultaneous verbalisation refers to a situation in which participants speak aloud while working [Blessing and Chakrabarti, 2009, p. 262]. The aim is to provide insight into the cognitive behaviour of participants, which may not be obtained through normal observation. When participants are asked to verbalise their thoughts while working, this is called ‘think aloud’. The most important characteristic of simultaneous verbalisation is the real-time aspect – while working on the problem, the problem-solver is ‘thinking aloud’. Ericsson and Simon [1993] have given extensive coverage to the use of ‘think aloud’. As stated in Ericsson [2002], “...participants are not asked to describe or explain how they solve these problems. Instead they are asked to remain focused on solving the problem and merely to give verbal expression to those thoughts that emerge in attention while generating the solution under normal (silent) conditions”. According to Ericsson and Simon, verbal reports generated out of this verbalisation tap short-term memory. Such reports thus reflect at least a part of cognitive processes and come close to representing thinking processes.

The suitability of verbal reports based on ‘think aloud’ as a valid means for studying cognitive processes has widely been subject to discussion. Several reports, such as Cross et al. [1996], however, suggest that despite of its limitations, analysis of think-aloud protocols qualifies as a means for design research.

In this research, teams of two designers were involved, rather than individual designers. A pilot study involving a single participant showed that verbalisation was insufficient. Hence, the study focused on teams of two participants. It was assumed that two designers solving the given problem together would continuously exchange thoughts and improve verbalisation. A subsequent test run confirmed this.

3.1.2 Set-up of the empirical study

The empirical study is designed to take place in a laboratory setting. The set-up of the study, which is shown in Figure 3, was devised to be ‘mobile’. The same equipment and set-up was used at all locations where the study was conducted. Two camcorders were used – one focussed on the papers with which the participants worked, and the other capturing the entire set-up. The designers used paper and pencil. No catalogues were given and the designers consulted no other source of information. No time limit was given for solving the task, but the entire exercise was to be completed within a working day. The researcher was present during the exercise, but not involved. No interruption was planned; designers could take a break if they wanted.

Figure 3: Set-up of the empirical study: to the left the researcher, to the right two participants involved in the pilot study

3.1.3 Design task

The design task involved the development of a device for baking biscuits, which is suitable for household use. This task was chosen on the basis of several criteria. First, since the study was to be conducted in three countries, it was important that participants could conjure up an image of the device, i.e. it should be clear after reading the task which functionality the resulted device should have. At the same time, participants should not be in a position to recall a solution from memory due to being familiar with such a device.

Second, the volume of the task had to be such, that it could be solved within a working day, as this was the maximum duration allowed by the companies, whose employees were involved as participants. Third, in developing the solution, no sources of information would be made available, such as looking into a catalogue or asking a colleague. It meant that the task should be such that a practicing designer can solve it without needing expertise from a specific field.

Based on the terminology used by Blessing and Chakrabarti [2009, p. 249], the task used in this study can be called *realistic*, i.e. it is derived from a real task and adapted to suit the research constraints. The task is included in Appendix A.

3.1.4 Selection of participants

The designers who participated in the study were practicing designers with a limited number of years of working experience. The decision to choose participants with a limited number of years of working experience was based on the assumption that a longer working experience would carry the risk that the corporate culture, compared to the cultural background of the designers, may come to the fore.

It was assumed that if designers are drawn from industrial practice with a similar number of years of working experience, they would have a similar level of design knowledge. This would mean that all participating designers share a similar base, which is a prerequisite for comparing the design processes in different cultures.

The participating designers worked for national and international companies in their respective countries. In each case, both designers came from the same company and from the same hierarchical level. This means that they knew each other and could contribute to the design process free from hierarchical barriers.

3.2 Data analysis

3.2.1 Method of data analysis

The theoretically derived characteristics given in Table 1 (see Section 2.9) form the starting point for the analysis of the collected data. Each characteristic is analysed separately. First, the data sets within one culture are compared and checked for tendencies. After that, an inter-cultural comparison of the design processes is undertaken to compare the tendencies and identify similarities and differences in designing. The overall approach taken to analyse the data collected is shown in Figure 4. Details of the analysis are given in the respective section describing the findings (Chapters 4 and 5).

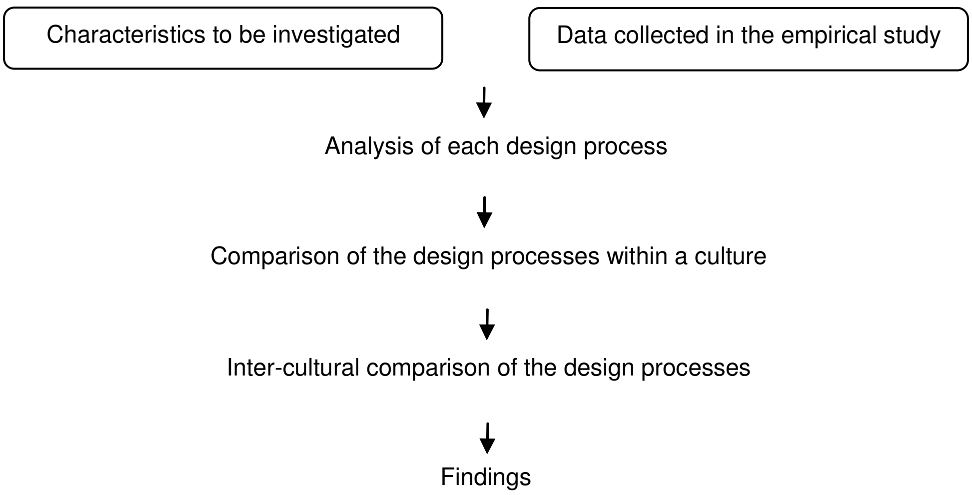


Figure 4: Approach taken to analyse the collected data

In a subsequent analysis the findings on individual characteristics in a design case are compared to find out how these can be linked to each other.

The quality of the observed design processes and the developed solutions is not assessed.

3.2.2 Processing data

The collected data was processed before it could be used for the analysis. Data processing included transcribing the video recordings, applying coding schemes to transcriptions of the design processes and generating output reports. In processing and analysing data, the original language was retained. Each hour of video required more than 40 hours for data processing. A large part of the consumed time was needed for the transcriptions. Two designers developing a solution together meant an almost continuous stream of words, sometimes even uttered in parallel. Yet, the resulting data is very rich.

Transcriptions

The speech of the designers was transcribed into protocols using the 'f4' transcription software [f4, 2009]. All design processes were transcribed in full.

Coding

The protocols were first coded using the main coding scheme based on design activities (see Figure 5). The full main coding scheme is given in Appendix B. This coding scheme was used to segment the protocols. This coding scheme helped to select the segments of the protocols (i.e. of the design processes) relevant for the analysis of a particular characteristic, based on the link between the design activity and the cultural characteristic shown in Table 1 (see Section 2.9).

The categories are based on the systematic design process according to Pahl and Beitz [Pahl et al., 2007; p. 130, 160 & 229], which is widely known. This scheme was developed before the data was collected. The inter-encoder reliability was found to be 78% before being consulted and 90% after being consulted by the second encoder.

Analyse the task
Analyse the requirements
Identify functions
Combine functions into a structure
Find solutions for functions
……
Evaluate solutions
Generate a concept
……
Generate embodiment for functions
Evaluate embodiment for functions
……
Generate overall embodiment

Figure 5: Main coding scheme

The second round of coding focused on the analysis of the characteristics in Table 1 (see Section 2.9). The specific coding scheme for each characteristic is given in the respective section where the findings are presented (Chapter 4). These schemes were not developed beforehand, but during the analysis. An exception, is the scheme for coding the functions of the given design problem, which was developed beforehand. The following categories and codes were used for the functions:

– Store ingredients (1)
– Mix ingredients (2)
– Transport ingredients (3)
– Shape biscuits (4)
– Bake biscuits (5)
– Various auxiliary functions (6)

Figure 6 shows an example of a coded protocol. The explanation is as following:

– Column 1: A vertical line shows a segment (a segment is a part of the transcribed speech, which is assigned a separate code)
– Column 2: A running number of interactions between the two designers
– Column 3: Running time of the recorded design process (Format – hours:minutes:seconds:frames)
– Column 4: Which of the two designers is currently speaking
– Column 5: Transcribed speech
– Column 6: Main coding based on design activities (see Appendix B; 5.3 denotes 'Find solutions for functions' and 5.4 denotes 'Find other solutions for functions')

– Column 7: Second coding based on the functions of the given design problem (see above; 2 denotes the function 'Mix ingredients')

When transcribing, the speech of a designer is entered in a row as long as he speaks. The moment the other designer starts speaking, a new row is used. All such rows which carry a certain thought and pertain to the same design activity form a segment.

Various symbols are used to facilitate the understanding of transcribed speech – '...' denotes when the speech was interrupted either by a designer himself or by the other designer; '[???]' denotes when a part of the speech could not be understood; a comment in square brackets is used to denote a gesture or action of designers.

1	**2**	**3**	**4**	**5**	**6**	**7**
	196	00:27:05:8	D1	...Actually if you say how it do typically the mixing [???] manually, we pour all the ingredients and try to mix with some spoon or something.	5.3	2
	197	00:27:18:5	D2	Yes, yes		
	198	00:27:19:6	D1	So, may be this is one of the concepts which can be automated.		
	199	00:27:23:8	D2	Yes		
	200	00:27:26:2	D1	So, may be the spoon here [drawing page 3], this rotates and may be moves up and down and here you have ingredients.		
	201	00:27:33:7	D2	OK, one more thing is that you have container here [pointing and drawing page 3], you pour all the ingredients here, there is a [???] like this. And this container will be rotating...	5.4	2
	202	00:27:56:0	D1	...rotating		
	203	00:27:56:9	D2	This will be stationary.		
	204	00:27:57:8	D1	Yes		
	205	00:27:58:6	D2	A typical [???]		
	206	00:28:02:7	D1	So, this [pointing at page 3] is stationary and...		
	207	00:28:05:0	D2	...this container will be rotating.		

Figure 6: An example of a coded protocol

Durations of segments shown in Figure 6 are 27 seconds and 32 seconds, and are typical examples for the design activities ‘Find solutions for functions’ and ‘Find other solutions for functions’. Typical examples of durations of other design activities are:

- ‘Analyse the requirements’: 20 seconds
- ‘Evaluate solutions for functions’: 16 seconds
- ‘Generate/ improve embodiment for functions’: 30 seconds
- ‘Evaluate embodiment for functions’: 14 seconds

Generating output reports

Based on the first coding scheme, two types of reports were generated using the ‘Interact’ software of Mangold [Mangold, 2009]:

- Durations: charts showing the duration of performed design activities in % of the total design time for a particular case
- Timeline diagrams: representations of design activities over time (i.e. the running time of the design process) for a particular case

The main output reports for all observed cases are given in Appendices C and D.

Both types of report were generated in different variations, for instance, duration charts showing not only each design activity separately, but also showing a few design activities combined, or a timeline diagram showing not only when a design activity was performed, but also showing when a design activity was performed for which function.

3.2.3 Discussion

In Table 2 the key details of the empirical study and data analysis are summarised.

Table 2: Key details of the empirical study and data analysis

Data collection	Simultaneous verbalisation while solving the given design problem in a team of two designers and a subsequent interview after the designers had finalised the task; recording per video
Setting	Laboratory situation; no external source of information consulted during developing of solution
Task	Realistic (to develop a device for baking biscuits, which is suitable for household use)
Observed process	From task clarification until a rough embodiment; use of paper and pencil; rough embodiment sketch as deliverable
Time constraint	No time limit was given for solving the problem, but the entire exercise was to be completed within a working day (including answering of interview questions)

Number of cases	14 cases (four each in Germany and India, and six in China)
Case size	Two designers in each case
Participants	Designers drawn from industrial practice in Germany, India and China with a limited number of years of working experience
Duration	Total of 47 hours of recorded design processes; varying between approx. 2 and 5.5 hours per case; in addition, time for interviewing
Coding	Main coding scheme based on design activities (developed beforehand); various sub-coding schemes based on the characteristics to be investigated (developed during the analysis)
Analysis	Based on video recordings, transcriptions, paper sheets on which the designers developed their solutions, answers given to interview questions, and output reports

The results of the empirical study are presented in Chapters 4 and 5.

East West
'a revelation into the workings of Indian music'.
The Butterfield Blues Band

4 Findings – Influence of cultural characteristics

This chapter focuses on the second research question, i.e. how the design processes of designers from different cultures differ, and addresses characteristics 1-6 of Table 1 (see Section 2.9). Theses pertain to the influence of cultural characteristics observed in designing. The second part of the findings is presented in the next chapter and addresses aspect 7 of Table 1, i.e. tendencies for the cultural groups pertaining to the nature of the design processes.

Section 4.1 addresses the influence of the set-up of the study. Sections 4.2 – 4.7 describe how the cultural characteristics derived from literature were observed to influence the design activities (i.e. design approaches) in the design processes. Section 4.8 discusses the findings. In Section 4.9, the findings on individual cultural characteristics are combined to show how they fit together in a design case.

As described in the previous chapter, the findings are based on the analysis and comparison of 14 design processes, which were recorded in a laboratory setting – four each with designers from Germany and India and six with designers from China. The designers who participated in the empirical study are denoted in the following as: G-designers (designers from Germany); I-designers (designers from India); C-designers (designers from China).

4.1 Influence of the set-up of the study

First some general findings are presented based on the answers given by the designers in the interviews. The interviews were conducted immediately after the designers had finalised the given design task. The general findings pertain to how the participating designers experienced the set-up of the empirical study. The aim was to find out whether this context might have caused any effects on problem solving process.

The designers were asked the following questions:

- How did you find the situation that you had to voice your thoughts?
- How did you find the situation that you developed and drew your solution on paper?
- How did you find the situation that the experiment was video-recorded?
- Was there a source of information which you missed during problem-solving?
- Was it clear after reading the task what was to be done?

The questions were answered in 12 cases; in two cases no data could be collected on these questions. In all 12 cases the designers stated that it posed no problem to verbalise their thoughts and exchange these with their partner. They also stated that it was not unusual to develop and draw solutions on paper. In four cases the designers added that drawing on paper is how they normally work when they are at the initial stage of developing solutions. All designers stated that they did not feel disturbed or distracted by being video-recorded. A frequent statement was that during the exercise they were busy developing solutions and forgot about being video-recorded. When asked about missing sources of information, in three cases the designers stated that they would have liked to gather some information about the current trend in the market.

All designers confirmed that it was clear after reading the task what was to be done. The expected deliverable was a rough overall embodiment for the device. The papers on which the designers developed and sketched their solutions show that in all cases such an embodiment was indeed generated, although the level of detailing differs.

During the 47 hours of recording, the researcher needed to remind designers to voice their thoughts only in two instances. Further, the designers only had to be reminded once about developing a solution together.

In summary, it can be concluded that the set-up of the empirical study did not seem to have constrained the designers in solving their task.

4.2 Addressing situational influences – Analysing problem and requirements

People in different cultures explain and predict behaviour based on different grounds (see Section 2.4.3). In Western cultures it is likely that behaviour is attributed to a person itself. In East Asian cultures it is likely that behaviour is attributed to the accompanying situation. The difference in addressing situational influences might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers predict user needs differently when they analyse the given problem and requirements. It is expected that the I- and C-designers make a different prediction of user needs, which is based on considering the situational influences while using the device, than the G-designers do. The question is whether there are differences in the observed design cases regarding the situational influences that are taken into consideration when analysing the problem and requirements and whether the differences have a link to the mentioned cultural characteristic.

Method of data analysis

Of concern in this section are the design activities that were coded as ‘analyse the task’ and ‘analyse the requirements’ (see Section 3.2.2). These design activities underwent a sub-coding. The classification was developed during the analysis of the design activities. This resulted in the following four categories:

- functionality the device should fulfil;
- use of the device;
- input and output of the device (i.e. the ingredients and the form of the output);
- market and cost.

Findings

The focus is on the use of the device. This category appeared in all design cases. 'Device easy to use and operate' or 'user can make biscuits in various shapes' are examples of use-related aspects which appeared in this category in most of the design cases (Note: the device should be easy to use was given as one of the requirements in the design task; see also Appendix A). A comparison of the cases shows, however, that in some instances differences can be observed between the G- and I-cases in the way in which the use-related aspects are analysed and further specified. In three (I2, I3, I4) of the four I-cases the I-designers tried to put themselves in the position of a user. They tried to imagine how the user will interact with the device and how a particular use situation might take place. The influences addressed by the I-designers (in three cases) are related to the particular use situations.

An example describes the difference between the G- and I-cases with the help of the use-related aspect 'device easy to use and operate'. After this aspect was identified by the designers, it was specified in the G-cases as 'easy to clean for the user' or 'intuitive and self-explaining operation of the device', whereas in the I-cases, it was specified in more detail as 'the lower number of operations a user has to do in baking' or 'provision needed for different mixing options for ingredients'.

In the C-cases the use-related aspects are addressed. However, the collected data does not show explicit reference to whether particular use situations are taken into consideration or not.

Discussion

A comparison of the investigated design processes shows that in their analysis the G- and I-designers predicted user needs by considering how users would use the device and what they might find useful. The I-designers, however, addressed the situational influences. In doing so the I-designers acted as expected based on the suggestions made in the literature on culture , i.e. people in East Asian cultures tend to analyse behaviour together with the accompanying situation (see Section 2.4.3).

The difference found between the designers in considering situational influences when they analysed the problem and requirements indicates a possible link of these two design activities to the cultural characteristic 'addressing situational influences'. However, only few instances of differences between the G- and I-cases could be found, and addressing situational influences could not be observed in the C-cases, as suggested by the literature on culture.

4.3 Analytic versus holistic – Finding solutions for functions

People in Western cultures (analytically minded) and in East Asian cultures (holistically minded) differ in their perception in terms of composition of the world (see Section 2.4.1). Analytically minded people are inclined to see the world as consisting of unconnected objects; holistically minded people are inclined to see the world as consisting of inter-connected objects (wholes). The different perceptual styles might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers approach problem-solving differently when they work on the given problem and find solutions for its functions. It is expected that the G-designers treat the functions in an analytic way, i.e. separately, because the functions are seen as unconnected, and the I- and C-designers treat the functions in a holistic way, i.e. together, because the functions are seen as inter-connected. The question is whether there are differences in the observed design cases in terms of treating the functions analytically or holistically when finding solutions and whether the differences have a link to the mentioned cultural characteristic.

Method of data analysis

After the first coding based on design activities, a second coding was undertaken based on the functions of the given problem (see Section 3.2.2), which were determined beforehand:

- Store ingredients
- Mix ingredients
- Transport ingredients
- Shape biscuits
- Bake biscuits
- Various auxiliary functions

The focus in this section is on how each function is treated when its solution is found, i.e. separately or together with other functions. The paper on which the designers wrote and sketched their solutions provided additional information.

Findings

In all cases the designers were observed to work analytically. When they started finding solutions for functions, the first few functions were treated separately, i.e. as stand-alone and independent from other functions.

After that, however, it was observed that in six cases, two from each culture, functions were treated in a holistic way, i.e. together, but to a different extent. The difference is described in the following.

In two G-cases (G1 & G3), after solutions for the first few functions were found, the embodiment for these functions was generated. This partial embodiment acted as a first reference point for finding solutions for the other functions. The overall embodiment was generated in these cases later in the design process (see Section 5.1.2).

The two I- and two C-cases (I1, I2, C1 & C2) at that point generated the overall embodiment, even though only the solutions for a first few functions were found. In these cases the overall embodiment acted as a first reference point for finding solutions for the other functions. The partial embodiment was generated in these cases at different points of time in the design process (see Section 5.1.2).

A comparison of the mentioned cases (two G- with two I- & two C-) shows the following. In the I- and C-cases the functions are treated together for (i.e. the holistic way of working spans across) the design activities which lie 'more apart' (more apart as per the main coding scheme, Appendix B; e.g. finding solutions for functions and generating overall embodiment), than those in the G-cases (e.g. finding solutions for functions and generating partial embodiment). The difference is illustrated in Figure 7. That is, the holistic way of working is more pronounced in the I- and C-cases than in the G-cases.

In the remaining eight cases (two G-, two I- & four C-) the holistic way of working when finding solutions for functions was not observed. In these cases, functions were continued to be treated separately and the partial or overall embodiment did not act as a reference point for finding solutions for the other functions. Details of when design activities were performed in the design cases are given in Section 5.1.2 and Appendix D.

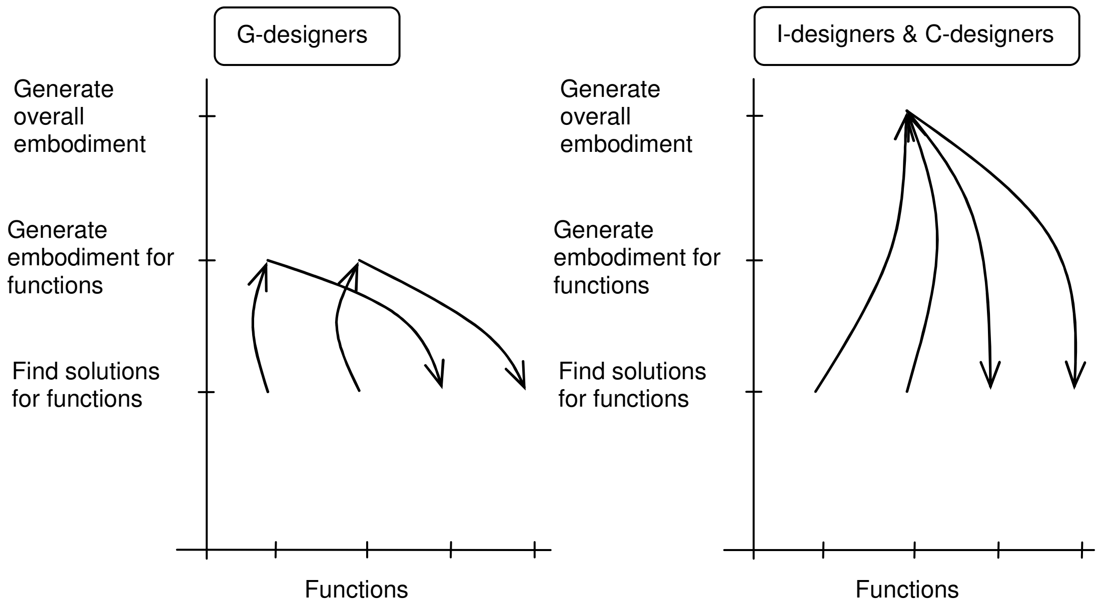


Figure 7: Differences in designers' approaches when finding solutions for functions

Discussion

The analysis shows that in finding solutions all designers worked on the first few functions separately, which indicates an analytic way of working. In eight of the 14 cases the way of working remained analytical for the other functions. In the other six cases (two each G-, I- & C-) when the solutions for other functions were found these were treated together, which indicates the presence of a holistic way of working. A comparison of these cases shows that the holistic way of working is more pronounced in the I- and C-cases than in the G-cases.

The findings present a mixed picture. That the functions of the given problem are worked on separately in all cases can be the result of the designers' professional experience or knowledge of systematic design (see Section 5.2). The presence of a holistic way of working is, however, only to some extent in line with what was expected based on the literature on culture (see Section 2.4.1). In two of the four G-cases the designers worked not only analytically but also holistically, and only in two out of four I-cases and two out of six C-cases the designers worked holistically. The only observation in line with the literature is the fact that in the I- and C-cases the holistic way of working was more pronounced than in the G-cases. In summary, the differences in finding solutions for functions between the G-, I- and C-cultural groups caused by the cultural characteristic 'analysis versus holism' are small and the differences indicate a possible link to the said cultural characteristic.

4.4 Objects versus relationships – Deriving selection criteria

People in different cultures have different foci of attention when perceiving the world (see Section 2.4.2). In Western cultures they are more attentive to objects and their properties. In East Asian cultures they are more attentive to the field (i.e. the environment) and to relationships between objects and the environment. This difference in paying attention might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers have different foci of attention, when they derive selection criteria to evaluate solutions and embodiments. It is expected that the G-designers mainly focus their attention on objects and derive selection criteria based on these, and the I- and C-designers mainly focus their attention to relationships between objects and the environment and derive selection criteria based on these. The question is whether the above differences can be observed in the design cases when deriving the selection criteria during the evaluation of solutions and embodiments and whether the differences have a link to the mentioned cultural characteristic.

Method of data analysis

The focus of the analysis is on all design activities (coded in the first pass) which pertain to evaluation of solutions and embodiments. These are: identify selection criteria, evaluate solutions for functions, evaluate overall solution, evaluate embodiment for functions (partial embodiment) and evaluate overall embodiment (see Section 3.2.2). All segments assigned to these design activities underwent a second coding, which was not developed in advance, but during the analysis of the activities. This resulted in the following categories:

- fulfilment of functionality by function carrier in conceptual phase;
- fulfilment of functionality by function carrier in partial embodiment;
- fulfilment of functionality by function carrier in overall embodiment;
- use situation involving the function carrier;
- user interface;
- market and cost.

Based on the categorisation, all design cases were compared for selection criteria derivation.

Findings

All G-, I- and C-designers worked on finding ways of achieving the fulfilment of functionalities. In deriving selection criteria when evaluating solutions and embodiments, however, they used different approaches.

In all four cases, the G-designers analysed and evaluated in the conceptual phase whether the selected function carriers would fulfil their functionalities. In the embodiment design phase, when elaborating the partial and overall embodiments, their attention remained focussed on the function carriers (the parts) and their functionalities. As a result, the selection criteria were mainly derived from the discussion on function carriers and fulfilment of their functionalities.

In three (I2, I3 & I4) of the four I-cases the I-designers also analysed and evaluated the fulfilment of functionalities, but not at the level of function carriers (parts). Their attention was focussed on processes which the function carriers are intended to realise, and they analysed and evaluated functionalities with the help of use situations involving the function carriers. While considering the use situations, the user was included in the functionality check. As a result, the selection criteria were mainly derived from the discussion on use situations.

A comparison of the G- and I-cases also shows that the main type of selection criteria used in one cultural group is also found to be present in the other, but then only in a few instances. For instance, in all G-cases a few selection criteria were derived based on the discussion on use situations. Similarly, in the three I-cases, a few selection criteria were also derived from the discussion based on function carriers and their functionalities in the partial and overall embodiments.

In four (C1, C2, C3 & C4) of the six C-cases the C-designers took a different approach when trying to achieve fulfilment of functionalities. Their discussion was mainly focussed on the user interface of the device. As a result the selection criteria were mainly derived from these discussions.

In all four G-cases and in the mentioned three I-cases, user interface played a role only in a few instances in the evaluation.

In the fourth I-case and remaining two C-cases the collected data does not show a clear tendency in deriving selection criteria.

A comparison of the investigated design processes shows that the G-designers predominantly focused on the attributes of function carriers. Their attention lay on function carriers (i.e. objects) that they were attending to at that particular moment. The selection criteria derived were linked to the objects. On the other hand, in three of the four I-cases and in four of the six C-cases, the attributes of use of the function carriers or use of the device dominated. The attention of the I- and C-designers lay not only on function carriers and the device (i.e. objects), but largely on use situations and the user interface (i.e. the field or environment in which the object is located). For them the relationship of the object to its environment seems as important as the object itself. The selection criteria derived were linked to the relationships of the objects to their environment.

Discussion

A difference is found between the design cases based on the focus of attention when deriving the selection criteria during the evaluation of solutions and embodiments. The G-designers focussed mainly on objects, whereas the I- and C-designers focussed mainly on relationships between objects and the environment. In doing so the designers from different cultural groups acted as expected based on the suggestions made in the literature on culture (see Section 2.4.2). The cultural characteristic 'objects versus relationships' was found to have the expected influence in all three cultural groups.

The limitation of the findings in this section lies in the fact that the said cultural characteristic is not found to have an observable influence in all I- and C-cases.

4.5 Formal versus intuitive reasoning – Evaluating solutions and embodiments

According to the literature, cultural preferences exist in reasoning (see Section 2.4.4). People in Western cultures prefer formal reasoning, which is rule-based and emphasises logical inference. People in East Asian cultures prefer intuitive reasoning, which is similarity-based and makes use of experience. The different lines of reasoning might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers reason differently when they evaluate solutions and embodiments. It is expected that the reasoning is either formal or intuitive, i.e. the G- and I-designers make more use of rules and logic, and the C-designers make more use of association and experience. The question is whether differences can be observed in the design cases in terms of the kind of reasoning involved in evaluating solutions and embodiments and whether the differences have a link to the mentioned cultural characteristic.

The cultural emphases of the I-designers with respect to this cultural characteristic should be noticed. As described in Section 2.5, due to the holistic orientation the I-designers are assumed as having East Asian cultural emphases for the three cultural characteristics described in Sections 4.2, 4.3 and 4.4. However, in the case of the cultural characteristic 'formal versus intuitive reasoning' the I-designers are assumed as having Western cultural emphases due to the use of logic. This means that, if the application of logic is observed in the I-cases, this would indicate that the reasoning is formal and the findings are in line with what is expected based on the literature on culture.

Method of data analysis

The analysis is based on the first coding of design activities (see Section 3.2.2). All design activities which pertain to solution finding, embodiment generation and evaluation are used in the analysis.

Findings

In the design cases, only reasoning by applying logic, i.e. formal reasoning is observed when evaluating solutions or embodiments, and only in few instances – three instances in two G-cases (G2 & G4) and three instances in one I-case (I3). The designers were not observed using similarity detection (i.e. tracking an association based on an already noticed similarity) or making use of experience (i.e. drawing an association from experience) when they evaluated solutions and embodiments, i.e. intuitive reasoning was not observed.

In all six instances, in which formal reasoning is observed, the reasoning followed the same line (see below), i.e. no difference was observed between the G- and I-designers. The application of logic was marked by the appearance of an argument used beside a selection criterion to underline what speaks in favour of the selected solution or embodiment.

Typical for the appearance of reasoning using logic, and the difference to other evaluations observed in the design processes, was a chain of design activities, which is shown in Figure 8. After a solution was found or an embodiment was generated, it was evaluated. However, it was not merely evaluated against a selection criterion and selected, but augmented with an argument, before it was finally accepted. The argument appeared after an evaluation based on the selection criterion was made and reinforced the choice for the solution or embodiment.

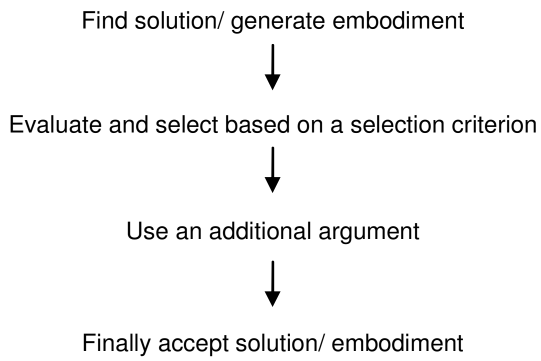


Figure 8: Appearance of formal reasoning using logic

Discussion

A comparison of the investigated design processes shows only formal reasoning, and only in few instances when evaluating solutions or embodiments. These six instances involved the application of logic and were found in two G- and one I-cases. This is in line with the suggestions made in literature (see Section 2.4.4). The small number of cases in which formal reasoning is observed and the absence of observing intuitive reasoning make it difficult to draw firm conclusions about a possible link of the findings with the cultural characteristic ‘formal versus intuitive reasoning’.

The limitation of the findings in this section lies in the fact that only in a few of the G- and I-cases and only in a few instances formal reasoning is observed. Another limitation is that intuitive reasoning is not observed in the C-cases.

4.6 Dealing with contradictions – Evaluating and improving solutions and embodiments

Cultural differences exist in the way people deal with contradictions (see Section 2.4.5). People in Western cultures tend to resolve a contradiction by deciding which of the two propositions is correct, i.e. they tend to avoid a contradiction. People in East Asian cultures tend to find some truth in both propositions and embrace both, i.e. they tend to accept a contradiction. The difference in dealing with contradictions might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers handle a contradictory situation differently when they evaluate and improve solutions and embodiments. It is expected that the G- and I-designers avoid a contradiction, i.e. they derive a clear picture of the situation before deciding about the next step, and the C-designers accept a contradiction, i.e. they seek a compromise. The question is whether differences can be observed in the design cases in terms of how a contradiction is dealt with when evaluating and improving solutions and embodiments and whether the differences have a link to the mentioned cultural characteristic.

Again, the cultural emphases of the I-designers with respect to this cultural characteristic should be noticed. As described in Sections 2.5 and 4.5, the I-designers are assumed as having Western cultural emphases, where the use of logic is involved. The application of logic is expected to lead to an approach of avoiding contradictions rather than accepting contradictions and formulation of a compromise, because, as mentioned in Section 2.4.5, contradictory propositions do not go well with logical thinking. This suggests that for the cultural characteristic 'dealing with contradictions' the I-designers avoid contradiction, and hence are assumed as having Western cultural emphases. If avoidance of contradiction is observed in the I-cases, this would indicate that the findings are in line with what is expected based on the literature on culture.

Method of data analysis

The analysis is based on the first coding of design activities (see Section 3.2.2). All design activities which pertain to evaluation and improvement of solution and embodiment are used in the analysis.

Findings

In most improvement activities, a solution or an embodiment was evaluated against a single criterion, or, if more than one criterion were used, these did not cause a contradictory situation.

A contradictory situation is observed to be handled only for improving solutions for functions; in improving embodiments no such situation is observed. A contradictory situation arose only in a few instances of improving solutions – in three instances in two G-cases (G2 & G3) and in one instance in one I-case (I3). In all four instances such a situation arose and was handled according to the same line (see below), i.e. no difference was observed between the G- and I-designers.

This paragraph describes and Figure 9 shows, how a contradictory situation arose and how it was handled in the four instances. A solution for a function was evaluated against a first criterion and an improvement to the solution was proposed. The proposed, improved solution was evaluated against a second criterion. However, an improvement with respect to the first criterion meant a deterioration of the solution with respect to the second criterion. The evaluations of the solution did not present a clear picture for solution improvement and a contradictory situation arose. When facing such a contradiction, the designers did not decide which of the two evaluations they should prefer. Since they did not resolve the contradiction by choosing one of the two propositions, an avoidance of contradiction is not observed. Further, the designers tried to find a compromise considering both evaluations. They improved the solution again, but with a limited functionality by adding a new boundary condition. Since they embraced both propositions, this indicates the acceptance of contradiction.

Evaluate a solution against a first criterion

↓

Propose an improvement to the solution

↓

Evaluate the proposed, improved solution against a second criterion

↓

Contradiction

↓

No evaluation preferred → no avoidance of contradiction

↓

Find a compromise → acceptance of contradiction

Figure 9: Approach taken in handling (accepting) a contradiction

No instance of avoiding a contradiction was observed. In none of the C-cases dealing with a contradiction was observed.

Discussion

The approach observed in dealing with contradictions in the four instances involving the G- and I-designers is not in line with what was expected based on the literature on culture (see Section 2.4.5). The G- and I-designers did not avoid a contradiction, but accepted a contradiction, as expected in East Asian cultures. A link of the findings in this section with the cultural characteristic 'dealing with contradictions' is not identifiable.

The limitation of the findings in this section lies in the fact that dealing with contradictions is observed only in a few of the G- and I-cases and only in a few instances. Another limitation is that dealing with contradictions is not observed in the C-cases.

4.7 Monochronic versus polychronic – Working on functions

People in different cultures experience and manage time differently (see Section 2.2). In many Western cultures people are likely to be monochromic, i.e. pay attention to and do one thing at a time. In Asian cultures people are likely to be polychronic, i.e. are involved with many things at the same time. Perceiving time differently might have an influence on the design process of designers with different cultural backgrounds.

The assumption is that the G-, I- and C-designers have a different order in which various design activities for functions are performed. It is expected that the order is monochronic in nature for the G-designers, and polychronic in nature for the I- and C-designers. The question is whether the above differences can be observed in the design cases when working on functions and whether the differences have a link to the mentioned cultural characteristic.

Method of data analysis

In addition to the first coding of the transcribed processes (based on design activities), a second coding of the segments was undertaken based on the function the designers are addressing in a design activity (see Section 3.2.2). A timeline diagram based on both codings shows which design activities are performed, in which order, for each function. The diagrams based on both codings are used to identify patterns, which reveal the nature of the design process, in the sense of monochronic or polychronic.

The coding assumes that at any given moment in time, designers will perform a particular design activity for a particular function, which is basically a monochronic activity. To identify monochronic and polychronic order in the design processes, the following definitions are used:

- Monochronic order in performing design activities appears, when after a design activity is performed for a particular function, the designer continues the same design activity for another function, or the designer switches to another design activity for the same function. During a given period of time only one design activity is performed on one function at a time.
- Polychronic order in performing design activities appears, when after a design activity is performed for a particular function, the same design activity for another function or another design activity for the same function is started. Then the designer continues with the initial design activity and function, suggesting that this design activity was only interrupted. This is then followed by a switch over to the second function or to the second design activity, and so on. This going back and forth means that during a given period of time a design activity for more than one function or more than one design activity for a function is virtually performed 'in parallel'.

Findings

Three kinds of pattern were identified for design activities. One each monochronic and polychronic pattern is explained also with the help of a timeline diagram.

1. Monochronic – same design activity performed for different functions, one at a time

This pattern is observed in one instance each in two I-cases – in one case while generating a partial embodiment and in another case while finding solutions in the conceptual design phase.

In one I-case (I2), the designers were in the process of generating a partial embodiment for a function. They consulted briefly the already generated overall embodiment (see

Figure 10) and then continued again working on the partial embodiment for the function. Immediately after generating the partial embodiment for this function, they started generating the partial embodiment for the second function, and after its completion, the same design activity was performed for a third function. While working on the second and third function the respective partial embodiments were also briefly evaluated.

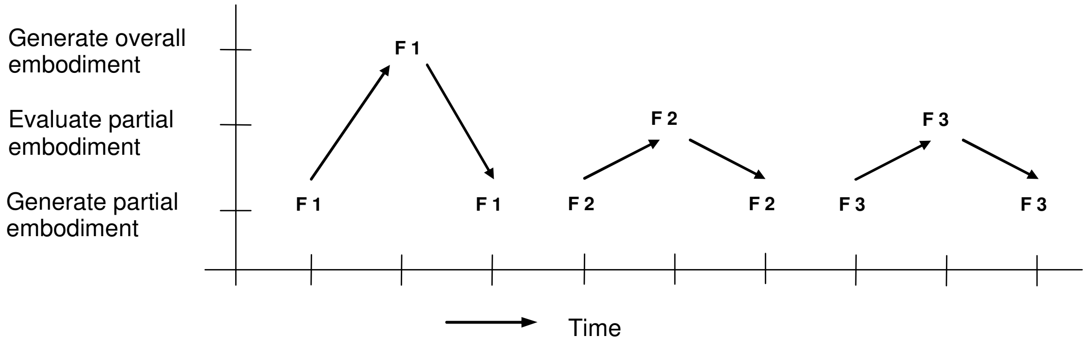


Figure 10: Monochronic approach (F = Function)

Even though the designers briefly switched to another design activity, as shown in Figure 10, their attention remained on the generation of the partial embodiment. The partial embodiments were generated for each function before the designers moved to the next function, i.e. during a given period of time one design activity was performed on one function at a time. This shows a monochronic approach. The total period in which this monochronic approach was observed for the three functions is around seven minutes.

The monochronic approach is clearer in the other I-case (I3). The designers started finding solutions for a function. Subsequently, the same design activity was performed for a second function and thereafter for a third function. During a given period of time only one design activity (finding solutions for functions) was performed on one function at a time. Figure 11 shows this approach with the help of a timeline diagram.

It should be noted that both design activities, 'Find solutions for functions' (5.3) and 'Find other solutions for functions' (5.4), were coded separately. However, during the analysis, both activities are seen as having the same nature, hence considered together as one design activity (i.e. finding solutions for functions).

The diagram shows for the I-case (I3) which design activities were performed, in which order, for different functions. The three periods, denoted as 1, 2 and 3 in the diagram, show when the designers found solutions for the three functions. The y-axis, the time-axis, shows that this design activity was performed one after another for the three functions, and during each of the three periods only one design activity (finding solutions for functions) was performed at a time. For example, in period 1, 5.3.2 and 5.4.2 denote that the design activities with the code 5.3 (Find solutions for functions) and with the code 5.4 (Find other solutions for functions) were performed for the function with the code 2 (Mix ingredients) (see Section 3.2.2 and Appendix B). The total period in which this monochronic approach was observed for the three functions is around 17 minutes.

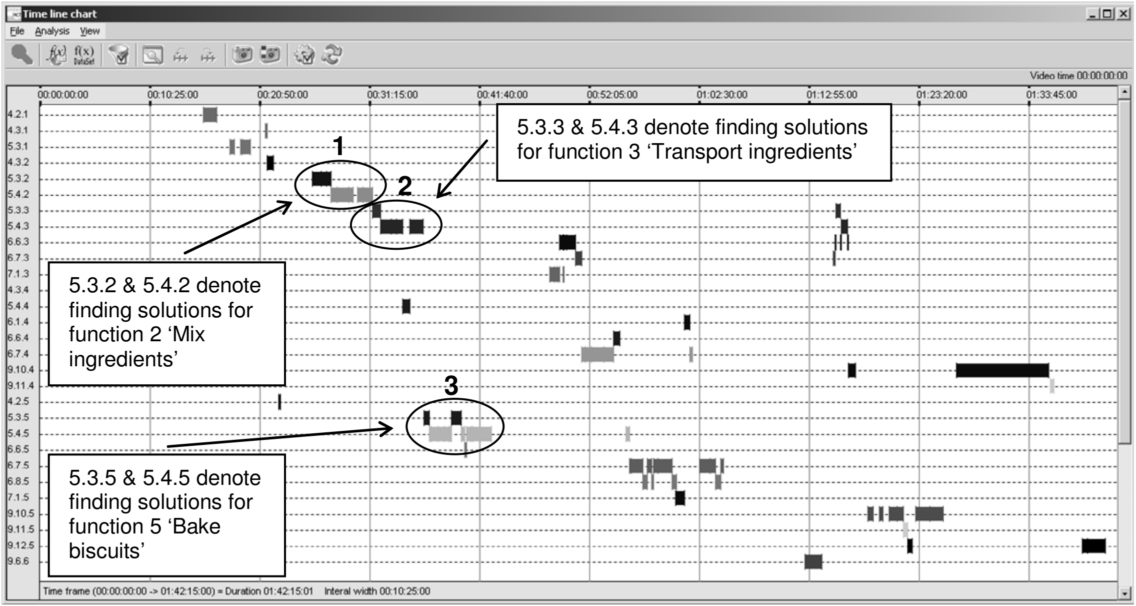


Figure 11: Monochronic approach

Figure 12 is a schematic representation of the monochronic approach described above.

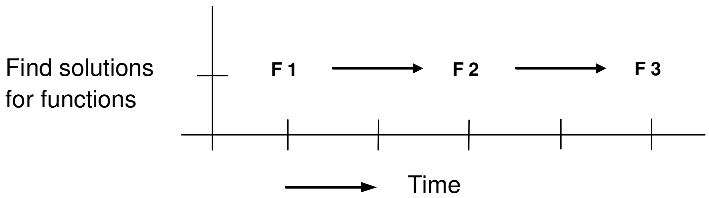


Figure 12: Monochronic approach (F = Function)

2. Polychronic – same design activity performed virtually in parallel for two functions

This pattern is observed in one instance each in one I- and one G-case (I2 & G2) while finding solutions for functions. In both cases, the designers started finding a solution for a function, switched over to a second function and started finding a solution for this function. They came back to the first function, continued finding a solution and then switched over again to the second function to continue finding a solution. The jumps back and forth between the two functions followed in quick succession and were repeated several times, before the designers moved to the next function or next design activity. Figure 13 shows this approach.

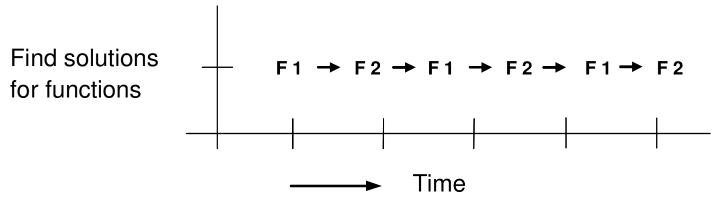


Figure 13: Polychronic approach (F = Function)

The designers started, interrupted and continued performing the same design activity during a given period of time, virtually in parallel for two functions; hence the approach is identified as polychronic. The period in which this polychronic approach was observed is around five minutes in each of the cases.

3. Polychronic – many design activities performed virtually in parallel for the same function

This pattern is observed in three instances in two G-cases (G1 & G3), when the designers found, evaluated and improved solutions for a function. This pattern appears in G1-case for one function (i.e. one instance) and in G3-case for two functions (i.e. two instances – first for the first function and then for the second function).

In both cases, the designers started finding a solution for a function. One or more solutions were generated. After a negative evaluation of a solution, either the solution was improved, or a new solution was found, or another already found solution was taken. Another round or more followed with the same design activities. During this period the designers sometimes completed a design activity (in particular evaluating solutions) before moving to another design activity. However, on other occasions a design activity was interrupted and the designers moved to another design activity, and then went back to the first one. In one of the three instances, an additional design activity, generating partial embodiment, was performed. While working on this function sometimes another function was included in the discussion, when the designers tried to obtain a complete picture of the solution on which they were working. However, they remained focussed on the first function and continued working on it.

Summing up, the designers switched back and forth between the design activities performed for a function. During a given period of time, many design activities were performed virtually in parallel for the same function, hence the approach is identified as polychronic.

Figure 14 shows this polychronic approach for the G3-case with the help of a timeline diagram, first for the first function and then for the second function. The diagram shows which design activities were performed, in which order, for different functions. The segments F1 – F5 denote that the y-axis displays the performed design activities arranged according to the functions, i.e. first for the function with the code 1, then for the function with the code 2, and so on.

The two periods, denoted as 1 and 2 in the diagram, show that many design activities were performed in aforementioned polychronic order for the function with the code 2 (Mix ingredients) in the period 1 and for the function with the code 5 (Bake biscuits) in the period 2 (see Section 3.2.2 and Appendix B). The periods in which this polychronic approach was observed are around 20 minutes for one function in the G1-case, and around 21 minutes and 19 minutes for the two functions in the G3-case.

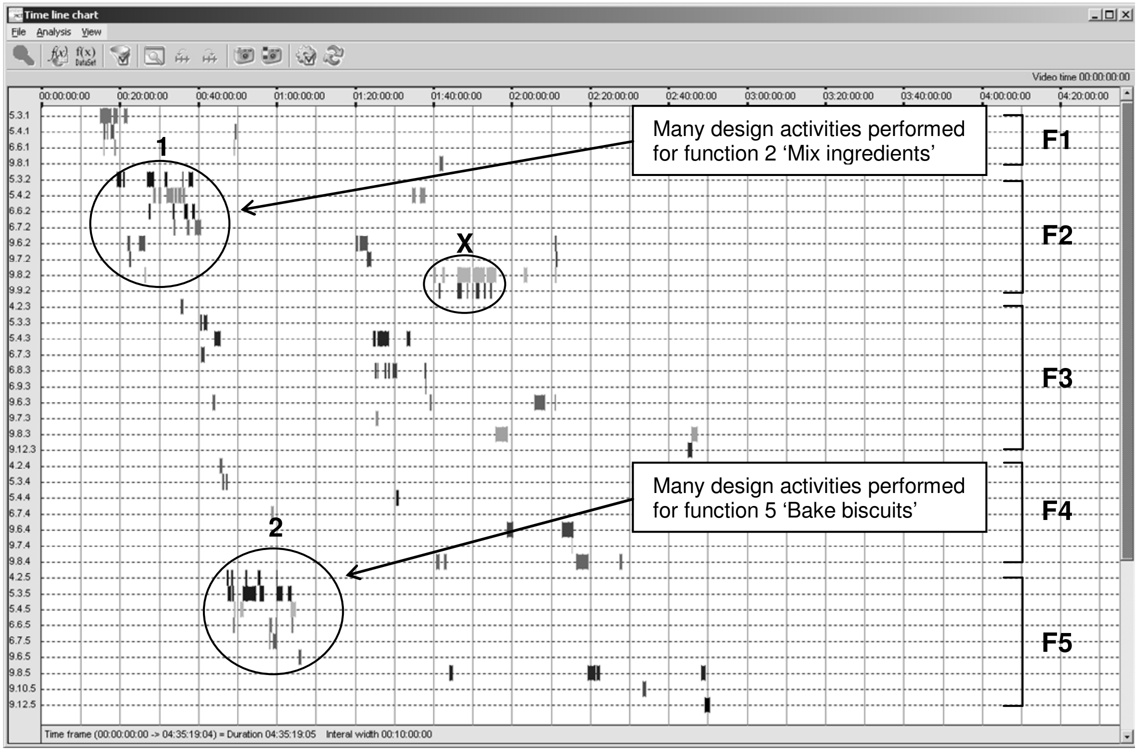


Figure 14: Polychronic approach

Figure 15 is a schematic representation of the polychronic approach described above.

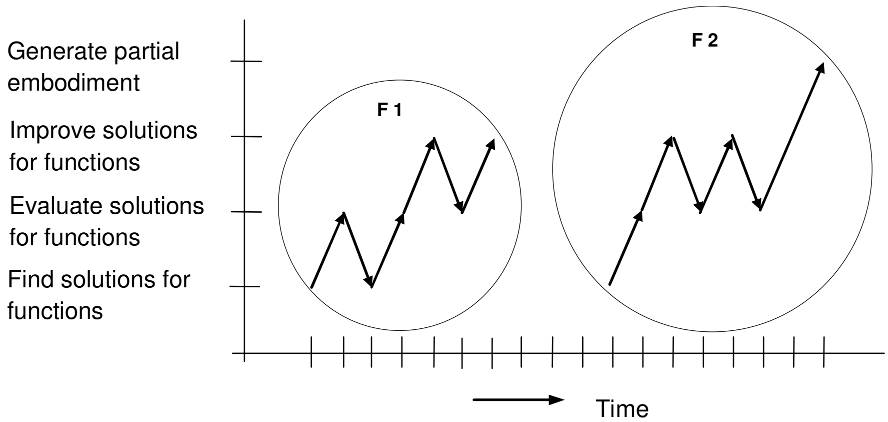


Figure 15: Polychronic approach (F = Function)

Discussion

The analysis of the design processes shows the presence of monochronic and polychronic approaches, however only in five cases: in two instances in two I-cases (I2 & I3) it is monochronic, and in five instances in one I- and three G-cases (I2, G1, G2 & G3) it is polychronic. The polychronic approach (Figures 14 & 15) observed in the G1- and G3-cases matches with the 'function-oriented approach' observed by Fricke and Günther in their study with designers from Germany (see Section 2.7.1).

As Figures 11 and 14 show, in the periods in which a monochronic or polychronic pattern is observed, the design activities appear as a 'bunch' for one or many functions. In rest of the design process time the design activities performed for one or many functions are distributed across the timeline diagram, so that a pattern is not identifiable. The same is also true for the remaining nine (out of 14) cases in which no monochronic or polychronic patterns were identified.

The findings in the aforementioned five cases are not in line with what was expected based on the definitions given earlier in this section. In the G-cases not monochronic but polychronic approaches appeared, and in the I-cases not only polychronic but also monochronic approaches appeared. Hence, a link of the findings to the definitions given in this section and to the cultural characteristic 'monochronic versus polychronic' (see Section 2.2) is not identifiable. An alternative explanation is sought for what may have caused the monochronic and polychronic approaches to appear.

To answer this question all seven instances (in five cases) in which the monochronic and polychronic approaches appeared are compared. One common observation made in all these instances is the flow of ideas in the periods when the monochronic or polychronic approaches appeared. It seems that in these periods the designers could hardly stem the flow of ideas, and wanted to work out as many details as possible for one or many functions and complete one or more design activities. The designers were very intensively engaged in performing design activities one after another for one or many functions with hardly any interruption in these periods. For instance, Figure 11 shows that after solutions were found for the three functions one after another, hardly any time was invested in this design activity at a later stage in the design process. Similarly, Figure 14 shows that after many design activities were performed one after another for each of the two functions in the respective periods, these functions were rarely consulted at a later stage in the design process, for instance when generating overall embodiment. Both examples show that in the mentioned periods the designers could make progress in problem-solving and could complete the design activities on which they were working. The flow of ideas in these periods presumably led the monochronic and polychronic approaches to appear. All seven periods mentioned in this section, in which the designers were intensively engaged in performing design activities, appeared in early phases of a design process.

There are other periods, in which design activities appear also as a 'bunch', such as the period denoted as 'X' in Figure 14. However, a look at the video recordings, the transcriptions and the paper sheets on which the designers developed their solutions shows that in such periods the designers got stuck while working on a design activity and kept working over it. Hence, these periods are different than those seven described in the paragraph above, in which the designers could make progress in problem-solving. Hence these periods, such as the one denoted as 'X' in Figure 14, are not classified as monochronic or polychronic.

4.8 Discussion

The findings in Sections 4.2 – 4.7 present a mixed picture. The influence of the cultural characteristics on design approaches across investigated design cases and the cultural groups is found to vary and to be not always in line with the expectations. Table 3 summarises the findings.

Table 3: Findings on the cultural characteristics

Cultural Characteristic and its influence	**Design activities for which observed**	**Cases in which observed**	**Findings related to these cases**
Addressing situational influences; observed to have at least some influence; as expected only in I-cases (Section 4.2)	Analysing problem and requirements	I2, I3, I4	The designers addressed situational influences in predicting user needs.
Analytic versus holistic; observed to have at least some influence; as expected in some I- and C-cases/ small differences between cultural groups (Section 4.3)	Finding solutions for functions	G1, G3	The designers worked not only analytically, but also holistically, i.e. did not treat all functions separately.
		I1, I2	Holistic way of working is more pronounced, i.e. design activities are covered which lie more apart than those covered in the G-cases.
		C1, C2	Holistic way of working is more pronounced, i.e. design activities are covered which lie more apart than those covered in the G-cases.

Objects versus relationships; observed influence is clear; as expected in the G-, I- and C-cases/ clear differences between cultural groups (Section 4.4)	Deriving selection criteria	G1, G2, G3, G4	Attention mainly on objects (function carriers and fulfilment of their functionalities).
		I2, I3, I4	Attention mainly on relationships (use situations involving the function carriers).
		C1, C2, C3, C4	Attention mainly on relationships (user interface of the device).
Formal versus intuitive reasoning; influence not clear; observed as expected in a few G- and I-cases/ no difference between cultural groups (Section 4.5)	Evaluating solutions and embodiments	G2, G4	Formal reasoning (use of logic) appeared, i.e. an argument subsequent to an evaluation underlined the choice for a solution or an embodiment.
		I3	Formal reasoning (use of logic) appeared, i.e. an argument subsequent to an evaluation underlined the choice for a solution or an embodiment.
Dealing with contradictions; Influence not clear; observed other than as expected in a few G- and I-cases/ no difference between cultural groups (Section 4.6)	Evaluating and improving solutions and embodiments	G2, G3	Contradiction was not avoided, but accepted, i.e. the contradiction was not resolved by preferring one of the two evaluations, but a compromise was sought considering both evaluations.
		I3	Contradiction was not avoided, but accepted, i.e. the contradiction was not resolved by preferring one of the two evaluations, but a compromise was sought considering both evaluations.
Monochronic versus polychronic; influence not clear; observed other than as expected in some G- and I-cases (Section 4.7)	Various design activities while working on functions	G1, G2, G3	Polychronic approach appeared in two kinds of pattern, i.e. finding solutions performed virtually in parallel for two functions and many design activities performed virtually in parallel for the same function.
		I2, I3	Monochronic, i.e. same design activity performed for different functions, one at a time, and polychronic approaches, i.e. finding solutions performed virtually in parallel for two functions, appeared.

The influence of the cultural characteristic ‘object versus relationships’ is observed as expected and is clear. The cultural characteristic ‘analytic versus holistic’ is observed to have at least some influence, as expected, but only in some of the G-, I- and C-cases. Also the cultural characteristic ‘addressing situational influences’ is observed to have at least some influence, as expected, but only in the I-cases. The influence of the cultural characteristic 'formal versus intuitive reasoning' is observed as expected, but only in a few of the G- and I-cases and is not clear. The influence of the cultural characteristic 'dealing with contradictions' is observed other than as expected and is not clear. Also the influence of the cultural characteristic 'monochronic versus polychronic' is observed other than as expected and is not clear.

The individual cultural characteristics are found to exert influence, however, not always as expected. The following section deals with the combination of findings on individual cultural characteristics.

4.9 Combining findings based on individual cultural characteristics

The analysis of the observed design processes and the presentation of findings (Sections 4.2 – 4.7) focused on one cultural characteristic at a time. Section 2.4 described how each individual cultural characteristic can be seen as fitting into the framework of analysis and holism. For instance, people with an analytic orientation are inclined to focus on objects, hence they are likely to take notice of properties of the objects, which again makes it likely that they apply rules in reasoning. Similarly, people with a holistic orientation tend to attend the entire field, hence they are likely to take notice of situational influences and address these.

It can therefore be assumed that an analytic or a holistic orientation accompanies the designers throughout their design process, like a thread. Tracking such a thread could give a broad picture of how the analytic or holistic orientation has influenced the design process as a whole. Furthermore, if there is an overall orientation (i.e. analytic or holistic) in a design case, then it would be reflected in the findings related to the different cultural characteristics for this case. If the combination of findings is consistently analytic or holistic in nature, this would support the indication that the observations are likely to have been caused by the cultural characteristics.

The question in this section is, whether the findings on individual cultural characteristics in a design case fit together, i.e. are consistently of analytic or holistic nature.

Overall holistic orientation in three I-cases

In three of the four I-cases (I2, I3 & I4) the designers were observed addressing situational influences when analysing problem and requirements (see Section 4.2). In performing both design activities, the designers addressed user needs. In doing so, they took reference to interactions between the device and the user (i.e. the use situations). That the designers took notice of situational influences and paid attention to the field (i.e. the use situations) indicates a holistic orientation (see Section 2.4.3). The designers moved to deriving selection criteria after they had found solutions or generated embodiments. In deriving selection criteria, the use of the function carriers played a role and the selection criteria were mainly derived from a discussion of this aspect (see Section 4.4). This indicates again that during this design activity the designers continued paying attention to the field, emphasising a holistic orientation (see Section 2.4.2). The analysis shows that the overall holistic orientation accompanied the I-designers (in three of the four cases) and is reflected in the findings related to the two different cultural characteristics – ‘addressing situational influences’ and ‘objects versus relationships’. An example describes the presence of this overall holistic orientation. In one of the I-cases the designers identified that one of the requirements for easy use of the device is a comfortable interaction between a user and the device. At a later stage of the design process, when the designers evaluated solutions for the function ‘store ingredients’, they continued to pay attention to the field. The designers selected a solution that was expected to be less complicated in use.

Overall analytic orientation in one G-case

In one of the four G-cases (G2) reasoning by applying logic, i.e. formal reasoning, was observed when evaluating a solution (see Section 4.5). The designers used an argument beside a selection criterion to underline the choice for the solution. This indicates an analytic orientation (see Section 2.4.4). After finding a solution the designers generated and evaluated the embodiment for this solution. In deriving selection criteria to evaluate the embodiment, they took reference to the argument used earlier, and their discussion was focussed on the function carrier (the part) which they had developed and on its functionality (see Section 4.4). In doing so, the designers paid attention to the object, indicating again an analytic orientation (see Section 2.4.2). The analysis shows that the overall analytic orientation accompanied the G-designers (in one of the four cases) and is reflected in the findings related to the two different cultural characteristics – ‘formal versus intuitive reasoning’ and ‘objects versus relationships’.

Discussion

The findings on individual characteristics are found to be consistently holistic in three I-cases and consistently analytic in only one G-case. Further, in these cases the overall holistic or analytic orientation accompanied the designers only for two cultural characteristics each. No overall analytic or holistic orientation was observed in other cases. An analytic or a holistic orientation as described in cultural studies can thus only partially be observed in the investigated design processes.

Man of the world.
Peter Green

5 Findings – Nature of the design processes

This chapter continues focussing on the second research question, i.e. how the design processes of designers from different cultures differ, and addresses aspect 7 of Table 1, i.e. tendencies for the cultural groups pertaining to the nature of the design processes (see Section 2.9).

In Section 5.1 the findings on the nature of the observed design processes are presented. Section 5.2 addresses knowledge of systematic design among the participants of the empirical study. In Section 5.3 the findings of both previous sections are drawn together to analyse how the knowledge of systematic design could have affected the nature of the design processes. In Section 5.4 the findings from Chapters 4 and 5 are compared to derive their relation.

5.1 Analysis of the nature of the design processes

The questions addressed in this section are:

- Which design activities are performed and what are their durations (Section 5.1.1)?
- What is the order in which design activities are performed in the design processes (Section 5.1.2)?
- Which are the differences or similarities between the design cases and are there any tendencies to be observed for the cultural groups (Sections 5.1.1 & 5.1.2)?

5.1.1 Analysis based on durations of design activities

What are the durations of the performed design activities and are there observable tendencies for the cultural groups? This section presents findings on these questions.

Method of data analysis

Table 4 summarises the durations of the performed design activities (in % of the total design process duration) for the 14 design processes (four cases each with G- & I- and six cases with C-designers). The design activities and their relative durations are entered in rows, and the design cases are entered in columns. The output reports on durations of performed design activities are generated using the 'Interact' software of Mangold (see Section 3.2.2). For representation in Table 4 a few design activities are taken together and their durations added. For instance, task clarification contains the duration of two design activities – ‘analyse the task (1.1)’ and ‘analyse the requirements (1.2)’ (see Appendix B). In coding, however, both design activities were coded separately. ‘Other’ summarises a few design activities which are not relevant for the findings presented in this section. The duration chart in Appendix C shows all design activities and their durations as coded.

Table 4: Durations of design activities (%) for each design case

		Total design process duration in minutes													
		G1 230	G2 162	G3 275	G4 267	I1 141	I2 151	I3 102	I4 240	C1 184	C2 339	C3 152	C4 205	C5 224	C6 144
		Duration of design activities in % of the total design process duration for each case													
		G1	G2	G3	G4	I1	I2	I3	I4	C1	C2	C3	C4	C5	C6
Design activities	Task clarification 1.1, 2.1	6.2	5.0	5.2	10.3	11.1	13.0	10.8	6.4	9.3	6.2	8.8	18.7	7.9	19.2
	Task division 4.2, 4.3	7.0	2.1	2.0	6.0	3.5	0.4	6.7	10.0	2.1	0.6	5.8	5.0	1.6	3.5
	Solution generation 5.3, 5.4	18.6	14.7	16.3	15.1	9.2	6.0	22.2	15.0	20.7	2.4	2.4	5.0	4.3	7.5
	Criteria selection 6.1	2.6	0.2	0.8	2.6	1.9	0.1	3.2	0.5	1.1	2.4	1.0	2.2	0.6	0
	Solution evaluation 6.6, 6.8	7.4	2.2	2.4	13.9	0.3	1.1	7.4	3.8	2.4	0.7	0.2	0.1	0.2	0.2
	Solution improvement 6.7, 6.9	26.1	0.3	1.5	2.3	0	4.2	10.4	2.2	0	0	0.5	0	0.3	0
	Concept generation 7.1, 7.2	1.4	4.2	1.5	2.2	0.7	0	5.8	14.3	0	0	0.3	0	0	0
	Concept finalisation 8.1	0	0	0	0	0	1.2	0	25.0	0	0	0	0	0	0
	Partial embodiment generation 9.6, 9.8	3.5	37.4	19.8	0.5	11.0	11.4	5.0	0	25.5	20.4	0	18.0	40.2	17.1
	Partial embodiment evaluation 9.7, 9.9	0.5	8.8	1.9	0.4	0.4	1.2	0.7	0	0.7	7.4	0	3.3	4.5	0
	Overall embodiment generation 9.10, 9.12	18.8	17.0	37.5	20.5	45.0	34.4	22.2	10.8	22.0	48.0	21.2	20.2	16.1	42.2
	Overall embodiment evaluation 9.11	1.3	3.5	0.7	2.7	7.8	1.5	4.6	0	2.9	2.0	4.7	2.0	3.3	0.3
	Overall embodiment finalisation 9.13	4.7	4.5	9.2	23.5	8.8	26.0	0	0	13.2	5.0	54.5	25.6	18.7	9.6
	Other	2.2	0.3	1.2	0	0	0	1.1	12.0	0	4.6	0	0	0.3	0.4

Based on the % of time spent, each case is ranked for each design activity from high to low. The ranking is shown in Table 5. For each design activity all 14 cases are compared with respect to the % of time spent and the duration is labelled as: relatively large/ relatively average/ relatively small. Coloured cells highlight the relative scale. Together, the % of time spent and the place on the scale reveal which are the differences or similarities between the design cases and whether for a cultural group a tendency in performing one or many design activities can be recognised.

It should be noted that the ranking of the design activities does not say anything about the quality of the design processes.

Table 5: Ranking of design cases based on durations of design activities

		Ranking of design cases based on duration of design activities (% of time is shown below)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Design activities	Task clarification 1.1, 2.1	C6 19.2	C4 18.7	I2 13.0	I1 11.1	I3 10.8	G4 10.3	C1 9.3	C3 8.8	C5 7.9	I4 6.4	G1 6.2	C2 6.2	G3 5.2	G2 5.0
	Task division 4.2, 4.3	I4 10.0	G1 7.0	I3 6.7	G4 6.0	C3 5.8	C4 5.0	I1 3.5	C6 3.5	C1 2.1	G2 2.1	G3 2.0	C5 1.6	C2 0.6	I2 0.4
	Solution generation 5.3, 5.4	I3 22.2	C1 20.7	G1 18.6	G3 16.3	G4 15.1	I4 15.0	G2 14.7	I1 9.2	C6 7.5	I2 6.0	C4 5.0	C5 4.3	C2 2.4	C3 2.4
	Criteria selection 6.1	I3 3.2	G1 2.6	G4 2.6	C2 2.4	C4 2.2	I1 1.9	C1 1.1	C3 1.0	G3 0.8	C5 0.6	I4 0.5	G2 0.2	I2 0.1	C6 0
	Solution evaluation 6.6, 6.8	G4 13.9	G1 7.4	I3 7.4	I4 3.8	C1 2.4	G3 2.4	G2 2.2	I2 1.1	C2 0.7	I1 0.3	C3 0.2	C5 0.2	C6 0.2	C4 0.1
	Solution improvement 6.7, 6.9	G1 26.1	I3 10.4	I2 4.2	G4 2.3	I4 2.2	G3 1.5	C3 0.5	G2 0.3	C5 0.3	I1 0	C1 0	C2 0	C4 0	C6 0
	Concept generation 7.1, 7.2	I4 14.3	I3 5.8	G2 4.2	G4 2.2	G3 1.5	G1 1.4	I1 0.7	C3 0.3	I2 0	C1 0	C2 0	C4 0	C5 0	C6 0
	Concept finalisation 8.1	I4 25.0	I2 1.2	G1 0	G2 0	G3 0	G4 0	I1 0	I3 0	C1 0	C2 0	C3 0	C4 0	C5 0	C6 0
	Partial embodiment generation 9.6, 9.8	C5 40.2	G2 37.4	C1 25.5	C2 20.4	G3 19.8	C4 18.0	C6 17.1	I2 11.4	I1 11.0	I3 5.0	G1 3.5	G4 0.5	I4 0	C3 0
	Partial embodiment evaluation 9.7, 9.9	G2 8.8	C2 7.4	C5 4.5	C4 3.3	G3 1.9	I2 1.2	C1 0.7	I3 0.7	G1 0.5	I1 0.4	G4 0.4	I4 0	C3 0	C6 0
	Overall embodiment generation 9.10, 9.12	C2 48.0	I1 45.0	C6 42.2	G3 37.5	I2 34.4	I3 22.2	C1 22.0	C3 21.2	G4 20.5	C4 20.2	G1 18.8	G2 17.0	C5 16.1	I4 10.8
	Overall embodiment evaluation 9.11	I1 7.8	C3 4.7	I3 4.6	G2 3.5	C5 3.3	C1 2.9	G4 2.7	C2 2.0	C4 2.0	I2 1.5	G1 1.3	G3 0.7	C6 0.3	I4 0
	Overall embodiment finalisation 9.13	C3 54.5	I2 26.0	C4 25.6	G4 23.5	C5 18.7	C1 13.2	C6 9.6	G3 9.2	I1 8.8	C2 5.0	G1 4.7	G2 4.5	I3 0	I4 0

Findings

Task clarification covers two design activities: analyse the task and analyse the requirements. Task clarification was performed in all design cases. It also included identifying the boundary conditions relevant for the device to be developed. A relatively large amount of time was spent on task clarification in two C-cases. In three I-, one G- and three C-cases a relatively average amount of time was spent. In the remaining one I-, three G- and one C cases the amount of time spent was relatively small.

Task division covers two design activities: Identify functions and combine functions into a structure. In identifying functions the designers started with how a biscuit-making process works from beginning till end. The identified functions thus represented subprocesses of a biscuit-making process. The identified functions were arranged in a structure in two G- and two I-cases (G1, G4, I3 & I4). The amount of time spent was relatively large in one I-case, relatively average in two G-, one I- and two C-cases, and relatively small in two each G- and I- and four C-cases.

Two different starting points of a biscuit-making process were observed – starting from storing the ingredients or starting from shaping of already mixed ingredients. Depending on the starting point, more (for the first starting point) or less (for the second starting point) functions were identified, for which solutions were generated.

In two of the cases (C2 & C4), in which the second starting point was used, the designers were observed starting with generating the overall embodiment early (see Section 5.1.2). It is assumed that this might have lead to the identification of only some of the functions. Starting paying attention to the overall embodiment without having identified all functions might have hindered the designers in considering the biscuit-making process right from the beginning till the end. The contrary is observed in all G- and two I-cases (G1, G2, G3, G4, I3 & I4), and shows that when identifying functions the designers were focussed on this particular design activity. In these cases all functions (as per the coding scheme for functions; see Section 3.2.2) were identified first and the overall embodiment was generated later in the process.

<u>Solution generation</u> involves finding solutions for identified functions in the conceptual phase. A relatively large amount of time was spent in one I- and one C-cases. In all four cases, the G-designers spent a relatively average amount of time on solution generation, a value which matches that of one I-case. In two I- and five C-cases the amount of time spent was relatively small.

In one I- and one C-cases (I2 & C2) the designers found solutions for functions while generating a partial or overall embodiment in parallel. In these cases less time was spent on finding solutions for functions. It is assumed that the parallel working might have limited the designers in finding solutions for functions due to sharing attention and time with two design activities at the same time. Another possible limitation might have been that the constraints in realising an embodiment could have blocked some solutions for the functions. The contrary is observed in two G- and two I-cases (G2, G4, I3 & I4), and shows that when finding solutions for functions the designers worked mainly on this design activity. There were a few switches to other design activities, such as generating a partial embodiment, yet they continued finding solutions for functions and only switched to other design activities after having found some solutions.

In <u>criteria selection</u> the amount of time spent was relatively large in one I-case, relatively average in two G-, one I- and two C-cases, and relatively small or no in two each G- and I- and four C-cases. The generated solutions were <u>evaluated</u> in all cases. A relatively large amount of time was spent in one G-case, and in one G- and one I-cases it was relatively average. In the remaining two G-, three I- and all six C-cases the amount of time spent was relatively small. In <u>solution improvement</u> the amount of time spent was relatively large in one G-case, relatively average in one I-case, and relatively small or no in three each G- and I- and all six C-cases.

In one I-case (I4) a relatively large amount of time was spent on concept generation and concept finalisation. In this case the evaluated solutions for functions were combined to generate an overall solution and a principle solution for the generated concept was sketched. In all other cases the amount of time spent was either relatively average, relatively small, or no.

A mixed picture emerged concerning the partial embodiment generation. A relatively large amount of time was spent in one C- and one G-case, whereas a relatively average amount of time was spent in four C- and one G-cases. In the remaining two G-, all four I- and one C-cases either relatively small amount of time or no time was spent. In partial embodiment evaluation the amount of time spent was relatively large in one G- and one C-cases, relatively average in two C-cases, and relatively small or no in three G-, all four I- and three C-cases.

In overall embodiment generation the amount of time spent was relatively large in two C, two I- and one G-cases, and relatively average in one I-, four C- and three G-cases. In one I-case the amount of time spent on generating overall embodiment was relatively small, however, a relatively large amount of time was spent generating and finalising the concept. In overall embodiment evaluation the amount of time spent was relatively large in one I-case, relatively average in three C-, one I- and two G-cases, and relatively small or no in three C-, two G- and two I-cases.

Overall embodiment finalisation consists re-sketching of already generated overall embodiment and other activities, such as writing a user's manual at the very end of the process. The amount of time spent was relatively large in one C-case, relatively average in one I-, two C- and one G-cases, and relatively small or no in three each C-, G- and I-cases.

Next, G-, I- and C-cases are compared involving a combination of design activities.

In many cases a large percentage of the time was spent on generating embodiment (partial and overall). Hence, a comparison is drawn based on the total time spent on generating embodiment (Table 6). The comparison shows that quite a lot of time was spent – around 57% in two G-, one I- and two C-cases and around 46% in one I- and one C-cases. In one C-case the time spent was even 68%.

Table 6: Total time spent on generating embodiment

	G1	G2	G3	G4	I1	I2	I3	I4	C1	C2	C3	C4	C5	C6
Partial embodiment generation	3.5	37.4	19.8	0.5	11	11.4	5	0	25.5	20.4	0	18	40.2	17.1
Overall embodiment generation	18.8	17	37.5	20.5	45	34.4	22.2	10.8	22	48	21.2	20.2	16.1	42.2
Σ	21.8	54.4	57.3	21	56	45.8	27.2	10.8	47.5	68.4	21.2	38.2	56.3	59.3

A further comparison is drawn involving a combination of design activities. A 'balanced profile' of design activities is observed in the four G- and one I-cases (see Tables 4 & 5); these are G1, G2, G3, G4 and I3. A process with a balanced profile is defined as:

- One in which most of the design activities were performed and
- One in which the amount of time spent on most of the design activities deviated not much from their respective relative average.

In all other cases performed design activities were observed to have an 'unbalanced profile'. An example of an unbalanced profile is one I-case (I4), in which a relatively average amount of time was spent on finding solutions for functions, whereas partial embodiment generation was not performed and a relatively small amount of time was spent on overall embodiment generation. Other examples of unbalanced profiles are two C-cases (C2 & C5), in which quite a lot of time was spent on embodiment generation (partial and overall) and far less on finding solutions for functions.

Discussion

As Table 4 shows, most of the design activities are performed in all design cases. Differences and also similarities are found between the G-, I- and C-cases based on the durations of performed design activities. Only a few tendencies for a cultural group are identified, which are:

- The I-designers were observed to spend a relatively average amount of time on task clarification, the G-designers relatively small.
- The G-designers were observed to spend a relatively average amount of time on finding solutions for functions, the C-designers relatively small.
- The C-designers were observed to spend a relatively average amount of time on partial embodiment generation, the I-designers relatively small.
- The designers from all 3 cultural groups were observed to spend a relatively large or a relatively average amount of time on overall embodiment generation, and quite a lot of time on embodiment generation (partial and overall).

One of the key findings in this section is the balanced profile of design activities, which is observed in all G-cases and in the I3-case.

Other findings in performing design activities are:

- In two of the cases (C2 & C4), in which the designers were observed starting with generating the overall embodiment early, not all functions were identified. The contrary was observed for all four G-cases, and for I3- and I4-cases.
- Finding solutions for functions and working on embodiment generation at the same time resulted in less time spent for the first design activity (observed for I2- and C2-cases). The contrary was observed for G2-, G4-, I3- and I4-cases.

The literature presented in Chapter 2 did not provide any information with which the findings in this section could be compared.

5.1.2 Analysis based on the occurrence of design activities over time

What is the order in which design activities are performed in the design processes and are there observable tendencies for the cultural groups? This section presents findings on these questions.

Method of data analysis

The analysis in this section is based on timeline diagrams, representing the occurrence of performed design activities over time in a design case. The timeline diagrams were generated using the 'Interact' software of Mangold (see Section 3.2.2). Figure 16 shows such a diagram; the diagrams for all design cases are given in Appendix D.

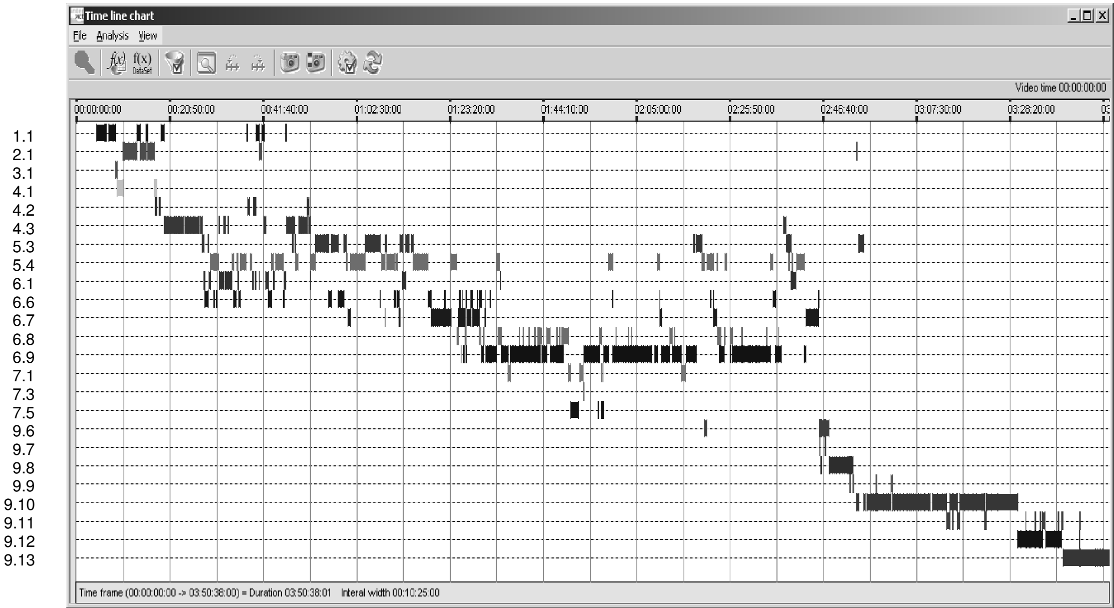


Figure16: Timeline diagram of an observed design process (G1)

To identify tendencies for the time of occurrence of design activities, each design process is divided into 10 segments of 10% of its running time. Each segment is analysed for the design activities and their percentage durations.

Findings

Task clarification (analysing the task and analysing the requirements) was performed in almost all design cases mostly in the first 20% of the running time.

In most of the G- and I-cases, working on task division (identifying functions and combining these into a structure) continued until 30% of the running time. In C-cases the designers started with task division after the first 10% and continued until 30% of the running time.

Solution generation (finding solutions for functions) was performed in three G-cases (G2, G3 & G4) mostly in the first 40% of the running time. There is a slight difference in the I- and C-cases. Solution generation was performed in three I-cases (I1, I2 & I4) mostly between 10-50% and in three C-cases (C1, C2 & C5) mostly between 10-40% of the running time.

The design activity partial embodiment generation presents a mixed picture. In a few G- and C-cases the designers started with this activity from the beginning of the process. Overall, partial embodiment generation occurred during 20-80% of the running time.

Overall embodiment generation was performed in one G-case (G2) from 40% of the running time and in three G-cases (G1, G3 & G4) from 50% of the running time until the end of the design process. The I-designers started working on this design activity in I2-case after 10% and in I1-case after 20% of the running time, and in both cases continued in the second half of the design process. In the other two I-cases the designers worked on this activity in the second half of the design process. In three C-cases (C1, C2 & C4) the designers started with generating the overall embodiment in the first 10% of the running time; the designers in the other three C-cases started shortly after (after 10% or 20% of the running time). In all C-cases the designers came back to this design activity repeatedly throughout the design process.

The tendencies for the cultural groups are illustrated in Figure 17. A tendency is found to exist for a cultural group when in half or more of the design cases in the respective cultural groups a design activity is performed for at least 5% of the time in a particular 10% time segment. For example, in the first two segments (i.e. 0-10% & 10-20%), task clarification was performed in three G-cases and in each of the segments in each case for at least 5% of the time.

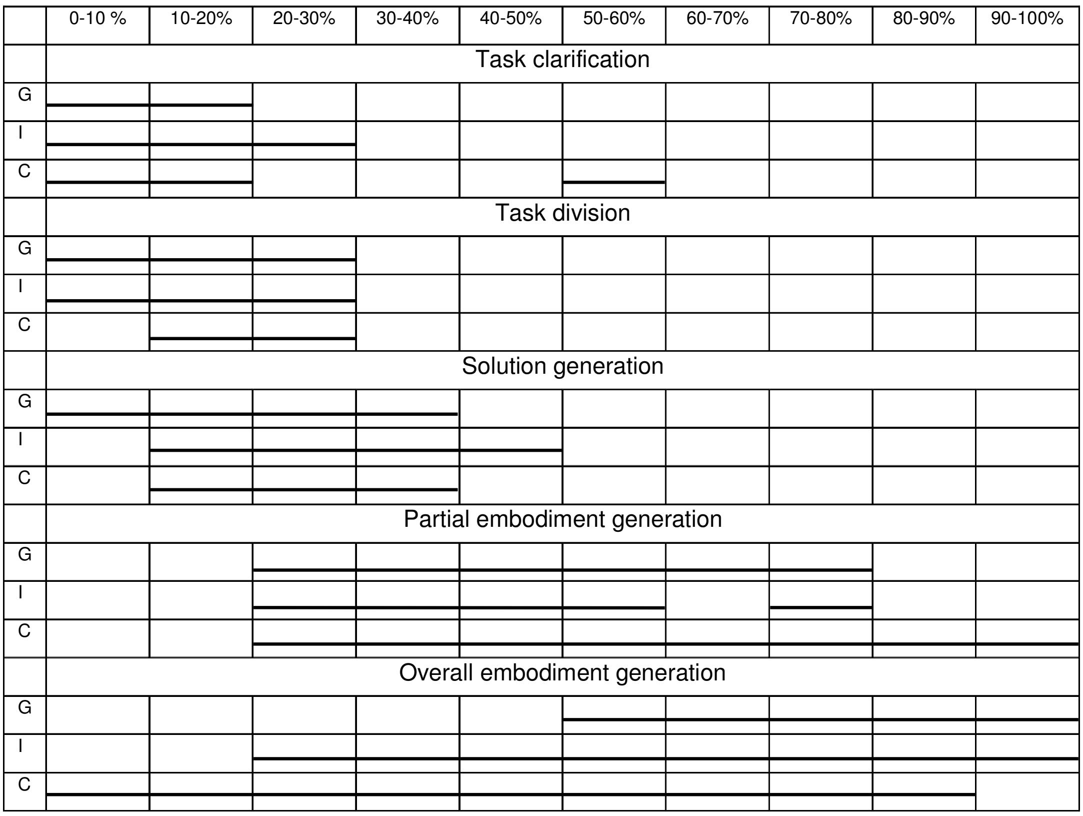


Figure17: Tendencies for the time of occurrence of the design activities

As Figure 17 shows, similarities are found between the G-, I- and C-cases for the time of occurrence of design activities; the only difference found is in the time of occurrence of overall embodiment generation. This design activity was performed in the G-cases in the second half of the design process, whereas in the C-cases also in the first half of the design process. The I-cases shared both tendencies.

Next, based on the 10% segmentation of the design processes, the order of occurrence of many design activities are compared. The comparison shows that the designers in G-, I- and C-cases started working on design activities in different orders; these are:

- ‘Overall embodiment generation’ started *after* ‘task division’: in all G-cases, three I- and three C-cases (I1, I3, I4, C3, C5 & C6)
- ‘Overall embodiment generation’ started *before* ‘task division’: in one I- and three C- cases (I2, C1, C2 & C4)
- ‘Overall embodiment generation’ started *after* ‘solution generation’: in all G-cases, three I- and three C-cases (I1, I3, I4, C2, C5 & C6)
- ‘Overall embodiment generation’ started *before* ‘solution generation’: in one I and three C- -cases (I2, C1, C3 & C4)
- ‘Overall embodiment generation’ started *after* ‘partial embodiment generation’: in: three G-, one I- and one C-cases (G1, G2, G3, I3 & C2)
- ‘Overall embodiment generation’ started *before* ‘partial embodiment generation’: in one G-, two I- and five C-cases (G4, I1, I2, C1, C3, C4, C5 & C6)

Note that the comparison given above does not state that a design activity was finished before work was started on another design activity. It only states that a design activity was started and another design activity was also started working on before the first design activity was finished.

The comparison shows tendencies for the G-, I- and C-cases. The C-designers in three or more (out of six) cases tended to address the overall embodiment details of the device first before they started addressing the individual details of functions. The G-designers in three or more (out of four) cases tended to act the other way round, i.e. they tended to address the individual details of functions first before they started addressing the overall embodiment details of the device. The I-designers tended to act in some cases as the G-designers in did and in some other cases as the C-designers did, i.e. they shared both tendencies. Summing up, the C-designers tended to work ‘from the outside inwards’, the G-designers tended to work ‘from the inside outwards’ and the I-designers shared both tendencies.

Discussion

As Figure 17 shows, similarities are found between the G-, I- and C-cases with regard to when design activities were performed in the design processes. The only difference found is that overall embodiment generation was performed in the G-cases in the second half of the design processes, in the C-cases also in the first half of the design processes, and in the I-cases as per both tendencies.

A comparison involving the order of occurrence of many design activities in each case shows the key difference between the G-, I- and C-cases: the C-designers tended to work 'from the outside inwards', the G-designers tended to work 'from the inside outwards' and the I-designers shared both tendencies.

The literature presented in Chapter 2 did not provide any information with which the findings in this section could be compared.

5.2 Knowledge of systematic design

This section addresses the knowledge of systematic design the designers had acquired during their education and in profession.

Method of data analysis

To collect data the designers were interviewed immediately after they had finalised the design task. The questions were about the study of systematic design while the designers were at the university and about the company-specific standard process which they apply at their work.

Findings

In G1 and G4 cases both designers and in G2, G3, I1 and I3 cases one designer each stated that they had acquired knowledge of systematic design or methods (e.g. brainstorming, morphological matrix or FMEA) while they were at the university. Further, in all cases except G1 (in which designers had teaching experience in systematic design), the designers stated that during their work they follow a systematic process while designing; they apply a company-specific standard process, which establishes the steps to be followed for product development. The duration of professional experience was as following:

- Less than five years: both designers in I1-, C2- and C3-cases; one designer each in I2-, I3-, I4-, C1-, C4- and C5-cases
- More than five years: both designers in G2-, G3-, G4- and C6-cases; one designer each in I2-, I3-, I4-, C1-, C4- and C5-cases

Note that for further analysis (see Table 7) it is not differentiated whether one or both designers in G2, G3, G4, I1 and I3 cases had acquired knowledge of systematic design through education and profession.

5.3 Knowledge of systematic design and balanced profile of design activities

This section analyses how the knowledge of systematic design could have affected the appearance of a balanced profile for the performed design activities (see Section 5.1.1).

In four (G2, G3, G4 & I3) out of five cases, in which a balanced profile was observed, the designers had acquired the knowledge of systematic design in education and profession. These are also the cases in which both designers (except I3, in which only one designer) had more than five years of professional experience. A possible explanation for this match is that from their knowledge and sufficient professional experience in systematic design the designers knew which design activities are to be performed in design process, and could divide their time well balanced for all design activities. The contrary is observed in the C2- and C3-cases, in which performed design activities had an unbalanced profile, and the designers had acquired the knowledge of systematic design only in profession and had less than five years of professional experience. An unbalanced profile is also observed in the I1-case, in which the designers had acquired the knowledge of systematic design in education and profession, but had less than five years of professional experience.

In the remaining six cases (I2, I4, C1, C4, C5 & C6) an unbalanced profile was observed, and the designers had acquired the knowledge of systematic design only in their profession. These are also the cases (except C6) in which one designer had more than five years of and another designer had less than five years of professional experience; in C6-case both designers had more than five years of professional experience. A possible explanation for the absence of a balanced profile in these cases is, also considering the findings of the paragraph above, the effect of insufficient professional experience and the knowledge of systematic design acquired only in profession and not in education.

Summing up, the knowledge of systematic design acquired both in education and in profession is found to be important for the appearance of a balanced profile, provided there is sufficient professional experience.

5.4 Relation of the findings

This section addresses how the findings on influences of the cultural characteristics (Chapter 4) can be related to the findings on the nature of the design processes presented in this chapter.

Table 7 gives an overview of which cultural characteristics are observed to influence which design cases (see Table 3, Section 4.8) and which process characteristics and personal characteristics are observed for which design cases (see Section 5.3). For the cultural characteristics following symbols are used: '+' in a coloured cell denotes influence of the characteristic as expected from the literature study; '+' in a cell denotes influence of the characteristic against expectations; '?' in a cell denotes that based on the findings no statement is possible on the influence of the characteristic; an empty cell denotes that no influence of the characteristic is observed. For the process characteristics and personal characteristics '+' in a cell denote the findings on the characteristic, and an empty cell denotes that there are no findings on the characteristic.

Table 7: Cultural, process and personal characteristics

	Cultural characteristics	G1	G2	G3	G4	I1	I2	I3	I4	C1	C2	C3	C4	C5	C6
1a	Addressing situational influences when analysing problem and requirements						+	+	+						
1b	Not addressing situational influences when analysing problem and requirements														
2a	Treating functions analytically when finding solutions	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2b	Treating functions holistically when finding solutions	+		+		+	+			+	+				
3a	Paying attention to objects when deriving selection criteria	+	+	+	+										
3b	Paying attention to relationships when deriving selection criteria						+	+	+	+	+	+	+		
4a	Giving formal reasoning when evaluating solutions		+		+			+							
4b	Giving intuitive reasoning when evaluating solutions														
5a	Avoiding a contradiction in dealing with selection criteria when improving solutions and embodiments		?	?				?							
5b	Accepting a contradiction in dealing with selection criteria when improving solutions and embodiments		?	?				?							
6a	Working on functions in a Monochronic way						+	+							
6b	Working on functions in a polychronic way	+	+	+			+								
	Process characteristics														
7a	Balanced profile of design activities	+	+	+	+			+							
7b	Unbalanced profile of design activities					+	+		+	+	+	+	+	+	+
	Personal characteristics														
8a	Knowledge of systematic design in education and profession		+	+	+	+		+							
8b	Knowledge of systematic design only in profession						+		+	+	+	+	+	+	+
9a	Sufficient professional experience (both designers > five years)		+	+	+										+
9b	Mixed professional experience (one designer > five years and one designer < five years)						+	+	+	+			+	+	
9c	Insufficient professional experience (both designers < five years)					+					+	+			

Table 7 shows that the cultural characteristics have influenced the design cases as expected from the literature study in all three cultural groups. Based on the number of cases in which the influences are observed and on the number of cultural characteristics which have exerted influence, no tendency could be found for a cultural group.

Table 7 also shows that the cultural characteristics influenced the designers' approaches irrespective of knowledge of systematic design and duration of professional experience. The analysis suggests that the influence of the cultural characteristics can be seen as a part of the designers' approaches which accompanied them.

Inside out, outside in
perpetual change.
Yes

6 Summary, contribution and discussion

The concluding chapter summarises the research presented in this thesis. The contribution of the research is discussed. A look is taken back at the empirical study and at the applied research approach, and forward to the future direction.

6.1 Summary

In the research presented in this thesis, influences of the cultural characteristics on design approaches are investigated using an empirical study. The participants of the study were designers drawn from industrial practice in Germany, India and China. The objective of the research is to support designers with different cultural backgrounds who are working together in design processes.

The introductory Chapter 1 presented the motivation behind the research, objective, research questions, scope of the research and the applied research approach. Chapter 2 addressed the first research question: which cultural characteristics could influence the approaches used by designers in designing? The state of the art was determined and the theoretical base for the research was established. Literature on culture, design and some related fields was reviewed. The literature revealed that whereas other fields have investigated the influence of culture, such an influence is not investigated for designers' approaches. How certain cultural characteristics are expected to influence design approaches was derived on the basis of the literature.

The theoretically determined characteristics were subjected to investigation. Details of the empirical study, which was conducted in Germany, India and China, were presented in Chapter 3. Data was collected with the help of video recordings of simultaneous verbalisation and interviews. 14 design processes (cases) of a total duration of 47 hours were captured – four each in Germany and India and six in China. In each case a team of two designers solved a given design problem in a laboratory setting. Also given in this chapter were the details on how the collected data was analysed.

Chapters 4 and 5 addressed the second research question: How do the design processes of designers from different cultures differ? The findings of the empirical study present a mixed picture. The influence of the cultural characteristics on design approaches across the investigated design cases and cultural groups was found to vary and to be not always in line with the expectations based on the literature.

The influence of the cultural characteristic ‘objects versus relationships’ was clear and observed in all three cultural groups as expected. When deriving selection criteria to evaluate solutions and embodiments, the designers in all four G-cases focussed their attention mainly on objects (i.e. on function carriers and fulfilment of their functionalities), whereas the designers in three I- and four C-cases focussed their attention mainly on relationships (i.e. the I-designers on use situations involving the function carriers and the C-designers on user interface of the device). No influence was observed in the rest of the cases.

The influence of further three cultural characteristics was observed as expected, but not for each cultural group and only for some of the cases within a cultural group. The cultural characteristic ‘addressing situational influences’ was observed to have at least some influence on the designers’ approaches when analysing problem and requirements. The designers in three I-cases, when compared to the G-designers, addressed situational influences in predicting user needs; no influence was observed in the C-cases. The cultural characteristic ‘analytic versus holistic’ was observed to have at least some influence on the designers’ approaches when finding solutions for functions. The holistic way of working was more pronounced in the two I- and two C-cases than in the two G-cases, i.e. design activities were covered in the I- and C-cases which lay more apart than those covered in the G-cases; no influence was observed in the rest of the cases. The influence of the cultural characteristic ‘formal versus intuitive reasoning’ on the designers’ approaches, when evaluating solutions or embodiments, was not clear because only formal reasoning was observed. The designers in two G- and one I-cases used an argument subsequent to an evaluation to underline the choice for a solution or an embodiment; no influence was observed in the C-cases.

The influence of the two cultural characteristics was observed to deviate from that what was expected and was not clear. The cultural characteristic ‘dealing with contradictions’ was observed to influence the designers’ approaches when evaluating and improving solutions in two G- and one I-cases. However, the designers did not resolve a contradiction by preferring one of the two evaluations (i.e. did not avoid a contradiction, as expected), but sought a compromise considering both evaluations (i.e. accepted the contradiction, as not expected); no influence was observed in the C-cases. The cultural characteristic ‘monochronic versus polychronic’ was observed to influence the designers’ approaches when working on functions in three G- and two I-cases. However, in the G-cases finding solutions was performed virtually in parallel for two functions, and many design activities were performed virtually in parallel for the same function (i.e. polychronic approaches appeared, as not expected). Further, in the I-cases finding solutions was performed virtually in parallel for two functions, and same design activity was performed for different functions, for one function at a time, (i.e. not only polychronic approaches, as expected, but also monochronic approaches, as not expected, appeared); no influence was observed in the C-cases.

Differences or similarities between the G-, I- and C-cases, and tendencies for the cultural groups were also investigated based on the nature of the design processes. A comparison based on the durations of performed design activities (in % of the total design process duration) showed that the designers from all 3 cultural groups spent quite a lot of time on embodiment generation (partial and overall). A balanced profile of the performed design activities was observed in all four G- and one I-cases. A comparison of the order in which design activities were performed showed different tendencies for the cultural groups: the C-designers tended to work ‘from the outside inwards’, the G-designers tended to work ‘from the inside outwards’, and the I-designers shared both tendencies.

The knowledge of systematic design acquired both in education and in profession was found to influence the design processes, i.e. a balanced profile for the performed design activities could be observed, provided there is sufficient professional experience. The findings also suggested that the influence of the cultural characteristics can be seen as a part of the designers’ approaches which accompanied them.

6.2 Findings rearranged according to the cultural groups

Table 8 sums up the findings presented in Chapters 4 and 5 rearranged according to G-, I- and C-cultural groups.

Table 8: Findings rearranged according to the cultural groups

	Cases	**Findings**
G-cases (n=4)	G1, G2, G3, G4	The designers had their attention mainly focussed on objects, i.e. on function carriers and fulfilment of their functionalities, when deriving selection criteria to evaluate solutions and embodiments (Section 4.4).
	G1, G2, G3, G4	The performed design activities had a balanced profile (Section 5.1.1).
	G1, G2, G3, G4	Overall embodiment generation was performed in the second half of the design process (Section 5.1.2).
	G1, G2, G3, G4	The designers tended to address the individual details of functions first before they started addressing the overall embodiment details of the device, i.e. they tended to work ‘from the inside outwards’ (Section 5.1.2).

	G1, G2, G3	Two kinds of polychronic approach pattern appeared when working on functions: finding solutions performed virtually in parallel for two functions and many design activities performed virtually in parallel for the same function (Section 4.7).
	G2, G3, G4	The knowledge of systematic design acquired in education and profession, and also sufficient professional experience were found to be important for the appearance of a balanced profile for the performed design activities (Section 5.3).
	G1, G3	The designers worked not only analytically, but also holistically, i.e. did not treat all functions separately when finding solutions (Section 4.3).
	G2, G4	Formal reasoning appeared when evaluating solutions or embodiments, i.e. the designers used an argument subsequent to an evaluation to underline the choice for a solution or an embodiment (Section 4.5).
	G2, G3	The designers did not avoid a contradiction, but accepted when improving solutions, i.e. the contradiction was not resolved by preferring one of the two evaluations, but a compromise was sought considering both evaluations (Section 4.6).
	G2, G3	The designers spent quite a lot of time on embodiment generation (partial and overall) (Section 5.1.1).
I-cases (n=4)	I1, I2, I3, I4	Overall embodiment generation was performed in some cases in the first and second half of the design process (as the designers in C-cases did), and in some other cases in the second half of the design process (as the designers in G-cases did) (Section 5.1.2).
	I1, I2, I3, I4	The designers tended to act (addressing the individual details of functions and addressing the overall embodiment details of the device) in some cases as the designers in G-cases did and in some other cases as the designers in C-cases did, i.e. they shared both tendencies (Section 5.1.2).
	I2, I3, I4	The designers addressed situational influences in predicting user needs when analysing problem and requirements (Section 4.2).
	I2, I3, I4	The designers had their attention mainly focussed on relationships, i.e. on use situations involving the function carriers, when deriving selection criteria to evaluate solutions and embodiments (Section 4.4).
	I1, I2	Holistic way of working was more pronounced when finding solutions for functions, i.e. design activities were covered which lay more apart than those covered in the G-cases (Section 4.3).

	I2, I3	Monochronic (i.e. same design activity performed for different functions, one at a time) and polychronic (i.e. finding solutions performed virtually in parallel for two functions) approach patterns appeared when working on functions (Section 4.7).
	I1, I2	The designers spent quite a lot of time on embodiment generation (partial and overall) (Section 5.1.1).
	I3	Formal reasoning appeared when evaluating solutions or embodiments, i.e. the designers used an argument subsequent to an evaluation to underline the choice for a solution or an embodiment (Section 4.5).
	I3	The designers did not avoid a contradiction, but accepted when improving solutions, i.e. the contradiction was not resolved by preferring one of the two evaluations, but a compromise was sought considering both evaluations (Section 4.6).
	I3	The performed design activities had a balanced profile (Section 5.1.1).
	I3	The knowledge of systematic design acquired in education and profession, and also sufficient professional experience were found to be important for the appearance of a balanced profile for the performed design activities (Section 5.3).
C-cases (n=6)	C1, C2, C3, C4, C5, C6	Overall embodiment generation was performed in the first and second half of the design process (Section 5.1.2).
	C1, C2, C3, C4, C5, C6	The designers tended to address the overall embodiment details of the device first before they started addressing the individual details of functions, i.e. they tended to work 'from the outside inwards' (Section 5.1.2).
	C1, C2, C3, C4	The designers had their attention mainly focussed on relationships, i.e. on user interface of the device, when deriving selection criteria to evaluate solutions and embodiments (Section 4.4).
	C1, C2, C5, C6	The designers spent quite a lot of time on embodiment generation (partial and overall) (Section 5.1.1).
	C1, C2	Holistic way of working was more pronounced when finding solutions for functions, i.e. design activities were covered which lay more apart than those covered in the G-cases (Section 4.3).
G-, I- & C-cases	The cultural characteristics influenced the designers' approaches irrespective of knowledge of systematic design and duration of professional experience. The analysis suggested that the influence of the cultural characteristics can be seen as a part of the designers' approaches which accompanied them (Section 5.4).	

6.3 Contribution of the research

Overall contribution of the research

Past research has shown that various kinds of influence, such as designers' experience or individual approaches, affect the design approaches. The findings of this research augment the existing picture by showing how cultural characteristics could influence design approaches.

Overall, the research provides an understanding of why and how designers with different cultural backgrounds may think and act differently in designing. Understanding approaches of designers from other cultures can also help understanding approaches of designers from one's own culture.

Contribution for design practice – Initial suggestions for design in multi-cultural teams

The findings of the empirical study described in Chapters 4 and 5 have revealed influence of the cultural characteristics on design approaches and differences in the courses of the G-, I- and C-design processes. The objective of the research is to support designers with different cultural backgrounds, who are working together in design processes.

<u>First</u>, the findings themselves can provide support by providing insights into how the design processes were actually performed by the designers from Germany, India and China. The insights, thus, can contribute to improved cooperation between designers. This knowledge could suggest project managers, for which design activities a difference and what kind of a difference might be expected between the designers working in multi-cultural teams. Project managers should be aware of following possible misunderstandings these differences can lead to, when designers are working together in multi-cultural teams:

- When working together in a design process, designers from India are likely to spend more time on task clarification than designers from Germany (see Section 5.1.1).
- When working together in a design process, designers from Germany are likely to spend more time on solution generation than designers from China (see Section 5.1.1).
- When working together in a design process, designers from China are likely to spend more time on partial embodiment generation than designers from India (see Section 5.1.1).
- When working together in a design process, designers from Germany and China are likely to work on overall embodiment generation at different point of time in the design process, i.e. either in the second half (designers from Germany) or not only in the second but also in the first half (designers from China) (see Section 5.1.2).

However, the findings have also shown that the designers from different cultural groups are likely to perform a design activity in the same manner, i.e. similarities are observed between the cultural groups. Based on the similarities following possible matches are suggested to work together in multi-cultural teams:

– When working together in a design process and finding solutions, designers from all three cultural groups, from Germany, India and China, are likely to treat functions separately and also together (see Section 4.3).
– When working together in a design process on functions, designers from both cultural groups, from Germany and India, are likely to perform the same design activity 'virtually in parallel' for more than one function (see Section 4.7).
– When working together in a design process with designers from Germany or China, designers from India are likely to work on overall embodiment generation either in the second half (as designers from Germany are likely to do) or not only in the second but also in the first half (as designers from China are likely to do) (see Section 5.1.2).

Second, as mentioned in Section 1.1, a possibility is sought to exploit different cultural backgrounds of designers. Ehrlenspiel advocates for a paradigm shift in product development – from element-oriented to integrated [2009; p. 191, 192]. The element-oriented approach focuses on dissecting the whole into its consisting elements and on deriving their properties based on analysis. The integrated, holistic approach moves the focus onto the entire system and on its environment, and is interdisciplinary. Despite an appeal for a paradigm shift, Ehrlenspiel adds, the analysis is still important.

For the findings of this research it means that the different approaches used by the designers, which are found to reflect their different points of view and different foci of attention out of analytic or holistic stance, could prove useful. The different cultural emphases of designers can be used in combination. A team of designers with different cultural backgrounds can be put together to work in a design project. Multi-cultural teams could be useful for following design activities:

– When analysing problem and requirements during task clarification, designers with different cultural backgrounds would predict user needs differently, by addressing or not addressing situational influences. Additionally addressing situational influences in predicting used needs could help specifying further requirements (see Section 4.2). Such an analysis of requirements could be useful.
– When finding solutions, designers with different cultural backgrounds would treat functions in different ways. When treating functions together, and not only separately, a partial or overall embodiment, which is based on the first few functions, could trigger solutions for further functions (see Section 4.3). Such a broad search for solutions could be useful.
– When evaluating solutions and embodiments, designers with different cultural backgrounds would derive selection criteria by paying attention not only to the

product to be developed (i.e. on fulfilment of functionalities by function carriers) but also on the environment of its use (i.e. on use situations involving the function carriers and on user interfaces) (see Section 4.4). Taking into account different information will offer a broad basis to derive selection criteria and could be useful for evaluating solutions and embodiments.

– When working on functions, designers may find that they are having a flow of ideas and want to work out as many details as possible by attending functions or design activities in different order. In such a case designers with different cultural backgrounds would not only perform the same design activity for different functions (one function at a time) or different design activities for the same function (one design activity at a time), but also the same design activity 'virtually in parallel' for more than one function or more than one design activity 'virtually in parallel' for the same function (see Section 4.7). Such a working on functions could be useful.

6.4 Limitations of the study

As discussed in Chapter 4, the set-up of the empirical study, such as verbalisation and exchanging thoughts, did not seem to have constrained the designers in solving their task. This section discusses other potential limitations of the study.

The number of 14 recorded cases (i.e. design processes) can be considered a limitation of the study. The data collection method (simultaneous verbalisation of two participants per case) was chosen because the resolution of the data was considered necessary to observe the cultural characteristics. However, this rich data (of several hours of verbalisation) requires a large effort for data analysis. The number of cases, which were investigated, was therefore limited. Also the laboratory situation in which the design processes were performed can be considered a limitation of the study. The designers were not allowed to consult any external source of information and had to develop the solution in one stretch within a few hours. In their usual working situation they do not have this limitation.

The selection of the cultural characteristics that were expected to influence design activities, and the assumption on which cultural characteristic will have an effect on which design activity can be considered as a limitation (see Section 2.9). Some cultural characteristics, which were found in the literature, were not expected to influence design activities within the context of this research, and hence were not included, though they might actually affect design processes. An example of such a characteristic is 'power distance' (see Section 2.1.1). After identifying the cultural characteristics that were expected to influence design activities, these were compared with characteristics of design approaches, in order to derive which cultural characteristic could have a strong effect on which design activity. Again, this is based on assumptions. Furthermore, it is possible that the influence of the cultural characteristics in a design process is different from that in a social situation. The cultural characteristics which are described in Sections 2.1 – 2.4 were studied in a different context than that of a design process.

6.5 Reflection on the research approach

The applied research approach is compared with the definition of analysis and holism to find out whether the research approach is of analytic or holistic nature and what might be the influence of such an association.

The applied research approach (see Section 1.4) is based on DRM (Design Research Methodology) [Blessing, 1994; Blessing & Chakrabarti, 2009]. The three parts of the research approach map onto the first three stages of DRM, and like the stages of DRM, are linked. While working on a part it is borne in mind how the result will flow into the next part. In the first two parts the focus is on analysis, i.e. analysis of literature and analysis of the recorded design processes. In the third part the focus is on synthesis, i.e. the findings of the empirical study are brought together to derive suggestions. Further, in the second part, possible links between the findings are identified.

The definition of analysis and holism as a paradigm is given in Section 2.4. Analytic thinking involves seeing the world as a collection of unconnected objects and focussing on attributes of the objects. Holistic thinking involves seeing the world as a collection of inter-connected objects and focussing on relationships between the objects and the field.

A comparison of the applied research approach with the definition of analysis and holism shows that the research approach contains elements of both types of thinking – analytic and holistic. Dividing the research into parts, which are linked, is an indication of both analytic (dividing) and holistic thinking (linking). The cultural characteristics are investigated separately, which is an indication of analytic thinking. Establishing a link between the findings is an indication of holistic thinking.

In the research approach, an individual investigation of influencing factors is considered necessary before their combined effect can be investigated, and links between the individual findings can be established. The applied research approach and also DRM follow a way that incorporates elements of multiple styles – in this case of analytic and holistic thinking, which is considered enriching for conducting research.

6.6 Future direction

A huge amount of data was analysed to obtain the findings, hence only three countries and only a limited number of cases were covered. Based on the research approach applied in this research, further studies can be carried out within the investigated countries, as well as in other countries of interest for internationally operating companies. A further study can also be carried out involving investigations in practice, thus avoiding the limitations of the laboratory setting. When more data becomes available, guidelines can be developed. In this study culturally influenced design approaches were investigated, but not their strength and limitations determined. When this is investigated in a further study, the findings can be used to develop guidelines. The cultural characteristics were investigated in this study for their influence on design approaches for a particular design activity. The study can be extended to include design activities other than the ones investigated in this study.

Appendix A: Design task

Biscuits are a favourite snack and are made industrially in various shapes and flavours from different ingredients. But in the past, biscuits were baked in small quantities at home. This possibility should be offered again in today's kitchen in a quick, convenient manner.

A device should be developed for baking biscuits which is appropriate for household use. The appliance should be able to accommodate and store necessary ingredients and deliver baked biscuits as output. Further requirements for the appliance are:

- It should not be larger than other comparable household appliances.
- It should be designed for a capacity of 1 kg.
- It should be easy to use.
- The needs of the user to the device and requirements to the finished product, i.e. biscuits, should be considered.
- The appliance should not cost more than other comparable household devices.

Determine the rough embodiment for the device (assembled view with main dimensions). In addition:

- Your solution should clearly show in principle the functionality of the device, i.e. how the entire baking process works from begin to end.
- It should be recognisable from the layout how the main parts are arranged in the embodiment.
- The embodiment details can be shown in a diagram.
- Device specifications, dimensions and materials should be defined only for the cases which are necessary at first.
- Standard parts and electronic components can be shown using symbols.

Please remember to voice your thoughts and discuss these with your colleague and to develop the solution together.

When you are working on a step and keep silent for a while, you will be reminded to voice your thoughts. Here is also a sign to point it out.

Appendix B: Main coding scheme

1.1	Analyse the task	7.3	Evaluate overall solution
2.1	Analyse the requirements	7.4	Improve overall solution
3.1	Formulate the problem	7.5	Generate other overall solutions
4.1	Identify overall function	7.6	Concretise other overall solutions
4.2	Identify functions	7.7	Evaluate other overall solutions
4.3	Combine functions into a structure	7.8	Improve other overall solutions
5.1	Find solution for overall function	8.1	Generate a concept
5.2	Find other solutions for overall function	9.1	Analyse embodiment-determining requirements
5.3	Find solutions for functions	9.2	Generate/ improve embodiment for overall function
5.4	Find other solutions for functions	9.3	Evaluate embodiment for overall function
6.1	Identify selection criteria	9.4	Generate/ improve other embodiments for overall function
6.2	Evaluate solution for overall function	9.5	Evaluate other embodiments for overall function
6.3	Improve solution for overall function	9.6	Generate/ improve embodiment for functions
6.4	Evaluate other solutions for overall function	9.7	Evaluate embodiment for functions
6.5	Improve other solutions for overall function	9.8	Generate/ improve other embodiments for functions
6.6	Evaluate solutions for functions	9.9	Evaluate other embodiments for functions
6.7	Improve solutions for functions	9.10	Generate overall embodiment
6.8	Evaluate other solutions for functions	9.11	Evaluate overall embodiment
6.9	Improve other solutions for functions	9.12	Improve overall embodiment
7.1	Combine solutions for functions into an overall solution	9.13	Finalise overall embodiment
7.2	Concretise overall solution		

Appendix C: Duration chart for observed cases

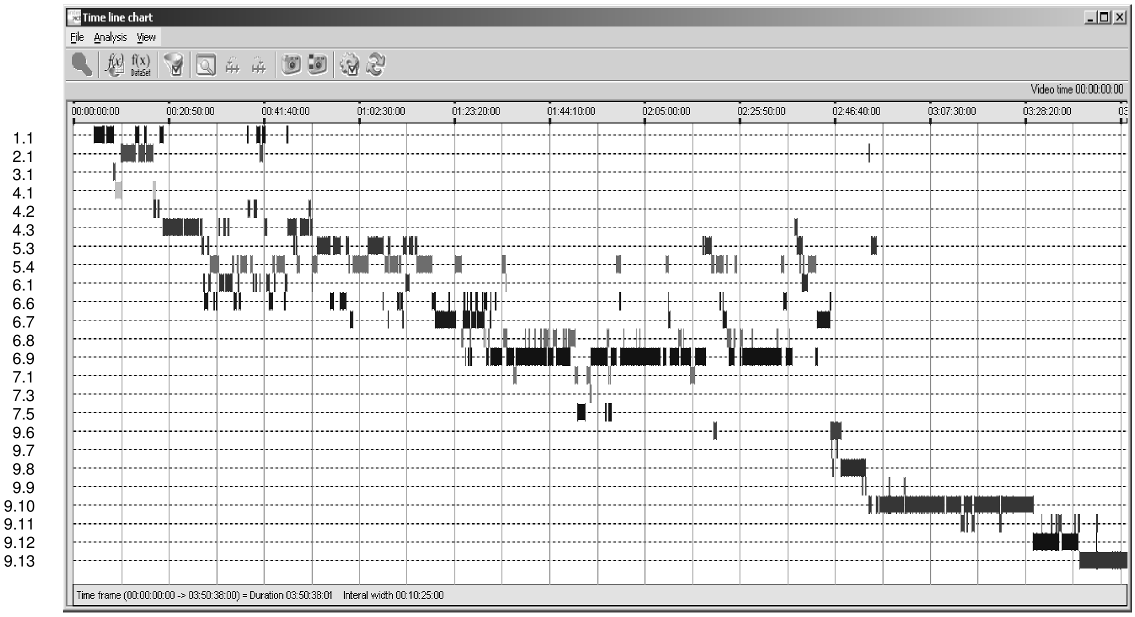
The duration reports on the performed design activities are generated using the ‘Inter-act’ software of Mangold. The first row shows the design cases. The first column shows the codes for the design activities (see Appendix B). The durations of the performed design activities shown in the chart are in % of the design time of the particular design case. Design activities not performed in any design case have been omitted from this chart. A missing value for a design activity in the chart means that it was not performed in the particular design case.

	G1	**G2**	**G3**	**G4**	**I1**	**I2**	**I3**	**I4**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
1.1	3.3	3.9	2.4	2.5	7.4	9.2	6.8	2.9	4.0	5.3	6.3	15.9	5.6	14.4
2.1	2.9	1.1	2.8	7.8	3.7	3.8	4.0	3.5	5.3	0.9	2.5	2.8	2.3	4.8
3.1	0.2													
4.1	0.8	0.1											0.3	0.4
4.2	0.8	1.3	2.0	1.1	3.5	0.4	2.3	3.7	2.1	0.6	2.4	4.8	1.6	3.5
4.3	6.2	0.8		4.9			4.4	6.3			3.4	0.2		
5.3	6.7	7.8	8.7	7.8	8.6	5.6	7.4	9.9	20.6	2.4	2.4	5.0	3.1	7.5
5.4	11.9	6.9	7.6	7.3	0.6	0.4	14.8	5.1	0.1	0.1			1.2	
6.1	2.6	0.2	0.8	2.6	1.9	0.1	3.2	0.5	1.1	2.4	1.0	2.2	0.6	
6.6	4.1	1.3	1.4	13.3	0.3	0.8	4.6	3.8	2.4	0.7	0.2	0.1	0.2	0.2
6.7	5.7		1.4	2.3		2.4	10.4	2.2			0.5		0.3	
6.8	3.3	0.9	1.0	0.6		0.3	2.8							
6.9	20.4	0.3	0.1			1.8								
7.1	1.4	0.4	0.3	2.2	0.7		5.8	11.8			0.3			
7.2		3.8	1.2					2.5						
7.3	0.1	0.2	0.3				1.1	2.7						
7.5	1.1							4.2						
7.7								5.1						
8.1						1.2		25.0						
9.1			0.9							4.6				
9.6	1	14.1	7.5	0.5	8.6	11.4	4.5		17.5	10.1		1.6	14.4	16.0
9.7	0.1	4.6	0.8	0.4	0.4	1.2	0.7		0.4	7.2		0.1	1.4	
9.8	2.5	23.3	12.3		2.4		0.5		8.0	10.3		16.4	25.8	1.1
9.9	0.4	4.2	1.1						0.3	0.2		3.2	3.1	
9.10	14.7	10.9	6.3	5.6	31.0	25.4	18.7	10.8	16.8	25.7	7.9	14	7.6	34.2
9.11	1.3	3.5	0.7	2.7	7.8	1.5	4.6		2.9	2.0	4.7	2.0	3.3	0.3
9.12	4.1	6.1	31.2	14.9	14.0	9.0	3.5		5.2	22.3	13.3	6.2	8.5	8.1
9.13	4.7	4.5	9.2	23.5	8.8	26.0			13.2	5.0	54.5	25.6	18.7	9.6

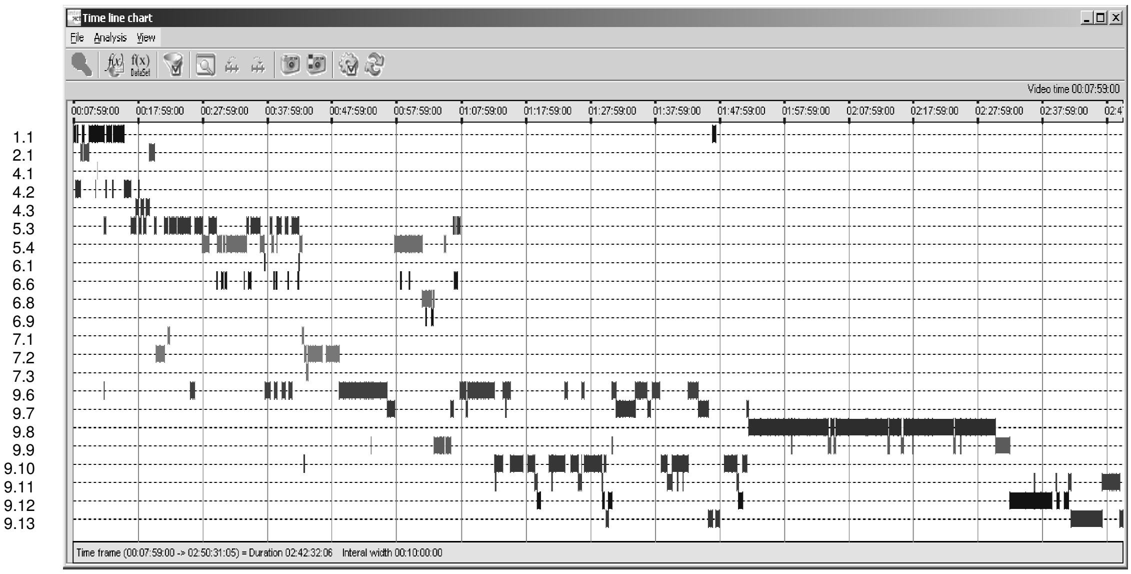
Appendix D: Timeline diagrams for observed cases

The timeline diagrams were generated using the ‘Interact’ software of Mangold. The running time of a recorded design process (case) is displayed along the X-axis, in the following format – hours:minutes:seconds:frames. The performed design activities are displayed along the Y-axis (see Appendix B for the design activity codes). This axis only shows the design activities that were actually performed in a particular case and hence, can differ from diagram to diagram.

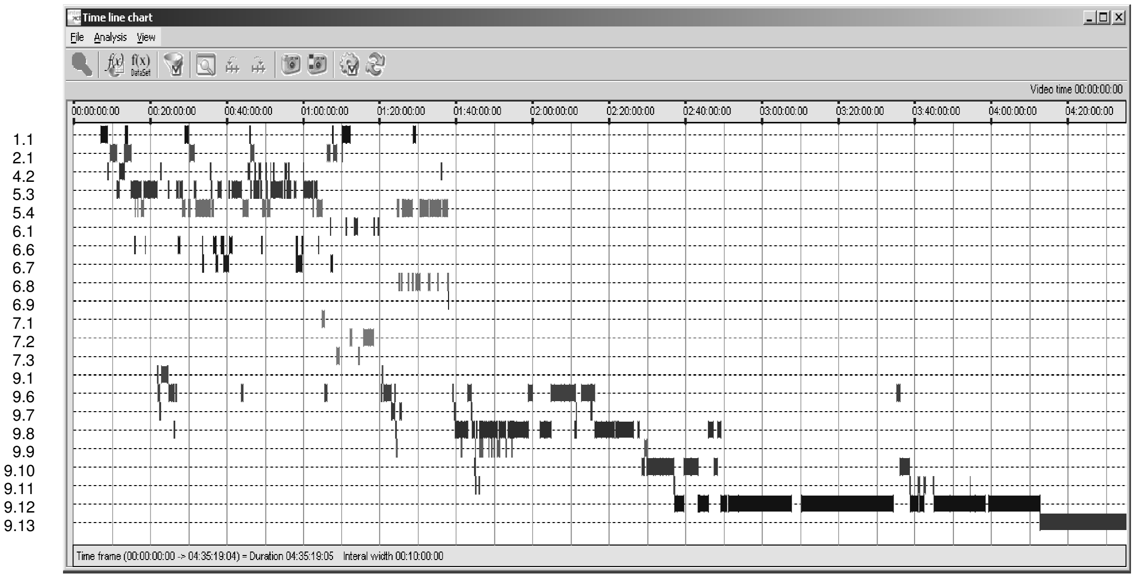
G1



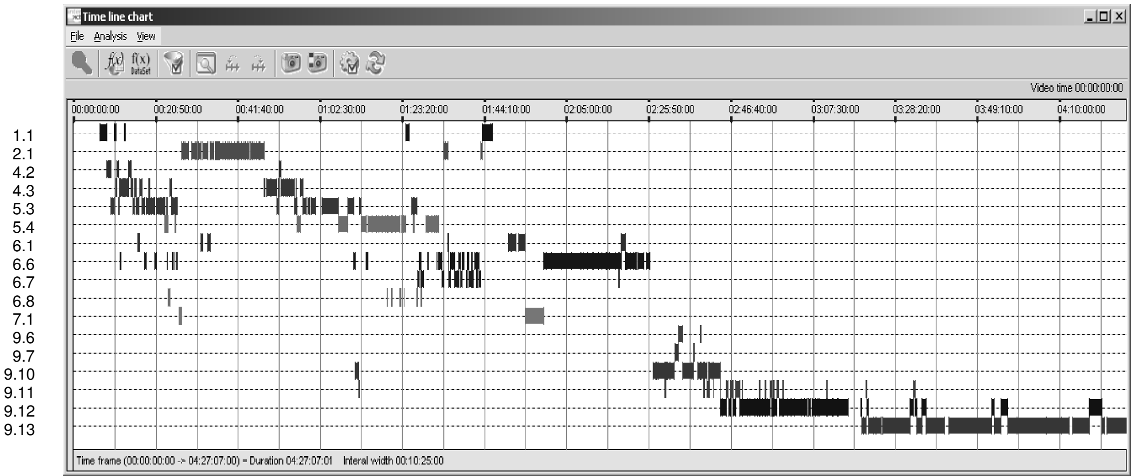
G2



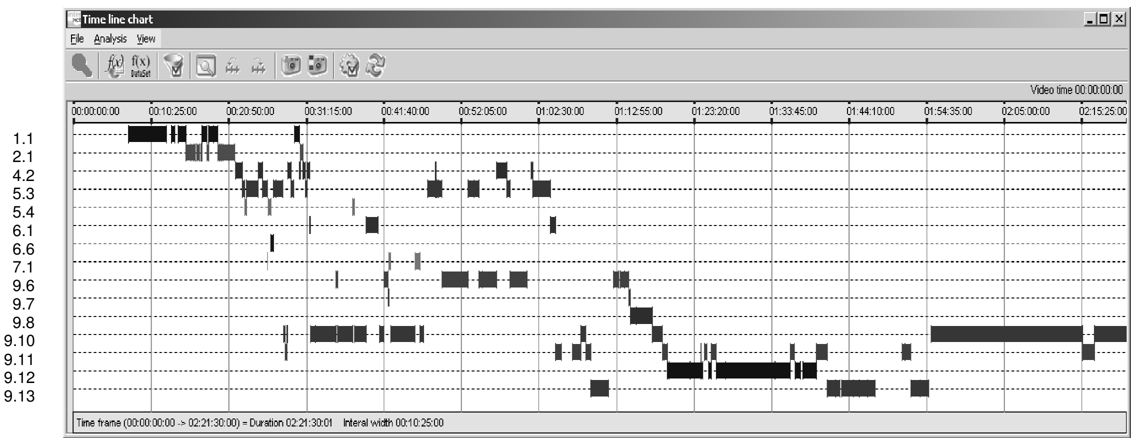
G3


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:20:00:00 00:40:00:00 01:00:00:00 01:20:00:00 01:40:00:00 02:00:00:00 02:20:00:00 02:40:00:00 03:00:00:00 03:20:00:00 03:40:00:00 04:00:00:00 04:20:00:00
1.1
2.1
4.2
5.3
5.4
6.1
6.6
6.7
6.8
6.9
7.1
7.2
7.3
9.1
9.6
9.7
9.8
9.9
9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 04:35:19:04) = Duration 04:35:19:05 Interal width 00:10:00:00

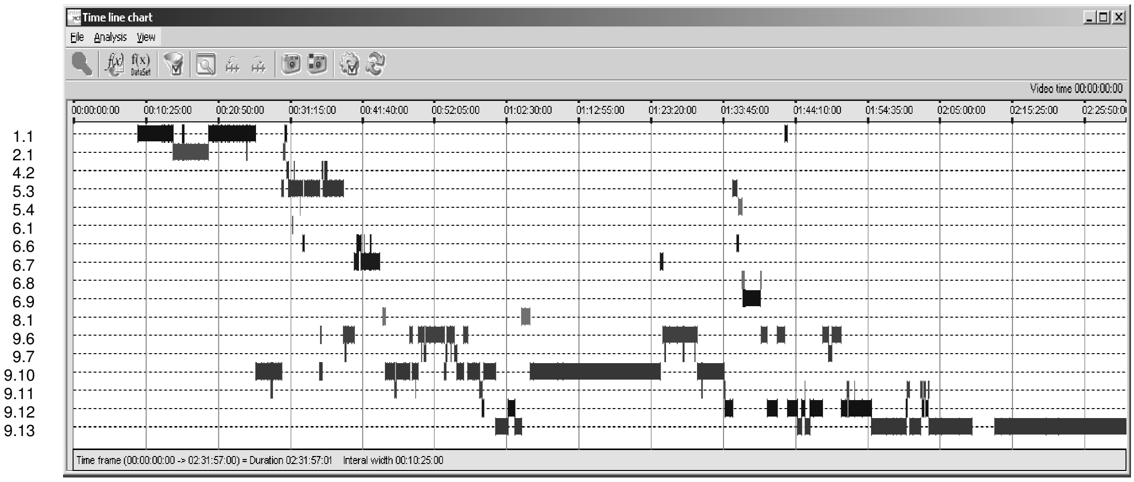
G4


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:20:50:00 00:41:40:00 01:02:30:00 01:23:20:00 01:44:10:00 02:05:00:00 02:25:50:00 02:46:40:00 03:07:30:00 03:28:20:00 03:49:10:00 04:10:00:00
1.1
2.1
4.2
4.3
5.3
5.4
6.1
6.6
6.7
6.8
7.1
9.6
9.7
9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 04:27:07:00) = Duration 04:27:07:01 Interal width 00:10:25:00

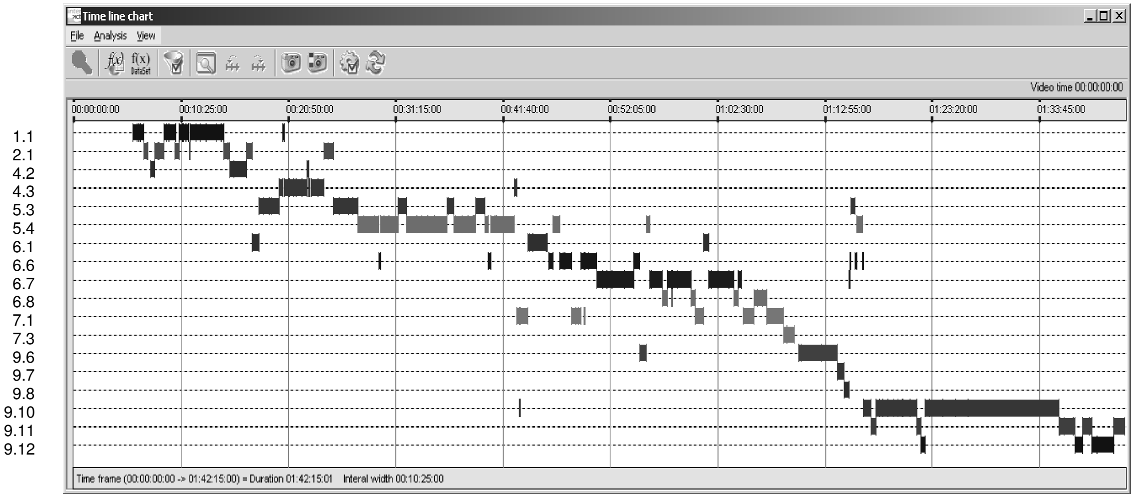
I1


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00 01:44:10:00 01:54:35:00 02:05:00:00 02:15:25:00
1.1
2.1
4.2
5.3
5.4
6.1
6.6
7.1
9.6
9.7
9.8
9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 02:21:30:00) = Duration 02:21:30:01 Interal width 00:10:25:00

I2


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00 01:44:10:00 01:54:35:00 02:05:00:00 02:15:25:00
1.1
2.1
4.2
5.3
5.4
6.1
6.6
6.7
6.8
6.9
8.1
9.6
9.7
9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 02:31:57:00) = Duration 02:31:57:01 Interal width 00:10:25:00

I3


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00
1.1
2.1
4.2
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5.4
6.1
6.6
6.7
6.8
7.1
7.3
9.6
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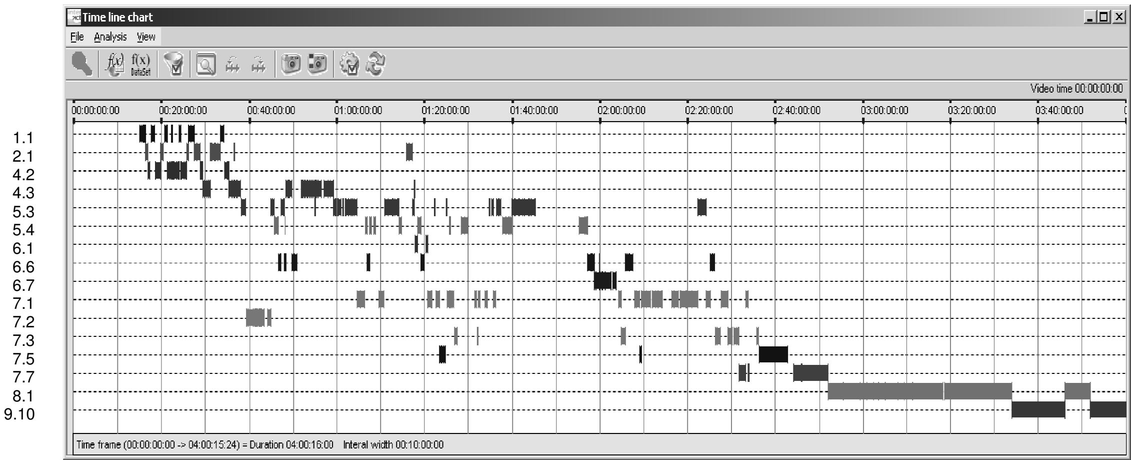
9.10
9.11
9.12
Time frame (00:00:00:00 -> 01:42:15:00) = Duration 01:42:15:01 Interal width 00:10:25:00

I4


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:20:00:00 00:40:00:00 01:00:00:00 01:20:00:00 01:40:00:00 02:00:00:00 02:20:00:00 02:40:00:00 03:00:00:00 03:20:00:00 03:40:00:00
1.1
2.1
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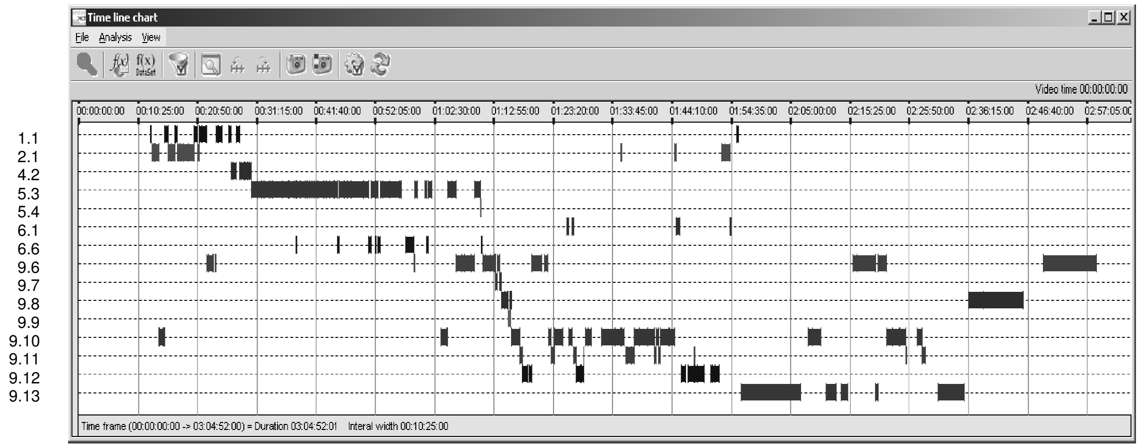
6.1
6.6
6.7
7.1
7.2
7.3
7.5
7.7
8.1
9.10
Time frame (00:00:00:00 -> 04:00:15:24) = Duration 04:00:16:00 Interal width 00:10:00:00

C1


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00 01:44:10:00 01:54:35:00 02:05:00:00 02:15:25:00 02:25:50:00 02:36:15:00 02:46:40:00 02:57:05:00
1.1
2.1
4.2
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5.4
6.1
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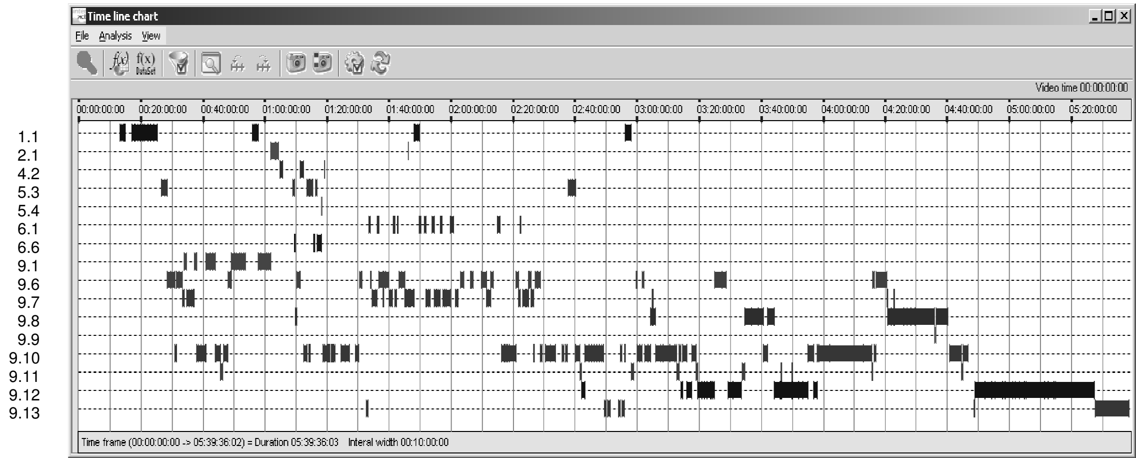
9.9
9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 03:04:52:00) = Duration 03:04:52:01 Interal width 00:10:25:00

C2


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:20:00:00 00:40:00:00 01:00:00:00 01:20:00:00 01:40:00:00 02:00:00:00 02:20:00:00 02:40:00:00 03:00:00:00 03:20:00:00 03:40:00:00 04:00:00:00 04:20:00:00 04:40:00:00 05:00:00:00 05:20:00:00
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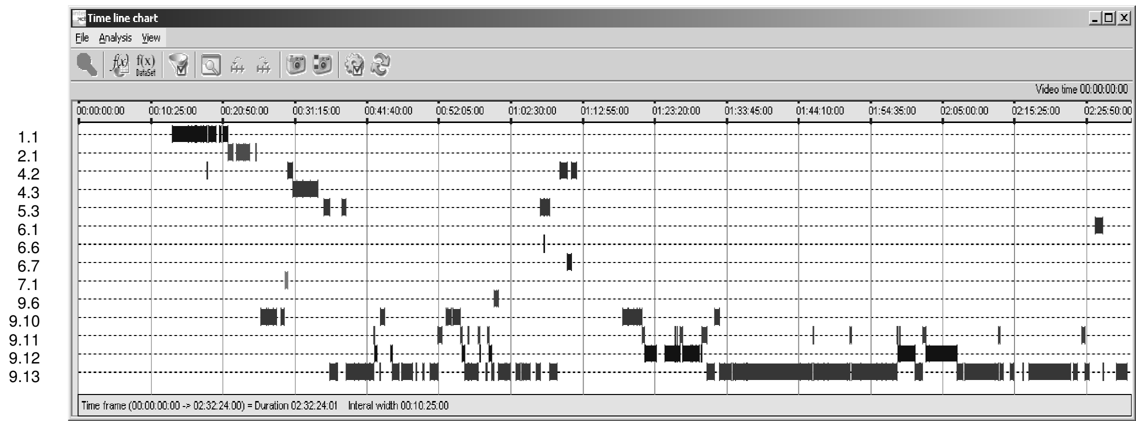
9.12
9.13
Time frame (00:00:00:00 -> 05:39:36:02) = Duration 05:39:36:03 Interal width 00:10:00:00

C3


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00 01:44:10:00 01:54:35:00 02:05:00:00 02:15:25:00 02:25:50:00
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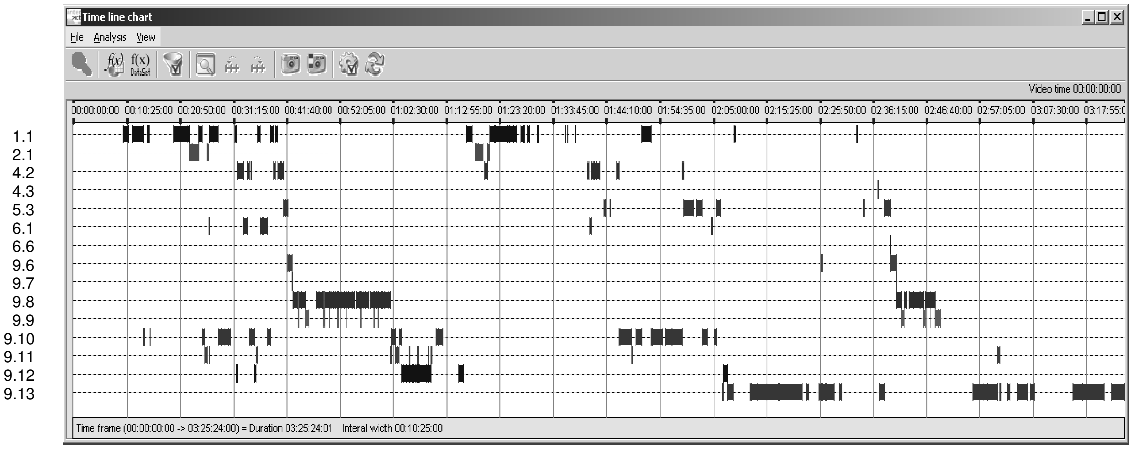
9.13
Time frame (00:00:00:00 -> 02:32:24:00) = Duration 02:32:24:01 Interal width 00:10:25:00

C4


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:25:00 00:20:50:00 00:31:15:00 00:41:40:00 00:52:05:00 01:02:30:00 01:12:55:00 01:23:20:00 01:33:45:00 01:44:10:00 01:54:35:00 02:05:00:00 02:15:25:00 02:25:50:00 02:36:15:00 02:46:40:00 02:57:05:00 03:07:30:00 03:17:55:0
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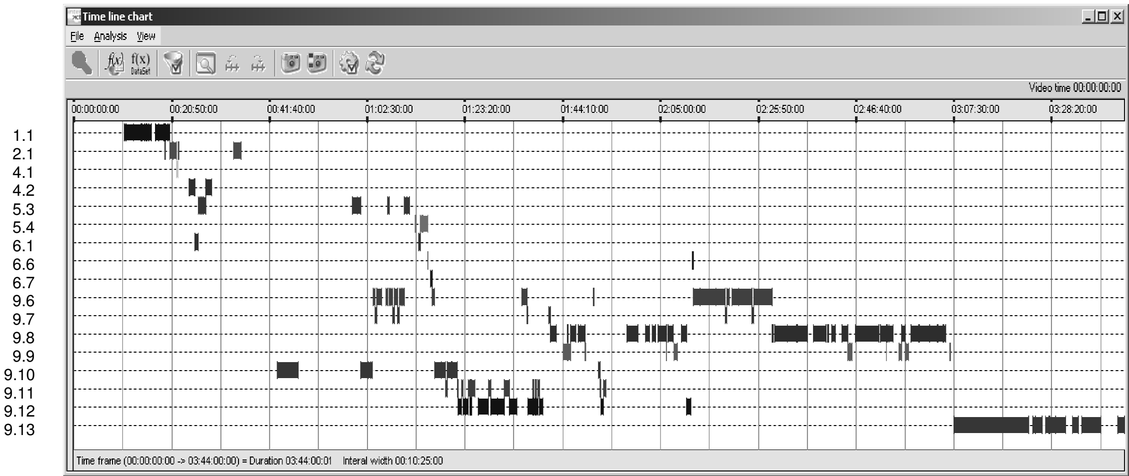
9.13
Time frame (00:00:00:00 -> 03:25:24:00) = Duration 03:25:24:01 Interal width 00:10:25:00

C5


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:20:50:00 00:41:40:00 01:02:30:00 01:23:20:00 01:44:10:00 02:05:00:00 02:25:50:00 02:46:40:00 03:07:30:00 03:28:20:00
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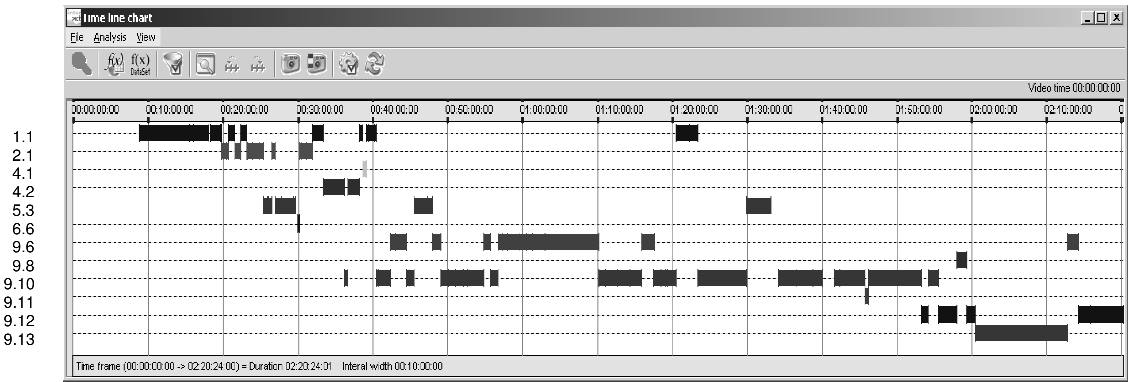
9.13
Time frame (00:00:00:00 -> 03:44:00:00) = Duration 03:44:00:01 Interal width 00:10:25:00

C6


Time line chart
File Analysis View
Video time 00:00:00:00
00:00:00:00 00:10:00:00 00:20:00:00 00:30:00:00 00:40:00:00 00:50:00:00 01:00:00:00 01:10:00:00 01:20:00:00 01:30:00:00 01:40:00:00 01:50:00:00 02:00:00:00 02:10:00:00
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9.10
9.11
9.12
9.13
Time frame (00:00:00:00 -> 02:20:24:00) = Duration 02:20:24:01 Interal width 00:10:00:00

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