Development of Novel Design Methodology for Product Mass Customization Based on Human Attributes and Cognitive Behaviours

A thesis submitted for the degree of Doctor of Philosophy

by

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Abstract

The competition in the global market is accelerating rapidly because of less technological gap, matured manufacturing level, and various changing customer needs. Increasingly customers choose products in terms of experience desires, psychological desires and whether the products can reflect their values, in addition to the main product functions. Moreover, there are a large number of small and medium sized manufacturing companies in the developing countries. OEM (Original Equipment Manufacturer) and simple mass production cannot generate good value for these manufacture companies, and they have been seeking new opportunities to create higher value for their products/services and satisfy different needs of customers.

Mass customization is one of the main business forms in the future, which can best meet the needs of individual customer, especially psychological needs. The key to mass customization is to provide enough modules to meet individual needs with a limited cost increase. The problem has been how to identify the real user needs and individual differences.

The purpose of this research is to develop a sound design methodology based upon the current product design theories and practices for future product innovation and sustainable growth of small and medium sized manufacturing enterprises. The research focuses on the user-product cognitive behaviours and the relationship between human attributes and product features. Orthogonal experiment, eye tracking technology and artificial neural network have been successfully applied in this research.

The research has developed a user needs hierarchy model and added value hierarchy model, and a robust theoretical basis to predict and evaluate (individual) user needs for product design.

The research has further made the following contributions:

1) The relationship between human attributes and product features has been established, which can help designers understand the differences of various customer groups;

2) The different effects of various influence factors on people's cognition and preference choice based on vision have been analysed and discussed;

3) A new method to identify, cluster, and combine common needs and personalized needs in early design stage for mass customization has been developed;

4) The research results can be reused in the future design of the same or similar kind of products.

Paper List

- **H. Wang**, and Q. Yang, 2010, *On Theoretical Framework for Innovation Design with Optimised Customization*, Proceedings of 2010 International Innovation Design and Management Summit Forum & Design Symposium of World Chinese，Innovation Design and Management, China Light Industry Press, pp.8-12.

- **H. Wang**, and Q. Yang, 2011, *Personalized Customization in Product Design Using Customer Attributes and Artificial Neural Network*, Proceedings of the Institution of Mechanical Engineers, Part B, Journal of Engineering Manufacture. (Accepted)

- **H. Wang**, and Q. Yang, 2012, *Eye Tracking Study of Customer Behaviour – the Influence of Human Attributes on Product Preference*, Design Studies. (Submitted)

- **H. Wang**, and Q. Yang, 2012, *Artificial Neural Networks Applied in Early Product Design Stage – a research for prediction customer preference in mass customization design*, Journal of Engineering Design. (to be submitted)

- **H. Wang**, and Q. Yang, 2012, *How to identify personalized needs in product mass customization design?* (in preparation)

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1.1 Problem Statement and Research Background

1.1.1 Background

In an era of global market competition, rivalry between companies is accelerating the development speed of industrial products. It often resulted in dozens or even hundreds of similar products in the market at the same time. The competitive advantage in technology area is becoming less obvious. Many product technologies have matured, or can be adopted by other competitors quickly. On the other hand, notwithstanding the existing products may already be enough to meet our needs in daily life, companies still seek new ideas to improve their products. Increasingly customers choose products in terms of how much experience and enjoyment the products can bring to them; and whether the products can reflect their tastes and/or styles (self value), in addition to the main product functions (Woodruff, 1997). Understanding of the relationship between human feelings and product features is necessary to address customer psychological demands. Industrial design needs sound methodology to assess and predict emotion factors of design. In 2001, the mixed perspectives of human factors and industrial design were registered on the International Conference on Affective Human Factors Design (CAHD) (Khalid, 2004).

In addition, mass customization is one of the new business competition frontier for both manufacturing and services. Compared with other design forms, customization design can best meet the needs of individual customer, especially psychological needs. The key to mass customization is that companies can provide a large number of personalized products with limited cost increase (Pine, 1993). Mass customization design can provide a good strategic advantage and economic value for enterprises. It can also satisfy different

tastes and/or styles (self value) of customers at the same time. “Make to order” model can also economize in materials, powers and storage space. In fact, there are many kinds of customization services based on e-commerce, for example, automobile industry, construction industry, apparel industry, entertainment industry, and part of computer and IT industry, etc (Bharati and Chaudhury, 2006).

A successful mass customization system should be based upon good understanding of individual thinking and psychological desire from all potential customers; provide enough variety of the product; and balance their cost and value (Pine, 1993) (Jiao, et al., 2007). Consequently, how to assess and identify the individual psychological desire of the customer is recognised as a crucial problem of mass customization. The depth of this problem involves two research aspects: human sensory characteristics and human emotion.

1.1.2 Research Context and Issues

The review of existing methods has identified more than hundred methods for the design and innovation at early stages, from understanding user needs to concept evaluation. However, while the core of emotional design in relation to human senses (cognition) and feelings (affection) is clear, there is still a lack of studies to delineate the connection between a product’s features (shape, colour, material, function, and interaction) and human attributes (gender, age, interests, habits, etc).

While many theoretical research about emotional design have presented the key elements of product-emotion model includes stimulus, emotion and product (Desmet and Hekkert, 2002; Norman, 2004; Fenech and Borg, 2007), the most applied methods and tools used in the early stage of product design involve only two elements - emotion and product (Russell, 1980; Ortony and Turner, 1990; Desmet and Hekkert, 2000; Reijneveld, et al., 2003; Scherer, 2005; Rossman and Marshall, 2011). They focus on measuring emotion scale. There are also some methods to measure sensory

characteristics of users (Jung, et al., 2000; Meitzler, et al., 2001; Warell, 2001; Henderson, et al., 2003; Vuori, et al., 2004; MindTools, 2006), such as eye-tracking and visual scanning, which can help designers and engineers objectively judge user's preference. However, because of the technology limitation, these methods are currently confined in the laboratory.

Furthermore, in the continuous design practices and human behaviour research, both designers and researchers have found that people usually do not know or cannot accurately describe what they want, especially when the thing is not necessary. It is also easy for people to produce bias, which exists in goal-directed information seeking (Robert and Wyer, 2008). People with different personalities may prefer the same product. Some twins, who have the same genes, may have different preference. The causes of preference differences may be complex. For these reasons, to make designers completely understand users' senses and feelings is difficult.

In recent years, many researchers have linked psychological elements (feeling and emotion) to design engineering technologies (Cristiano, et al., 2000; Schütte and Eklund, 2005; Yuan, et al., 2010; Wang, 2011), and have covered several fields, e.g. neuroscience, psychology, ergonomics, industrial design, marketing, etc, and have gained considerable attention. These research have aimed to develop an effective way to assess and predict customer's psychological demands.

1.1.3 Problem Statement and Significance

The main issue in mass customization design is the lack of any fundamental methods or tools to identify the concrete product features which evoke user's preferences (what they like about a product), and to understand the difference of individual senses and feelings. It is also the key issue to be addressed in this research.

The results of this research will establish a direct relationship between human attributes and product features and thus benefit mass customization design. Developing mass customization is not only a good solution for market competition, but also a good solution for manufacturing competition. Nowadays, a large number of similar products and matured technologies make lower profits for the manufacturing companies, especially in the countries which have a majority of small and medium-sized manufacturing companies.

Taking China for example, according to the statistics on manufacturing by Nations Industrial Development Organization (UNIDO), China shared the world manufacturing value added (MVA) up to 15.6% in 2009, and became the world's second largest manufacturing country (UNIDO, 2009). Thereinto, mobile phone output reached 619 million, which accounted for 50% of global production; microcomputer output reached 182 million units, which accounted for 60.9% of global production (China News, 2010). However, the Chinese manufacturing industry is still not very strong, and plays a surprisingly small role in the global industry and value chains. For example, each iPhone 4S is sold in the UK from £499 to £699 (sources from apple store), but only £7 or less is paid to China workers (Kraemer, et al., 2011). Most Chinese companies are at the bottom of the low value added industrial chain (Zhongyu Wang, President of China Enterprise Confederation) (Sohu Business, 2010).

In spite of this, “Made in China” has covered a variety of products from Airbus to daily merchandise, relating to material, technology, and manufacture. Chinese manufacturing is forming relatively complete industrial chains and management platforms. It brings a huge market demand, and also provides an important condition for innovation development in the future. Japanese economist Kenichi Ohmae mentioned in his book *“The China Shift”* that in the future China should not only focus on mass production, but also carry on personalized production (Ohmae, 2002). It is one of the Chinese economic developing trends. If the Chinese companies can provide personalized

products and services to both overseas and domestic markets with a similar price to mass production products, Chinese products will be very competitive (CCTV, 2004). Now, Chinese government is paying more attention to industrial design, and hope it can help Chinese manufacturing companies to produce more added value. In July 2010, eleven Chinese state ministries issued the Guidance on the promotion of the development of industrial design (Weihai Economic and Information Technology Committee, 2010). To build mass customization framework is thus a good developing way for both Chinese manufacturing and economic development. Thus, the research also has a widely theoretical and practical significance in the emerging economies like China, India, Brazil and Vietnam.

1.2 Aim and Objectives

Aim:

The aim of this research is to explore a novel design methodology based upon the current product design theories and practices for the future product innovation and the sustainable growth of small and medium sized manufacturing enterprises.

Objectives:

In order to fulfil the research aim, the following research objectives are identified:

1. **To identify the future developing trends of customer demands:** Accurately identifying customer needs is the basis of product design and innovation. For this objective, the research needs to analyse and establish the connections between the increasing customer needs and the changes of product features in different periods, and further infer the relationship between customer, designer, and product in the future business environment. It is the theoretical foundation to put forward research questions in the following stages.

2. **To develop a novel conceptual framework or model for mass customization design of products and services, which can benefit small and medium sized manufacture companies:** This model is built based upon the current design methods and aimed at manufacturing industry of the developing countries. Due to the existing manufacturing environment and capabilities, this model will firstly focus on digital products.

3. **To establish the relationship between human attributes and product features:** This will help identify concrete needs and feelings of customers, and subsequently relate them to new product elements or features. It is very important to decide the variety and number of product modules at the early design stage of mass customization circle, and to balance the diversity of alternatives and costs of the product.

4. **To build and evaluate an artificial neural network model to simulate customer preference choosing process, and to assess and predict customer's preference.** This model not only focuses on the prediction of potential customer needs, but can also handle the differences of individual feelings. The method adopted is based on Kansei Engineering, and is essentially an extension or generalisation of Kansei Engineering.

1.3 Scope of the Research

This research is developed mainly based on cognitive psychology, behaviour psychology, and existing design theories and methods. The research targets are limited to digital products and focus on Chinese customers. The reasons for these choices are as follows:

Firstly, the research aims to establish a sound design methodology to help small and median sized enterprises' (SMEs) development. There are a large number of manufacturing SMEs in China, and the research will probably continue in China in the

future.

Secondly, the experiment is in collaboration with Tianjin University (China) who provided the eye tracking equipment for this research.

Thirdly, China is one of the largest digital products manufacturing and consuming countries in the world, and has complete manufacturing supply chains. However, due to the large number of manufacture companies and intense competition, the profits of digital manufacturing are very low in China.

Fourthly, digital products as a kind of highly modular products have the best chance to realize mass customization. China is one of the major customer markets of digital products.

1.4 Structure of the Thesis

This thesis contains six chapters arranged according in the following sequence:

Chapter 1 − Introduction: This chapter introduces the problems from global market competition background in the world to developing countries' manufacturing background, and related research background of personalized research and mass customization research. In addition, it explains the research aim and objects, and describes the research scope and structure.

Chapter 2 − Literature Review: This chapter reviews the literatures which concerned with four aspects as follow:

a) To investigate the human needs, and product design and development history. In this aspect, a relationship model of human needs, design styles, and the main product feature in different periods will be summed up based on literature review. In addition, the user needs hierarchy and added value hierarchy will be presented in

this section.

b) To understand the current design drivers in the world.

c) To understand mainly design forms and theories in the recent years.

d) To investigate the existing design process, methods and tools which are applied in emotional design and/or emotion research.

Chapter 3 − Research Methods and Methodologies: This chapter focuses on the primary research. It shows research process; provides product cognition and appraisal process and user-product cognitive model; and presents the methods and methodologies which are used to approach this study. The main contents include user-product cognition study, vision measurement, survey and experiment design, and the theoretical basis of artificial neural network.

Chapter 4 – Results, Date Analysis and Discussion: This chapter includes the four main parts: orthogonal analysis and results, eye tracking experiment analysis and results, synthesis and discussion the above two parts results, and build artificial neural network model. The results involve to four kinds of human attributes. There are demographic factors, graph preferences, hobbies, and life styles. Through these analyses, a connection between human attributes and product feature will be revealed.

In addition, an artificial neural network model which connects human attributes and product features is developed in this chapter. It is essentially an extension of Kansei Engineering technology. It can be used to predict individual difference of customer preference choice, and/or to evaluate new product concepts based upon customer attributes.

Chapter 5 –Embryonic Form of Product Mass Customization: This chapter presents a feasible model for product mass customization framework based on literature review

and case study. Furthermore, a novel method is built in this chapter which is an extension or generalisation the existing design methods. The new method can be used to help designers to clear common needs and personalized needs and to identify individual customer needs and the variety and amount of product modules in the early design stage of mass customization development process.

Chapter 6– Conclusions: This last chapter provides a summary of the research; presents the research contributions; and points out the research limitations and the further suggestions.

Chapter 2 Literature Review

2.1 Introduction

Chapter 1 has given the background of this research, and described the research motivations, aim, objectives and specific research questions. This research aims to find a sound strategy for the sustainable growth of small and medium sized manufacture companies. OEM (Original Equipment Manufacturer) and simple mass production cannot generate good value for manufacture companies. The surplus products and excessive versions will lead to decrease the enterprise profits. Manufacture companies should explore a method to change the manufacturing for a higher added value.

Mass customization for mass customer goods will be a new economic form in the future (Pine, 1993). There are two most important factors in the product mass customization chain based on the existing technological level. One is successful modular design, and the other one is successful supply chain with advanced manufacture ability. According to the existing manufacturing environment, digital products have met the basic conditions for mass customization (more discussions in Chapter 5). Therefore, this thesis will focus on digital product mass customization design and evaluation methods.

In addition, product mass customization needs theories and methods to implement a product customization process/chain (design-order-redesign-production). Furthermore, these theories or methods should also enable the mass customization process to provide enough varieties and choices, and to satisfy each individual customer in a limited time and with a limited cost.

This chapter aims to explore the relationship between people, product and design through the literature review. This chapter is mainly composed of three parts: 1) to understand and sum up the developing process of human needs, main product features and the key points of design in different eras, and to predict their future trends (Section 2.2); 2) to introduce the mass production form, the main product design and development processes based on mass production and mass customization (Section 2.3); 3) to review the related existing design theories and methods, and discuss how to use the existing design theories and methods in product mass customization design (Section 2.4 and 2.5).

2.2 Overview of Product Design Development

2.2.1 Definition of Design

About forty years ago, both designers and engineers were exploring a question which looks simple but actually complex: what is design? It may be described in various explanations, such as: "*to mark out, plan or purpose a work as a verb; or a plan conceived in the mind as a noun*" (The Oxford English Dictionary, 1989). Design is all of human activities. All we do, almost at all times, is design (Papanek, 1991). Design is a process which configures all materials, elements and components together, and can give a product particular value from its performance, appearance and usability (Walsh, et al., 1992). Design is the core of innovation activity, and aims to establish the multifaceted qualities of products, processes, services, and other systems in the whole life cycles (Mozota, 2003). Design is a purposive application of innovation to bring ideas into products, services or processes (Bessant et al., 2005). Design is a value-drive activity, an engrossingly particular decision and a culture option (Potter, 2002).

To this day, design has changed from a single form work (only focus on structure, technology or aesthetics) to a complex integrated system. It covers a number of fields which involve psychology, marketing, technology, manufacture, aesthetics and sociology.

Design is not simply an activity to create something. It is also a process to explore the human experience and to satisfy the human inner feelings, which should be the starting point of design (Press and Cooper, 2003).

Design plays a lead role in connection with human needs and the physical form of products. Ulrich and Eppinger defined design that includes two functions: engineering design and industrial design (see Figure 2.1) (Ulrich and Eppinger, 2008).

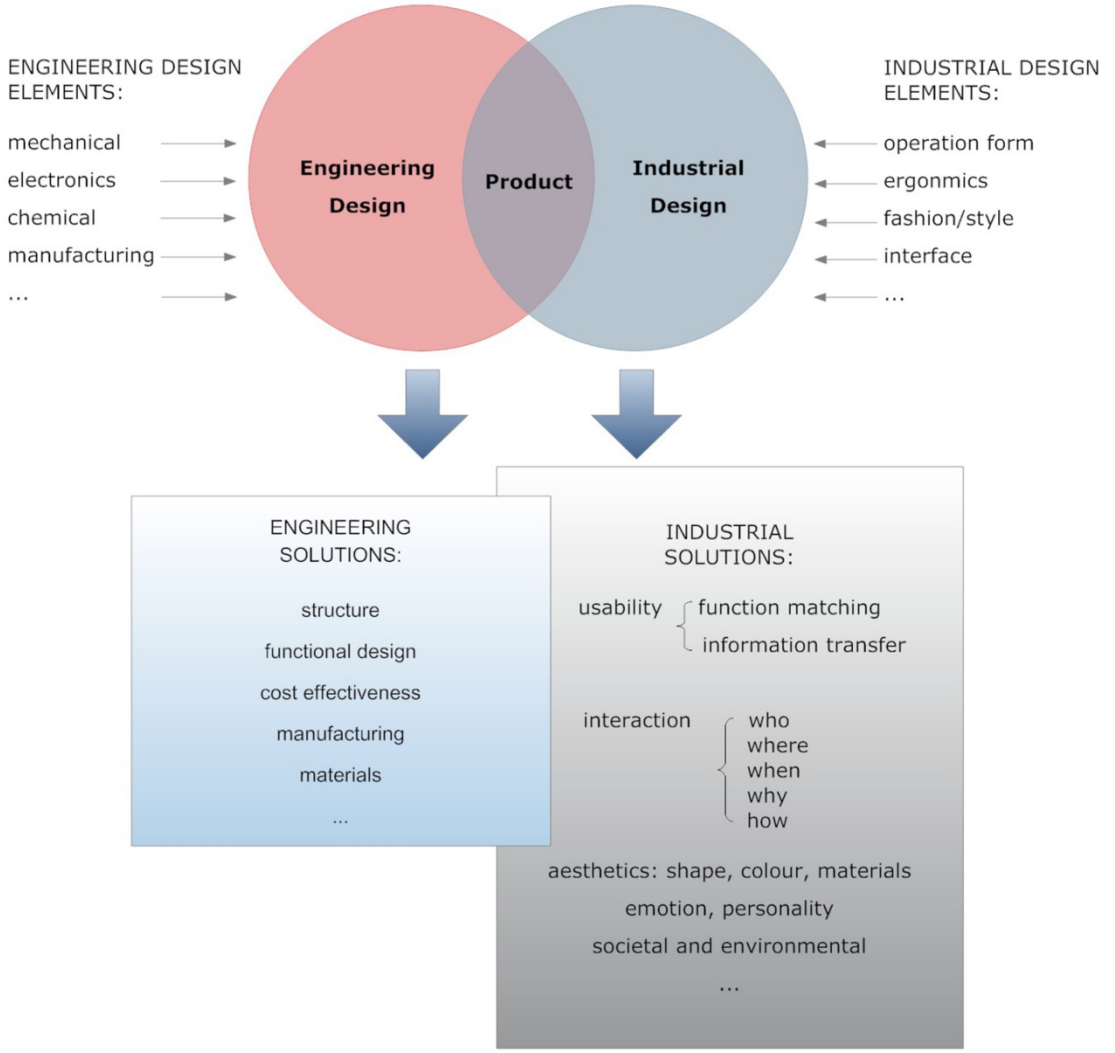


Figure 2.1: Product design context

The design conceptions have changed with the time. In different eras, the main aim of design is different. It reflects the development of economic environment, technology

level, human thinking and customer needs, and also shapes the various product characteristics in specific eras. The thesis will analyse the development process of human needs, and discuss the diversity of products at different stages from a design perspective in the following sections.

2.2.2 Human Needs Development

The most famous and widely used theory about human needs is proposed by Abraham H. Maslow (American humanistic psychologist). According to Maslow's theory, human needs can arrange themselves into a pyramid of hierarchy. This pyramid of hierarchy includes five levels. From the lowest to the highest, they are physiological needs, safety needs, social needs, esteem, and self-actualization. The hierarchies are defined be their prepotency, i.e. the upper level needs usually rest on the prior satisfaction of the lower level needs. Figure 2.2 shows the earliest and most widespread version of Maslow's human needs pyramid structure based on his 1943 paper *A Theory of Human Motivation* (Maslow, 1943).

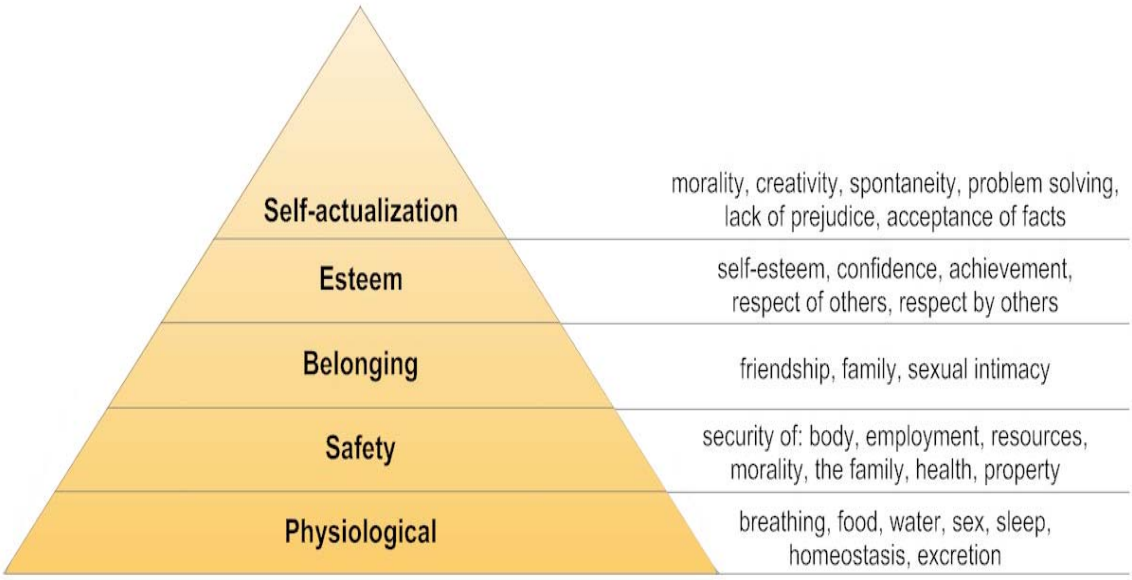


Figure 2.2: Maslow's hierarchy of needs pyramid (Maslow, 1943)

Maslow's theory is a reflection of natural evolution. In Figure 2.2, self-actualization was defined as a motivational capstone. While it is doubted in the later motivational psychological research (Koltko-Rivera, 2006), people's desires for self fulfilment as a tendency that one idiosyncratic is and everyone is capable of are demonstrated in our daily life. People always play several roles in one's life, such as parent, son, worker or inventor. Self-actualization causes greatest individual differences in these situations. However, the common feature of the needs for self-actualization is that they usually emerge after the satisfactions of prior needs: physiological, safety, belonging and esteem (Maslow, 1987).

A more accurate version which is contributed by Maslow in his later work is shown as in Figure 2.3. In this hierarchy pyramid, the human needs are arranged into six motivational levels (Maslow, 1969). The motivational capstone is defined as self-transcendence.

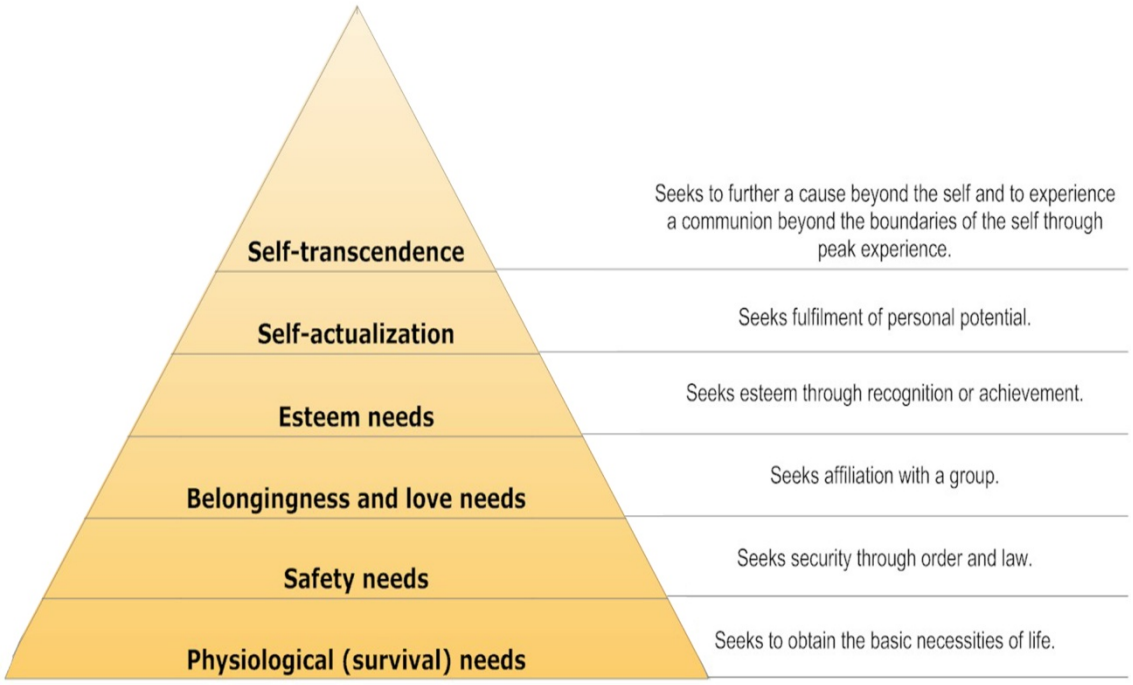


Figure 2.3: A rectified version with six motivational levels (Maslow, 1969)

The human needs hierarchy is one of the motivation theories. Motivation is one important class of determinants of behaviour. All behaviours are always motivated, and behaviours also always reflect the motivation. Although Maslow's theory was puzzling in the description of motivational capstone in psychology (Koltko-Rivera, 2006), it still has an important theoretical significance in other fields, especially to identify user needs for an innovation work.

2.2.3 Product Design Development and Drivers

2.2.3.1 Four Stages

In this section, the thesis will analyze the product characteristics based on four stages: Industrial Revolution (1750-1850) to 1920; 1920 to 1970; 1970 to 1990; 1990 to the present (Raizman, 2004; Wang, 2002; He, 2002; Rizzoli, 1996; Erlhoff, 1990). Products in each stage have different product features, and reflect different level of customer needs. For this research, it can be more effective to demonstrate the future trends of customer needs and product development, and to predict the relationship between people, design, and product in the future life and business activities.

After Industrial Revolution, the most obvious shift in this era is the emergence of mass production. New industrial technologies revolutionized productivity that had great impacts on the economic growth. Product innovation is absorbed in the structure and advanced science and technology.

However, the outcomes of industrial technology, the products still had many problems in terms of function, appearance, practicality and safety. How to deal with these problems was an urgent issue for both users and companies. The development of modern industrial design really began from the 1920s. Product design (appearance design) not focused only on upper society, but also focused on the whole customers.

Between 1970 and 1990, the most important invention is the generation of personal computer. In addition, Postmodernism is another characteristic of products in this era. Postmodernism is a philosophical movement which rejects all prescriptive conceptions or theories, and accepts only objective truth. This movement brought a wide influence on architecture and product design. Products in this stage had a structural aesthetic style.

From 1990s, the speed of product development is faster than any previous stages. For contemporary life, product is not only a simple manufactured thing, but also represents a conception, service, company/brand value, and even an experience.

Taking the development of digital products for example, the period of 1990 to now experienced three stages development including modularization, diversification, and personalization. The digital revolution is progressively turning the products with which we interact into smaller boxes which have more buttons and more functions, and makes us difficult to understand their mechanisms, operating principle and usage (Bolz 2000). Apple design has made another revolution in the world. Its extreme simple design style subverted our understanding of digital products (Okajima, 2007). Since the advent of new generation of Apple products, our products have become more emotion-oriented and user-friendly.

Table 2.1: Classical products from 1990 to now

SONY Walkman, 1994	NOKIA, 2005	iPhone 4S, 2011
		
Modularization	Diversification	Personalization
Mass production	Family product	E-commerce
Super market	User focus	Standardization
Product economy	Service economy	Experience economy

2.2.3.2 Three Drivers

The intense competition between companies has often resulted in dozens or even hundreds of similar products in the market at the same time. Often our products are already enough to deal with in our living needs indeed. However, products offering mere functionalities can hardly satisfy increasingly demanding customers. Thus, product manufacturers in order to survive in the competition must consider more and more factors for satisfying customers' increasing desires (the higher human needs). At the same time, designers can no longer only think how to show their artistic views and self personalities, but to consider how to make users accept and prefer the products.

New product design process transforms technical ideas or market needs and opportunities into a new product that will be launched into the market (Walsh, et al., 1992). In the present design and innovation activities, there are three development drivers which simultaneously exist in the current product competitions.

Technology-push:

Technology-push has resulted in the big shift from agricultural age to industrial age; and developed products from hand-made to mass production. It emerged first among the three development drivers. Technology-push means the advanced scientific understanding determines the rate and direction of innovation (Dosi, 1982). It is a process that a solution looks for problems to solve (Andersson and Keller, 2010). When a new technology is developed in the laboratory, companies hope it can be used in new products or services, and ultimately opens up a new marketplace (Johnson, et al., 2008).

Technology advancement is one of the important factors that can affect human needs development. A common view shows that technology-push has played a more important role than market-push in economic growth in the first fifty years of 20th century (Solow, 1956; Rothwell, 1994), and also is a powerful motor in the early stage of an innovation

process (Schumpeter, 1947; Usher, 1954).

However, technology-push has limitation, because the original technology-push process is a linear model (Gawarzynska, 2010). The unidirectional process cannot turn back to the front stages through evaluations and/or feedbacks. This means that the departments in the downstream (e.g. marketing) cannot play any active role in generating user needs or innovation ideas (Freeman and Louca, 2001). The new product was designed only for introduction and using an advanced technology. Thus, the early scientific research usually lacks market motivation; ignores the costs and other opportunities and changes which exist in the market and customer needs, and can influence the innovations and profitability of companies (Nemet, 2009).

In the end of the last century, technology-push has developed to a multi-dimensional model, and the strictly 'linear' model has been ignored (Schmoch, 2007). Technology provides sufficient possibilities for us to realize the functional, structural, and material requirements in a product. Scientific and technological research also began to notice the requirements and effects from market and customers.

Figure 2.4: Technology-push, first generation of innovation process

(Rothwell, 1994)

Market-pull:

Market-pull means that technology is driven forward by market needs, and typically represents a process that an existing problem looks for solutions (Andersson and Keller,

2010).

Since 1950s, many studies argued that the promotion effect of market-pull for rate and direction of innovation was more obvious than technology-push (Nemet, 2009). Unmet needs of people, different policies, technology problem of production, changes in prices (Hicks, 1968), and potential new markets (Vernon, 1966), all of these market conditions impel companies to carry out an innovation work on certain problems.

Like technology-push, market-pull also has some criticisms and debates. There are three most important problems among these debates (Nemet, 2009). Firstly, the problem is the definition of demands. The core of market-pull is to satisfy demands. The demands may be from users, their families, companies, societies, etc., the demands are always considered too comprehensive to be useful; or are inconsistent (Chidamber and Kon, 1994). The second problem is how to make companies identify potential needs from an almost unlimited set of possible marketing demands. Thirdly, the market-pull model is easy to ignore new technological possibilities.

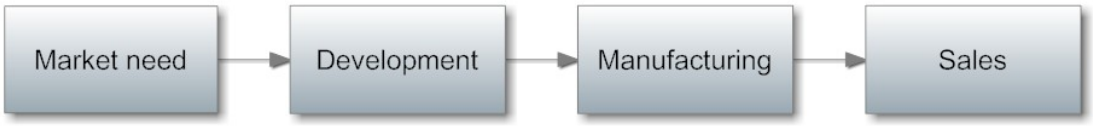


Figure 2.5: Market-pull, second generation of innovation process

(Rothwell, 1994)

Actually, innovation is not driven by only one department - technology or marketing. A successful product needs a useful technology with a market chance (Freeman, 1974), so technology-push and market-pull are both indispensable (Mowery and Rosenberg, 1979).

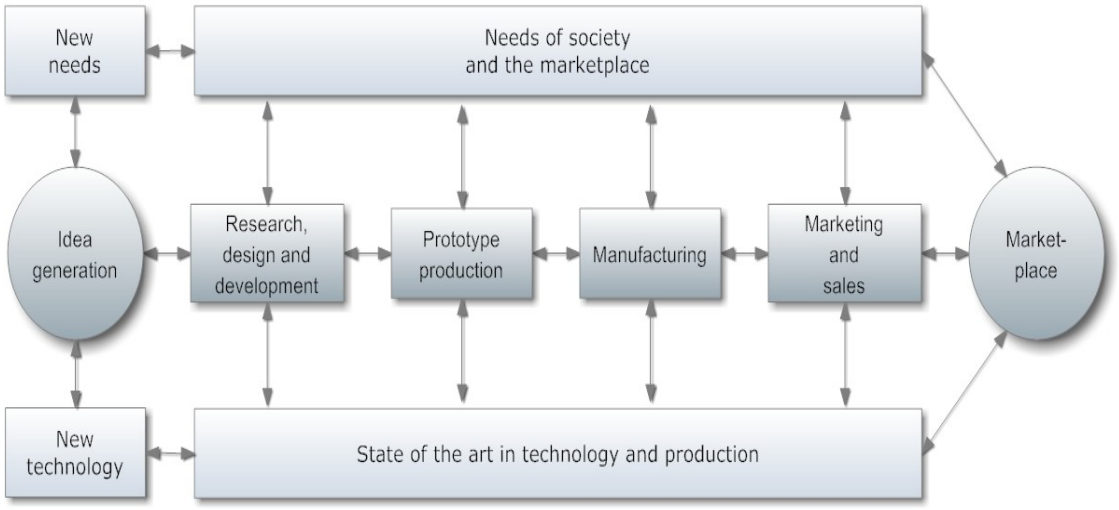


Figure 2.6: A "coupling" model, third generation of innovation process (Rothwell, 1994)

Experience and Emotion-driven:

Designers and engineers often discuss what kind of product or service people like to purchase. A successful product means that it can not only satisfy the user needs, but more importantly, it can be accepted by its target customers (Ljungerga & Edwards, 2003). Joseph Campbell said that *"what people seek is not the meaning of life but the experience of being alive"* (Alben, 1997). Nowadays, it is easy to find the rate of product replacement is faster than ever, and we often purchase the same kind of industrial products in our life, for example, bags, mugs, mobile phones, and even cars. Increasingly customers choose products in terms of their special requirements and feelings (Nagamachi, 1995), in addition to the main product functions. The new standard of successful product is that it can not only satisfy the user needs, but can also provide their users with a fantastic experience with pleasure, excitement, and satisfaction.

Emotion as a product innovation driver is widely concerned in the 21st century. Our emotion for a product is usually caused by interaction (experience) with the product. Experience can evoke human's emotion and new motivations. Nowadays, many companies develop products in order to create a better experience for users. However, in

fact, the influence of experience on product innovation has existed as long as the human development.

Figure 2.7 takes hand tools for example. It shows human experience affects the increasing human needs and product innovation.

Figure 2.7: Process of hand tools development

As shown in Figure 2.7, the development of hand tools has gone through a very long time from Stone Age to now. Its development has shown a complete process about increasing human needs, technological progress and social development in different periods. Initially, people just used certain stones with special shape to help obtain food, which is the basic function of the earliest hand tools, but they were not easy to use. Gradually, the users of these tools had additional requirement: good usability. In general, when the lower-level feature or requirement can be satisfied and is mature, the higher-level requirement will appear in accordance with the social development. Today, there are so many different kinds of hand tools in the market. They have various designed functions and high quality (including safety and reliability), and many of them have been used to represent different personality or even fashion.

Through comparison, we can find that human needs promote push both technology and market development, and simultaneously, new products can lead to human needs growth (see Figure 2.8). The essence of the emotive-driven is the user-driven.

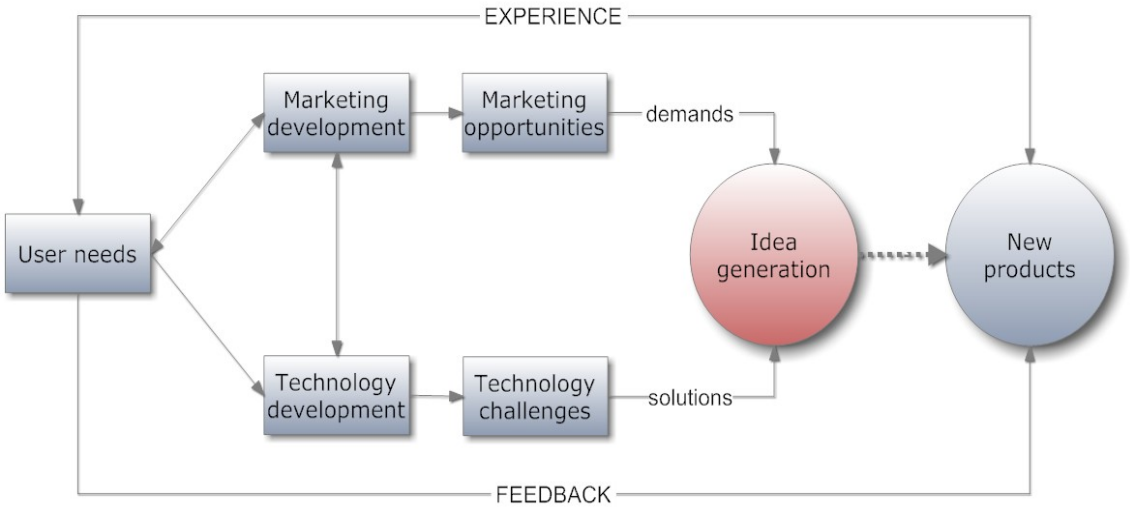


Figure 2.8: User-driven innovation process model

2.2.4 Summary and Discussion

As discussed above, a process of modern design development is summarised in Figure 2.9.

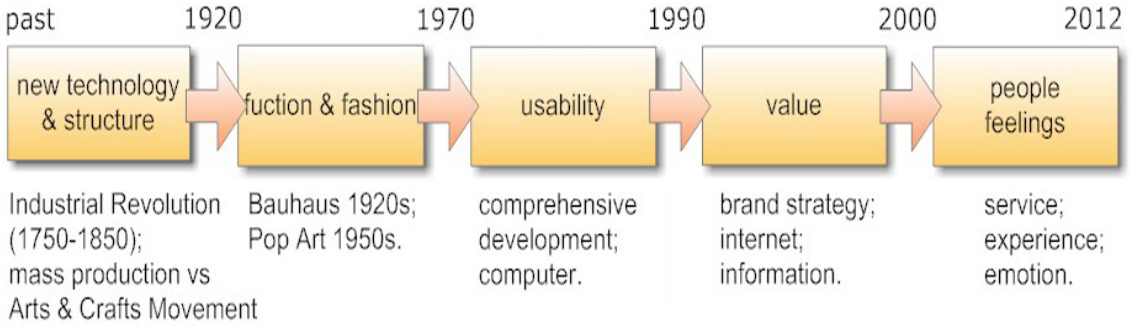


Figure 2.9: Main shifts in design development

According to the analysis of the various product developments in different periods, the pyramid structure of hierarchy can also be applied to describe the development and their prepotency of user needs (see Figure 2.10).

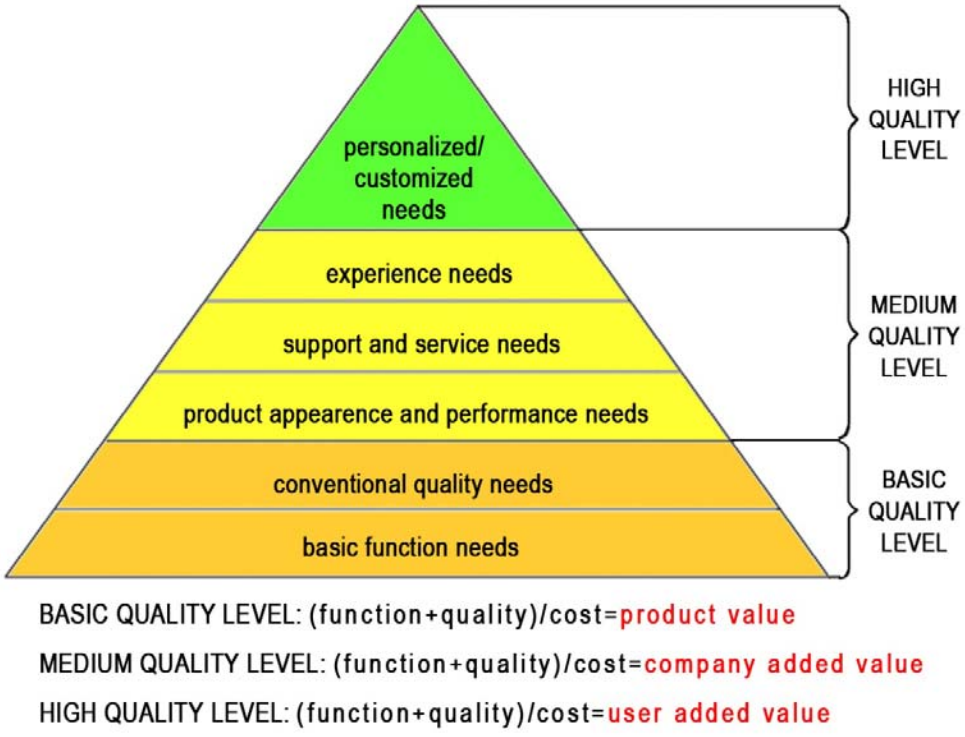


Figure 2.10: Pyramid of the user needs hierarchy

This pyramid of hierarchy includes six levels of needs with corresponding three levels of quality. From the lowest level to the highest level, the needs include basic function needs, conventional quality needs, appearance and performance needs, support and service needs, experience needs, and personalized/customized needs.

- Basic function represents the basic purpose of a product. It determines which category the product belongs to. For example, mobile phone belongs to phones (sub-category of electronics). Mobile phone has so many functions such as taking photo and playing music, but its basic function is to communicate with someone.

- Conventional quality focuses on safety, usability, stability and durability. It involves the quality of the product's materials, technology and production.

Basic function needs and conventional quality needs belong to basic quality level. Basic quality is parameterization quality and reflects the value of product itself. Technology plays a key role at this level. The requirements of this level focus on the major function of products which can be implemented successfully and satisfy the motivation (action motivation) of users.

- Product appearance reflects the aesthetic and fashion features of a product. It involves shape, colour and texture. Product performance means that the product should be used more convenient and friendly. For example, the past digital product usually had very detailed user manual/instructions, but now the user manual is very simple. Good semantics, interface and interaction design make users understand the functions of a product and how to use it quickly and easily.

- Support and service needs mean that besides its own features and functions, a product has expanding features or functions by product family or attachments, or can provide some related services. For example, a teapot matches cups and plates from the same product family with the same style; a laptop may have exclusive bag,

various cable connections, headphone, speaker system, etc as its supporting attachments; or a music player has simple music download service and additional maintenance service. From this level, the user needs are not only focus on the product itself, but also involve its using environment.

- Experience needs mean that besides the above, products have features which can provide integrated consideration and can promote positive emotions for their users, for example, enjoyment and being taken seriously. It combines the product, user, environment and culture. A complete service for customers, which include using environment, methods and process. In this hierarchy, the product not only focuses on physical needs, but also cares users' psychological needs.

Product appearance and performance needs, support and service needs, and experience needs compose medium quality level and reflect company added value.

- Personalized/customized needs are defined as the capstone of the user needs. It reflects self value of people. A personalized or customized product can brand its user like a business card, and show the user's thinking, personality, hobbies, attitude to the life, and taste.

Like the human needs pyramid, in the user needs pyramid, the hierarchies also are defined by their priorities. In addition, the user needs pyramid can reflect technology level, market condition, and economy development (Pine and Gilmore, 1999). When a higher-level user needs appeared, it means that among the competitions, the related technology has matured, and the lower level business market has been already in saturation. Companies have to seek new approaches to satisfy a higher-level user needs and create new added value source to maintain an edge in fierce competitions.

Moreover, although our products have enough diversification, people still expect new products. Human perpetually wants to seek better experience. They hope they can have

more pleasure, exciting and eudemonic experience when they use a product. At present, most of companies can easily meet lower four levels of user needs pyramid, viz. basic function needs, conventional quality needs, product appearance and performance needs, support and service needs, and stand at the fifth level. Experience design and emotion design have become the mainstream in the product innovation process. To further improve user's experience, designers and engineers try to distinctly measure and understand customers' feelings and thinking. However, it is extremely difficult indeed. Because the existing products are enough to satisfy general customer needs, people cannot even describe what they want and what they like exactly (Franke and Piller, 2003). Only when they see a fantastic product, they will discover "ah, that is what I want/like". Therefore, a designer needs methods to find out inspiration of customer, and let them discover what the better and more colourful experience they want. Table 2.2 shows relationships between user needs and design in different stages.

Table 2.2: Relationship between user needs and design

	User Needs	Design Focus	Relationship
future	Customization	Self value	Design by user
	Personalized	User feeling	Design with user
present	Special experience	Brand/cultural experience	Design for user
	Extended support/service	Added value	Design for customer
past	Appearance & performance	Competition	Design for marketing
	Conventional quality	Good quality	Design for technology
	Basic function	New technology	Design for technology

2.3 Mass Production and Mass Customization

2.3.1 Mass Production

Mass production is to produce the standardized product in a large quantity. Nowadays, mass production is almost applied to all kinds of industrial products.

Since the Industrial Revolution, especially after the First World War, the old manufacturing system had not supported the increasing purchase demands and the growth of many large companies. A new manufacturing form was adopted, generally based on standardization and assembly line, and can bring high efficiency and low costs. This manufacturing form is called mass production. Through the one hundred years development, mass production system has been a mature and successful manufacturing system. (Pine, 1993)

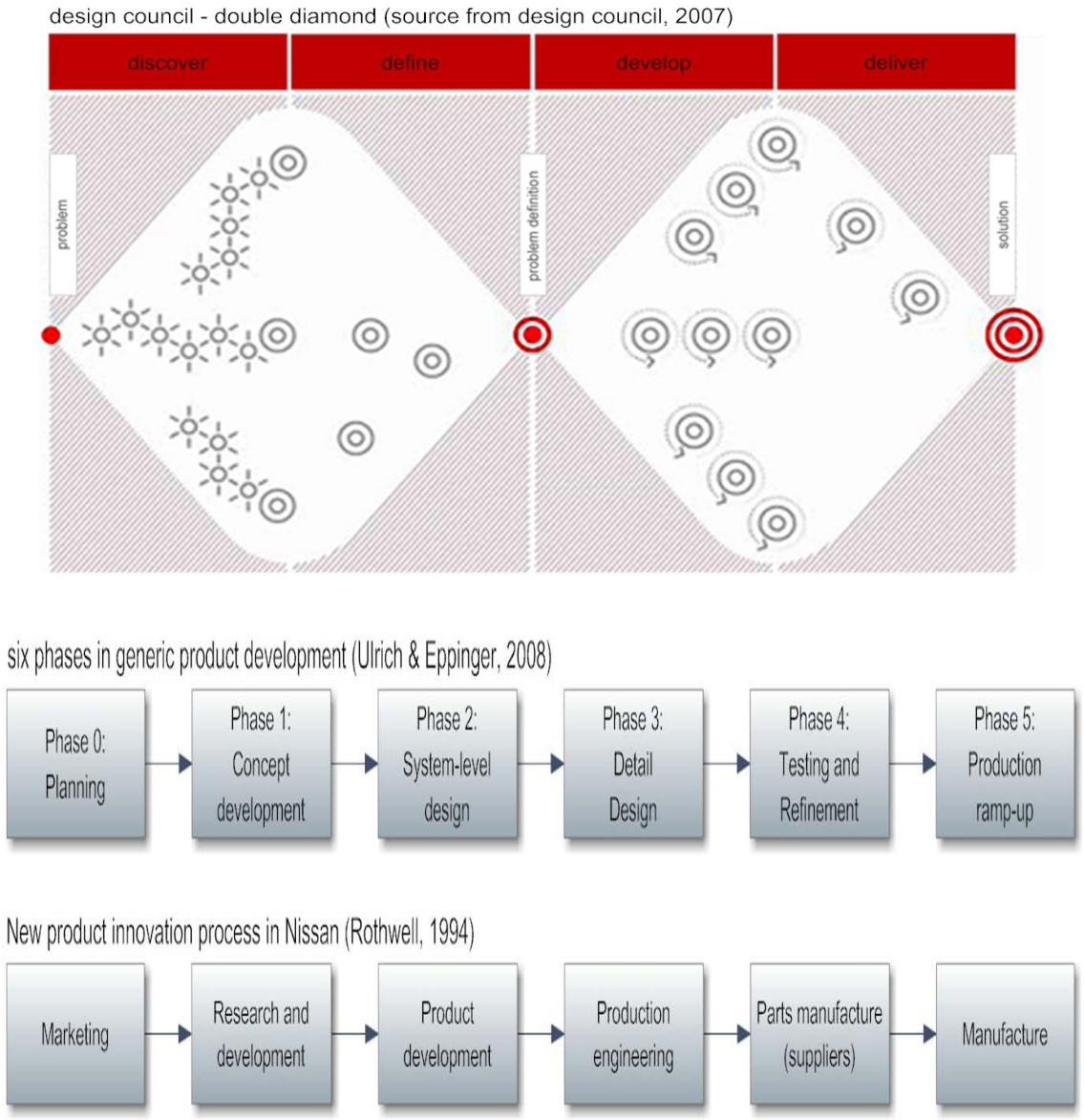


Figure 2.11: Three typical innovation processes based on the present production form

The continuous expanding scale of production (as original equipment manufacturer), expansion product lines and mergers or cooperation have allowed companies to gain more market share. Of course, if a company offers a large number and variety of products, the profit of this company will be diminishing returns (Jiao, et al., 2007). Therefore, companies need to balance production number and proportion to get the most profit.

However, since the end of the 20th century, mass production has been under tremendous pressure from the saturated market; product cost and speed of production; and product variety and increasing changes of the customer needs (Kotha, 1996). To deal with these conflicting issues, manufacturers need more advanced and effective strategy and method to support them to adapt to the increasing international competitive market and the increasing diversity of customer requirements.

For this reason, flexible manufacturing system (Berry, et al., 1995; Browne, et al., 1995), agile manufacturing (Yusuf, et al., 1999), modularity-based manufacturing (Tu, et al., 2004), customer-driven manufacturing system (Murakoshi, 1994; Cristiano, 2000; Jodlbauer, 2008), and family product manufacturing (Gonzalez-Zugasti, 2000; Simpson, 2001; Jose, 2003) as popularised manufacturing concepts and research topic have been advocated in the 21st century.

2.3.2 Mass Customization

As a new economic and technological concept, mass customization was first predicted by America futurist Alvin Toffler in his book *Future Shock* in the 1970s. The concept is attributed by Stan Davis (Davis, 1996) in Future Perfect. Mass customization is the idea of satisfying the individual customer needs with mass production's efficiency and cost (Tseng and Jiao, 2001). It has recently become a new frontier of competition for technology innovation, manufacturing, and service industries (Pine, 1993; Tseng and Jiao, 1996).

Mass customization is a system which gathers all the resources and stakeholders (enterprises and customers, suppliers and manufacturers; developers and users) within one production process. The aim, also as the core of mass customization, is a product which can provide enough choices, enough changes, high efficiency, low cost, and with a high quality which can meet individual customer demands and senses. It has been corroborated and accepted that customers are willing to pay more for the product which

can provide their personalized size, taste, style, need, or expression according to their individual feelings (Tseng and Du, 1998; Tseng and Jiao, 2001).

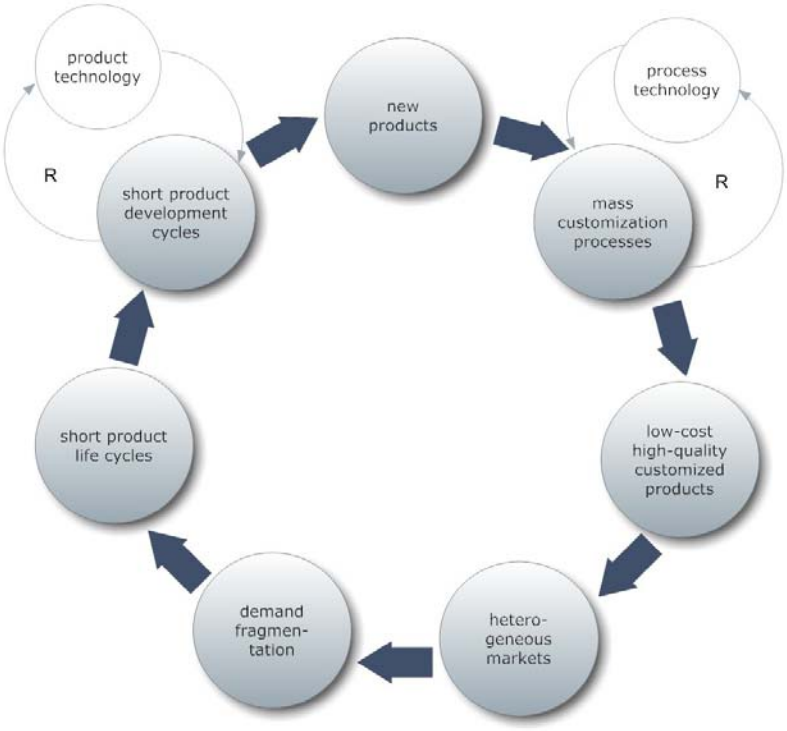


Figure 2.12: A paradigm of mass customization (Pine, 1993)

In order to successfully provide customers with customized products at a lower price and a higher quality, companies focus on increasing the diversity of the product's external performance which customers can directly perceive, and try to make product customization into the whole or part of product module mass production through the reorganization of the product structure and/or manufacturing processes. In this way, before product sale or delivery to customers, the product can still be customized. Because the product is fully standardized and modularized, and customized service is in the later stage of the process, so "customer design product" will not influence product development.

Furthermore, the recently research about mass customization product design tends to use the similarity and versatility of product parts and structure (Tseng and Jiao, 1997); standardized modules; and product family (Tseng and Jiao, 1997; Tseng and Du, 1998)

to reduce the product's internal diversity.

Product Family Architecture:

Product Family Architecture reflects the ability of a manufacturing company as to how many product variants it can provide to satisfy customer needs (Tseng and Jiao, 1996). A product family involves a base product and building parts which can compose the base product. In Product Family Architecture system, every customized product can be defined to have M attributes, and every attribute include several levels. The method includes four components: building blocks, configuration rules, product line taxonomy, and economic evaluation (Tseng and Du, 1998).

Case-based Evolutionary Design:

Case-based Evolutionary Design (Tseng and Jiao, 1997) is a rectified design method based upon Case-based Design (Domeshek and Kolodner, 1992), and is developed for product mass customization.

Case-based Design is a method to describe how people use a product by applying memory-centred model. Its fundamental idea is that people can remember and adapt things what they did before, so when they are in a similar situation, people are good to point out what and how they should do (Domeshek and Kolodner, 1992).

The main idea of Case-based Evolutionary Design is to build an assumption according to existing related product designs or experiences. It emphasizes similar and common knowledge to the past designs. It can provide designers with a set of concepts and common solutions to new design case, and build case class by Product Family Architecture. (Tseng and Jiao, 1997)

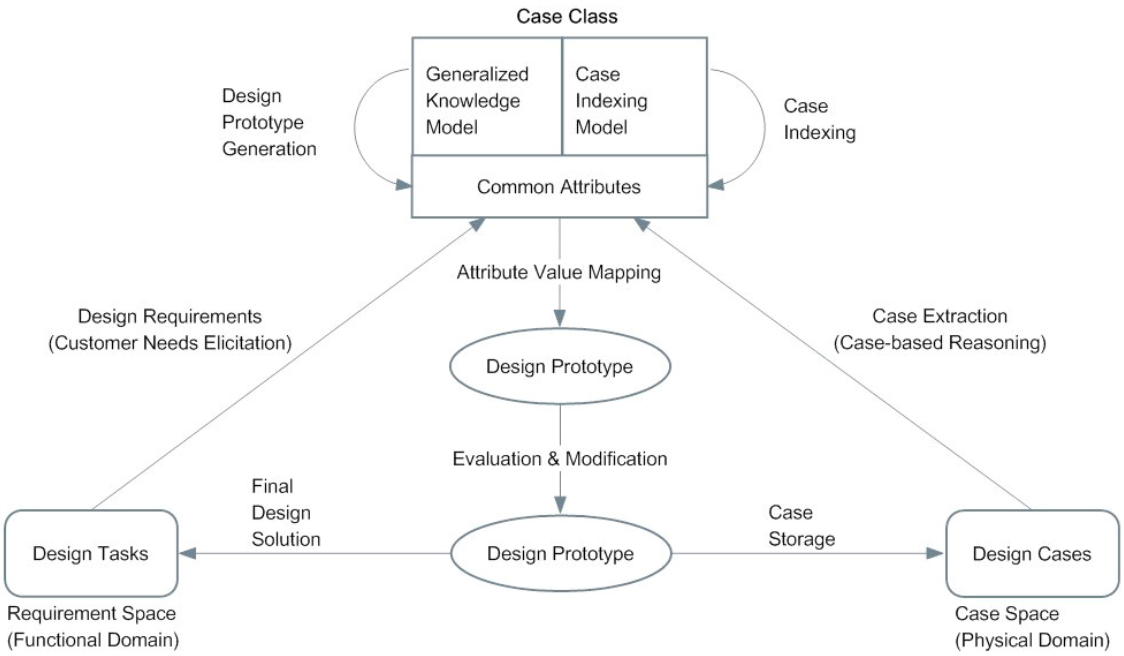


Figure 2.13: Case class centred design process model

(Tseng and Jiao, 1997)

However, Case-based Evolutionary Design is limited to the reuse of the past designs, and is not beneficial to create a new product and explore the new customer desires. It can possibly cause companies lose opportunities to innovate. The importance of a successful mass customization service is not how many parts customer can choose, but every part can match a special user's desire (need). It needs to build an integrated knowledge flow, gather user information and understand the deep needs of different customers (Zipkin, 2001; Franke and Piller, 2003).

2.4 Main Related Design Theories and Methodologies

Design is the core of innovation activity, and it aims to establish better and comprehensive qualities of products. It is also a process to explore and enhance the human experience. During decades of exploration and practice, designers have developed many effective design methods and methodologies for product innovation.

This section will introduce three main design conceptions that focus on human feelings (user experience process and psychological gratification) and are widely used in the present innovation activities.

2.4.1 Emotion Design

The customers' expectations of a product have been constantly increasing (as described in Figure 2.10). Functionality, stabilization, aesthetic attractiveness, usability, affordability, service and sustainability are all expected by the users. Users are generally expecting a higher/better quality of life through using products. Simply integrating all these features into a product is not enough for a successful product and to win in the present marketing competition. The recent design trend is to use all possible product features to trigger and evoke the positive human emotions, such as happiness, excitement, encouragement or inspiration (Demirbilek and Sener, 2003).

When the price advantage has been weakened by mature technologies, and functionality and usability are no longer the key to attract customers to buy a product, people are seeking a psychological gratification with an altogether different standard of evaluation: feel a product. More specifically, this psychological gratification means a feeling, an emotion, a momentary idea or inspiration derives from the experience with the product. At the same time, a positive emotion will have an effect on users' feelings, decisions and behaviours (Jensen, 1999). A neuroscience research by Damasio in 1994 has revealed that when we need to make a decision about whether we like or dislike something, the emotional response provides a key support, and if a person has impairment in emotion, he or she often cannot make a choice successfully in the alternatives (Dennett, 1995).

2.4.1.1 Definition of Emotion

Attempts to define the emotion can be traced to at least five centuries ago (the time of Descartes), or even earlier, which generated from the fields of religion and philosophy (Dormann, 2003). Emotion can express the motivation (Hirschman and Hollbrock, 1982). In early research, emotion was defined to involve two states, which are positive emotion and negative emotion (Fridja, 1988). Emotion is a complex and organised reflections, which not only concern psychological state (feeling, cognitive appraisals, or passion) but also physiologic state (behaviour) (Dormann, 2003).

2.4.1.2 Emotion and Feeling

Emotion and feeling are often difficult to distinguish or are used to explain each other. In fact, the explanation of "emotion" on the dictionary is "a strong human feeling" (Longman dictionary online). We always say "I feel happy; sad; hungry". Feeling reflects person's inner state of mind and the view of the external things or environment. It is an appraisal of what is good or bad; what can be agreed or disagreed; what is enjoyable or repulsive. It usually relates to an experience, a process, or a stimulus. (TenHouten, 2007)

2.4.1.3 Varieties of Emotion

Frijda (Frijda, 1994) classified the different emotions into four states according to the two characteristic factors:

- The first factor is whether the states are caused by an external stimulus (this stimuli might be a person, an object, or an environment). If yes, it is labelled as intentional; if no, it is labelled as non-intentional.
- The second factor is about duration of the states, respectively recorded as acute (seconds or minutes) and dispositional (whole life).

Table 2.3: Emotion states (Frijda, 1994)

	Intentional	**Non-intentional**
Acute	Emotions	Moods
Dispositional	Sentiments	Emotional traits

2.4.1.4 Four Emotional States

I. Emotions

Emotions are a kind of intentional states. Emotions imply a real time feeling of an experience, a process, or a stimulus, and are elicited by a particular event, an object, or surrounding things and environment, for example, we enjoy this party; tension the examination; and so on. Besides being object-related, emotions are acute states. They only exist for a relatively short period of time (Frijda, 1994).

In addition, people are usually able to very quickly recognize the subject of their emotions when they do a concrete thing or meet a particular event (Ekman and Davidson, 1994). For example, when we taste a dish, we can feel we like it (delicious); or dislike it (e.g. too salty) immediately, and then know what we want to do next (make a decision). However, sometimes a person may be unaware of the reason what can cause their emotion. The reason which causes these situations mostly is because the stimulus (things or events) are not concrete and specific enough.

II. Moods

Substantially, moods often arise by people's own thinking and physical state. Moods are not aimed at a particular thing, but moods can affect people's thinking to the surrounding things (Frijda, 1994). Thus, moods are non-intentional.

There are two main differences between emotions and moods. Firstly, moods are less

intensity than emotions (TenHouten, 2007), and usually are triggered by a series of combined things which people find difficult to recognize (Ekman, 1994). Secondly, comparing with emotions can start at the beginning of a particular event and finish at the end of this event; moods can persist and influence a relatively long time. For example, people might be cheerful for several days because of good weather, good job, and a winning game. In spite of this, moods are still defined as acute states, and only can be kept in a limited time.

III. Emotional Traits

Emotional traits can reflect the characteristic or human attribute of a certain person on mood (Watson and Clarack, 1994). It is interpreted an integral part of our personalities, and usually can last for a long time (several years or even a whole life). For example, this is a cheerful or gloomy person. In addition, like moods, emotional traits are not directed at a particular person, object, or environment. Thus, emotional traits are dispositional and non-intentional state.

People often confuse with moods and emotional traits, because most words which can describe moods can also be used to represent emotional traits, for example, this is a gloomy person, versus, this person is gloomy today (Frijda, 1994). Their difference is that while every people may have a gloomy mood sometime, not every people has a gloomy personality.

IV. Sentiments:

Like emotional traits, sentiments also reflect an integral characteristic of human attributes, and may persist throughout a very long time. The main difference between sentiments and emotional traits is that sentiments need an stimulus from an external object, for example a particular person or something. Besides, sentiments sometimes are more intens than emotions, and have subjective bias. For example, according to Frijda

(Frijda, 1994), being afraid of dogs (sentiment) and being frightened by a dog (emotion), are essentially different states.

2.4.1.5 Three Emotion Theories:

In the foregoing content, we cleared the difference of four affective states. Besides, for emotional design, we still need to understand how emotions are evoked and guide the human behaviours in psychology.

I. Evolutionary Theories

The evolutionary theory is based on the work of Darwin in natural evolution. He described that emotions can influence and control a people's behaviours for survival. In other words, the function of emotions is to help people choose safe actions, and then further create the new rules and needs in human life. For example, people fear fire because they know it is dangerous (emotion). This emotion makes people evolved to a impulse that when the fire alarm rings, they immediately stop and go to exit to increase their chances of survival (rule and need). The evolutionary theory provides us a basic understanding on how emotions are elicited and change our actions. However, this theory only focuses on the basic survival emotions, and cannot explain emotions such as inspiration (Plutchik, 1980).

II. Feedback theories

Nowadays, user needs a product that is much higher than the survival level. Whereas the evolutionary theory focuses on the function of emotions, it can suit to explore how people experience the emotion. Feedback theory primarily focuses on the emotional experience.

The first influential feedback theory was the James-Lange theory which is contributed by William James and Carl Lange in the late of 1800s (Schimmack and Crites, 2005;

Plotnik and Kouyoumdjian, 2010). The James-Lange theory claims people are the centre of the emotional experience. Our brains can translate each particular physiological change, and encode them to a different physiological pattern which is under each emotion or feeling. In short, our emotions are directed by our bodily changes (James, 2007). James (James, 1969), as cited by Plotnik and Kouyoumdjian (Plotnik and Kouyoumdjian, 2010), had illustrated seeing a bear as an example of his theory. When you see a bear, you feel frightened because you run rather than you run because you feel frightened (see Figure 2.14).

Figure 2.14: James-Lange theory

However, the later studies pointed out three problems of the James-Lange theory. The research about qualitative distinction emotions argues that every different emotion is not necessarily encoded with different pattern of feedback (Plotnik and Kouyoumdjian, 2010). Some emotions can share one physiological pattern, such as fear and nervous. Moreover, psychologists assert that emotion identification only based on bodily change is too simple. Sometimes we experience the emotion without any action (Frijda, 1987; Lazarus, 1994).

Walter Cannon and Phillip Bard proposed the Cannon-Bard theory to challenge the James-Lange theory. According to the Cannon-Bard theory, emotional feelings and bodily change happen at the same time. For example, when you see a bear it activates the stimulus transmits to the brain; the brain alerts and produces feelings and emotions, and at the same time, arouses a chain of bodily actions thus, you will simultaneously feel fear and run (see Figure 2.15) (Coon and Mitterer, 2006).

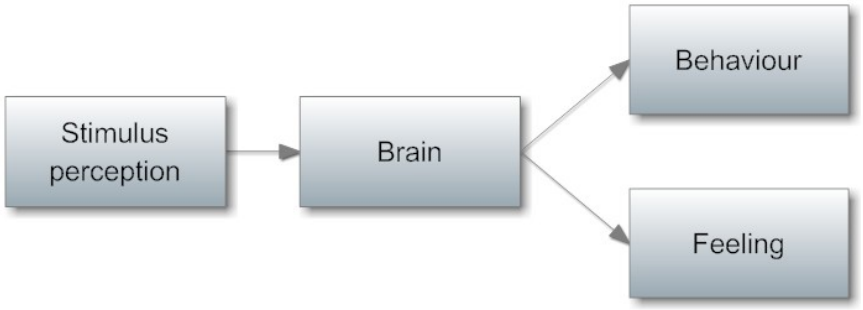


Figure 2.15: Cannon-Bard theory

The other solution of the James-Lange theory is the facial feedback theory. The facial feedback theory applied a response system which was more differentiated than autonomic nervous system. The theory proposes that emotion expressions are generated by facial muscles. All emotions are sorted into six distinct emotions (happiness, surprise, anger, fear, sadness and disgust) based on different expressions of facial muscles. (Schimmack and Crites, 2005; Plotnik and Kouyoumdjian, 2010)

III. Cognitive theories

The essence of cognitive theory is to understand how people make evaluations, judgements and decisions about the external people, objects or environments.

Current cognitive theories can be traced back to the work by Stanley Schachter and Jerome Singer (Schachter and Singer, 1962). They agreed and provided a solution with the James-Lange theory, called two-factor theory (Schimmack and Crites, 2005). According to this theory, an emotion occurred through two distinct factors (steps) synchronously. One factor is physiological arousal. That means if we feel physiological arousal, such as racing heart, heavy breathing or sweating etc. for whatever reason, it interprets that we are experiencing an emotion. The other factor is cognitive interpretation. Schachter and Singer performed a number of experiments and proposed that the physiological arousals feeling of all types of emotions are same. For example, both exciting and fear can make us racing heart, heavy breathing or sweating etc. Thus,

we need to cognize the surroundings to judge what emotion we feel. Figure 2.16 shows an example of two-factor theory. (Sanderson, 2009)

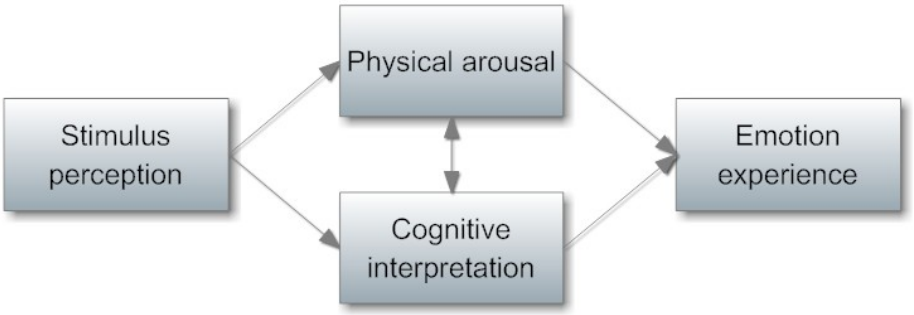


Figure 2.16: Two-factor theory (source from Sanderson, 2009)

Furthermore, Magda Arnold claims that the emotion always implicates an evaluation about weather an object will benefit a person. In his opinion, the experience process of emotion is substantially an appraisal process (Arnold, 1960). According to the cognitive appraisal theory, all emotions are started by people's appraisal of their surroundings. People explain or evaluate or think or judge an environment, an object, or an event, and then, they contribute to or result in an experience and feel different emotions. For example, a person earns one million pounds and hope to feel happy (stimulus); the person appraise and think about what can he/she do for happiness; he or she decides to travel around the world by appraising and thinking (action tendency); feel happy and smiling (behaviour and emotion) (Plotnik and Kouyoumdjian, 2010).

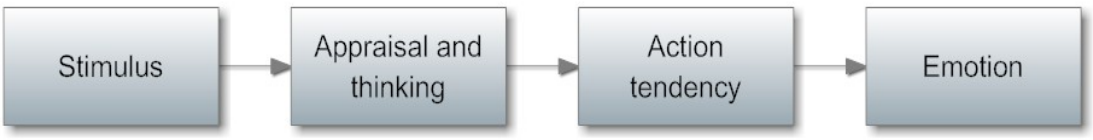


Figure 2.17: Cognitive appraisal theory

2.4.1.6 Summary:

In the last 100 years, psychologists have contributed a variety of definitions or theories of emotion, focusing on different manifestations, such as behavioural reactions, expressive reactions, physiological reactions or subjective reactions. However, until now, there is still no acknowledged theory or model to define emotion. In addition, among the various emotional theories, cognitive appraisal theory is best used in the current design work.

For the present product research, it is not enough to use only basic survival issues to explain how emotions are elicited and to explore how the emotions influence the decision and behaviour of people. Nowadays, there are many advanced design theories and methodologies derived from cognitive theories and human emotion researches. They focus on different design issues, but all of them aim to provide users a positive emotion.

2.4.2 Experience Design

One of most influential theories which derived from emotion research is experience design (Press and Cooper, 2003). Experience design is driven by commercial needs (Pine and Gilmore, 1999; Berry, et al., 2002), and has been widely used in design activities. When most design and innovation studies focus on how to solve core technology problems to improve human life quality, there is a large gap which exists between the growing abundance of advanced technologies and the successful commercial solutions. Experience design refers to the design of product, process, service, or environment to provide a higher quality of experience for users by using culturally relevant solutions (brand experience, e.g. Apple experience) (Pine and Gilmore, 1999; Goulden and McGroary, 2003). A brand experience creation is successful because this company provides a better user experience to customers rather than a user experience design is successful because company has a successful brand strategy and/or a more

famous brand.

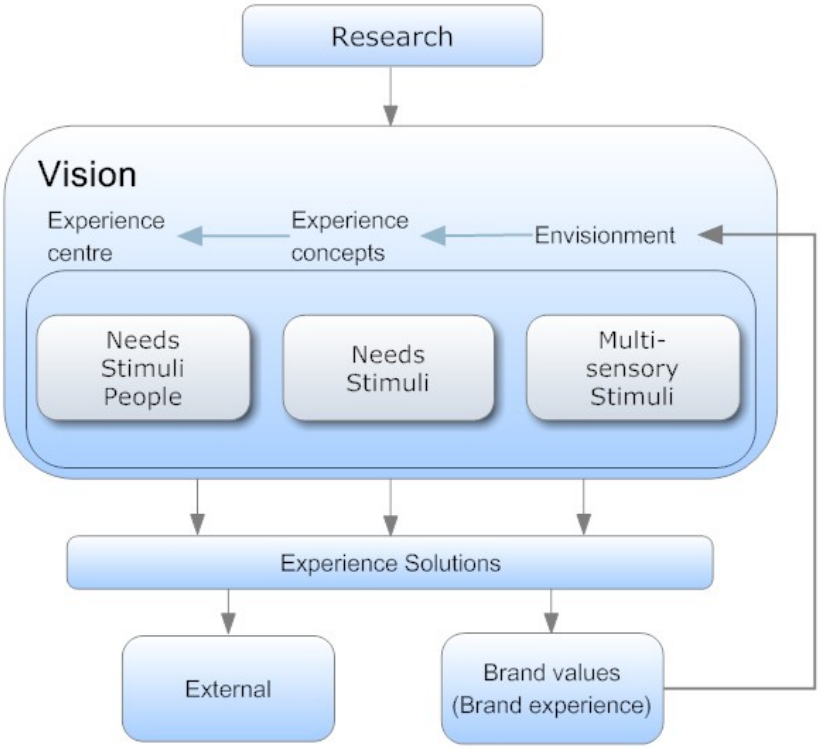


Figure 2.18: Experience creation process

(Goulden and McGroary, 2003)

2.4.3 Interaction Design

Interaction design was first advanced by Bill Moggridge and Bill Verplank in the mid-1980s. It mainly focuses on computer-related products, digital products and information-related products/services. Based on interaction design, four methods based on cognition research were developed and have been widely used in design practices.

I. Activity-centred Design

Donald Norman introduced a hierarchy of actions in an assignment, and advocated the action-centred design process (Norman, 2002). His thinking bases design on activity theory, and emphasizes that people adapts and interacts with the world by understanding activities (Cooper, et al., 2007).

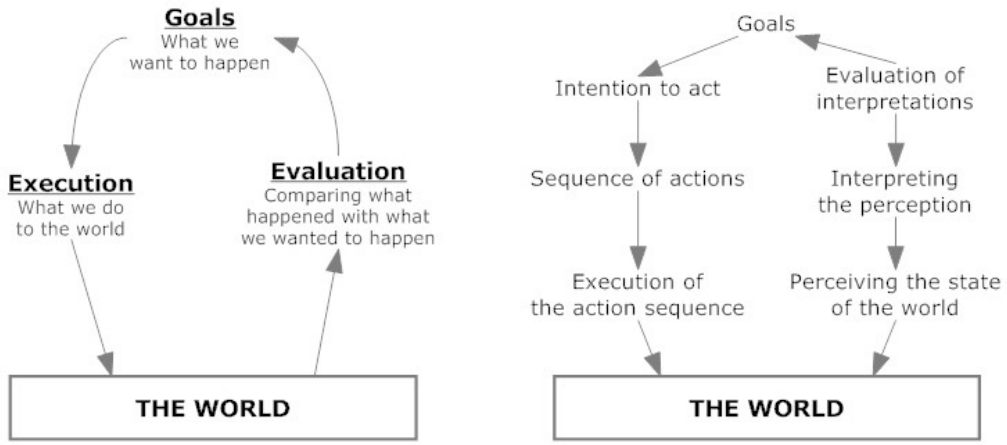


Figure 2.19: Action cycle and seven stages of action

(Norman, 2002)

II. Goal-oriented Design

Alan Cooper provided goal-oriented design method to approach interactive software design based on problem solving. This process is for creating successful interactional experience. According to Alan's method, we must truly understand the goals of users and solve the problem in the best possible way. He introduced the cognitive friction concept, and in modelling stage, behaviour patterns of target users are identified by analysing user persona archetypes. (Cooper, et al., 2007)

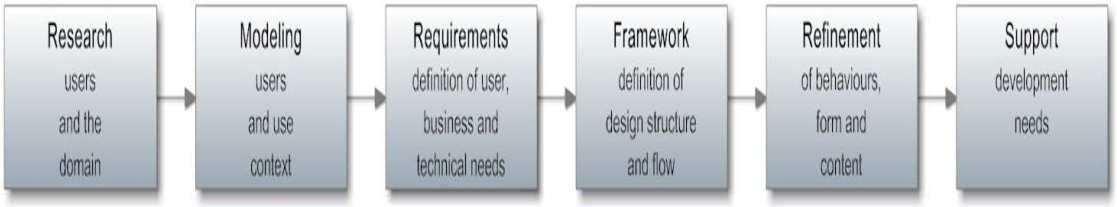


Figure 2.20: Goal-directed design process

(Cooper, et al., 2007)

III. Cognitive Dimensions

Cognitive dimensions framework is an evaluation method for user interface,

programming language and semantic design (Green and Petre, 1996). It uses common vocabularies to evaluate and optimize design solutions.

IV. Affective interaction design

Affective interaction design is based on sensory cognition and emotion. According to this theory, every design must be clear on its key aspects and be aware of their emotional effects on target users, improve positive emotions and avoid negative emotions (Sharp, et al., 2007). The heart of affective interaction design is people, who will feel, explore, use and play with the product (Alben, 1997).

2.4.4 User Centred Design (UCD)

User-centred design (UCD) is a design theory that focuses on people. It is also a multi-stage problem solving methodology and can be used in any product design stage, for example, concept design, engineering innovation, and production development. In recent years, user-centred design as a hot research topic covers so many disciplines, e.g. computer science, virtual technology, product and service design, enterprise management, ergonomics, quality evaluation, etc (Cooley, 2000; Maguire, 2001).

2.4.5 Quality Function Deployment (QFD)

Quality function deployment was introduced by Professor Yoji Akao in 1966. QFD focuses on and cover all customers' needs and transform these needs to design requirements, parts characteristics, process features, manufacture requirements, and build design quality characteristics for the finished product (Akao, 1990). It is a positive theory that can optimize all the processes by working through the customer-supplier chain and functions of product development, and focus on quality (Zairi, 1993).

QFD works by applying a quality house (Zucchelli, 1992). The house of quality (see Figure 2.21) is essential tool which maps customer requirements and then translate them

into tangible goods or services. Essentially the information of the quality house includes customer needs and wants, technical specifications or design requirements, target values, and competitive ratings on products or services.

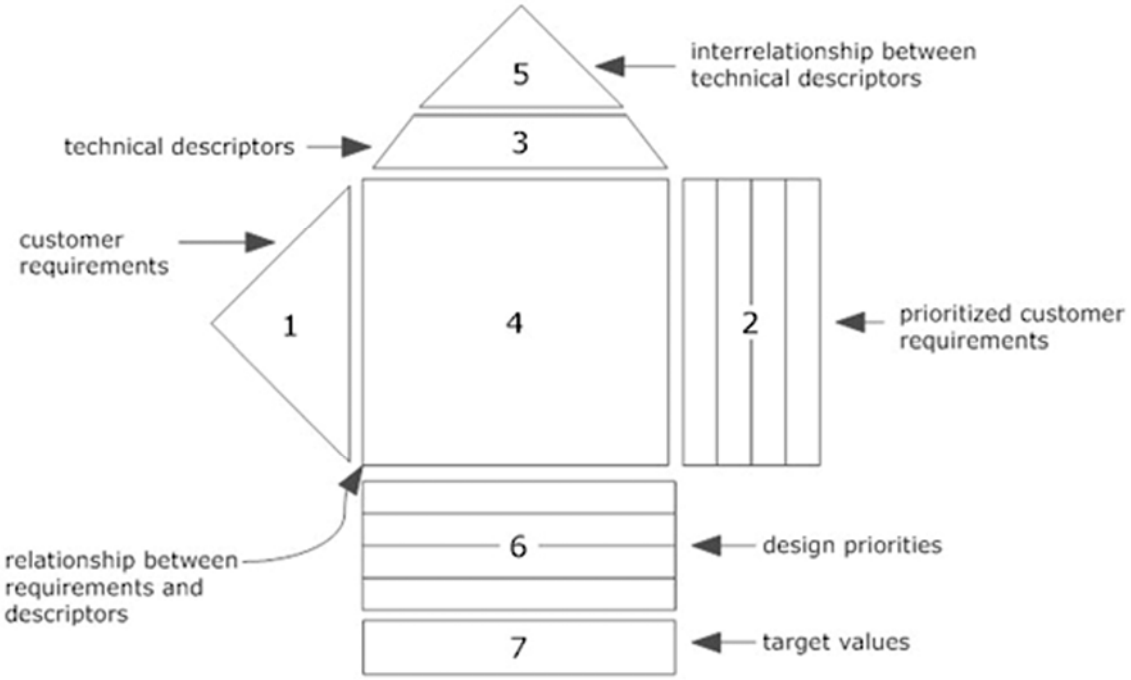


Figure 2.21: The house of quality (Zucchelli, 1992)

2.4.6 Axiomatic Design (AD)

Axiomatic design was introduced by Nam Pyo Suh in 1990. Axiomatic design is a creative design theory and also focuses on customer needs. The essential principles include domains, mapping, design axioms, hierarchy and decomposition, and a series of corollaries and theorems. There are four domains demarcating the different functions of activities in a design practice. There are customer domain, functional domain, physical domain, and process domain (Suh, 2001; Suh, 2005).

The domains create demarcation lines between four different functions of a design activity. The domain structure is illustrated in Figure 2.22. The left domain relative to the domain on its right means “what we want to achieve”. The right domain is the design solution relative to the left domain, and means “how we propose to satisfy the

requirements specified in the left domain".

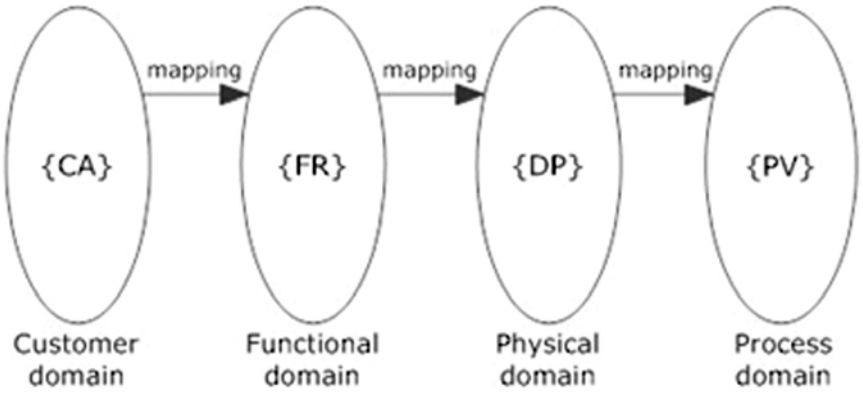


Figure 2.22: Design domains and mapping (Suh, 2001)

2.5 Overview of Design Methods Based on Emotion

The start of a design activity is to consider how to arouse users to feel happy and which product features can evoke and encourage positive emotions. Focusing on how to understand people's feelings and further indentify product features, the research collects and compares 68 methods for emotion design which are recognized by the Design and Emotion Society. Among these, there are 12 methods for measuring the emotional reactions to products, and 8 of them are applied in real design practices; 11 methods can define product features, and 2 of them can directly connect with user emotions and product features. Thus, 10 methods are selected to review in this section.

2.5.1 Measuring The Emotional Reaction to Product

Product Emotion Measurement (PrEmo):

Emotional responses of consumer to a product are difficult to describe. PrEmo is a self report program. The preliminary version of the PrEmo interface was based on 18 animations with 18 measured different emotional character expressions (see Figure 2.23). There are nine positive emotions, i.e. enthusiastic, inspired, desiring, appreciative, pleasantly surprised, attracted, content, fascinated, and softened; and nine negative

emotions, i.e. disgusted, indignant, contempt, aversive, disappointed, dissatisfied, bored, disillusioned, and vulnerable. The limitation of PrEmo is that it can only measure emotions elicited by static stimuli (e.g. sharp, colour), but cannot measure emotions by dynamic stimuli (e.g. product usage) (Desmet, et al., 2000). The rectified version has 14 cartoon character animations, as shown as Figure 2.24.

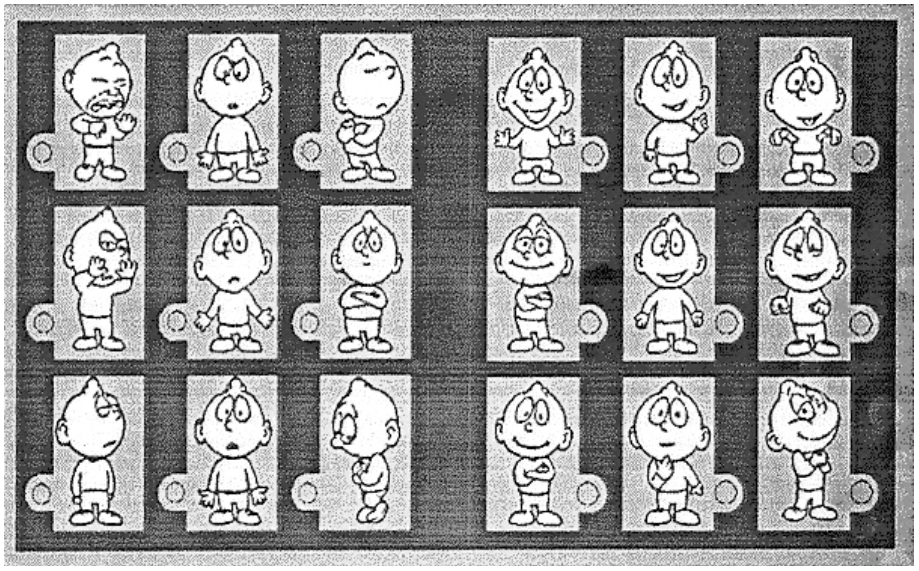


Figure 2.23: PrEmo with 18 emotions (Desmet, 2000)

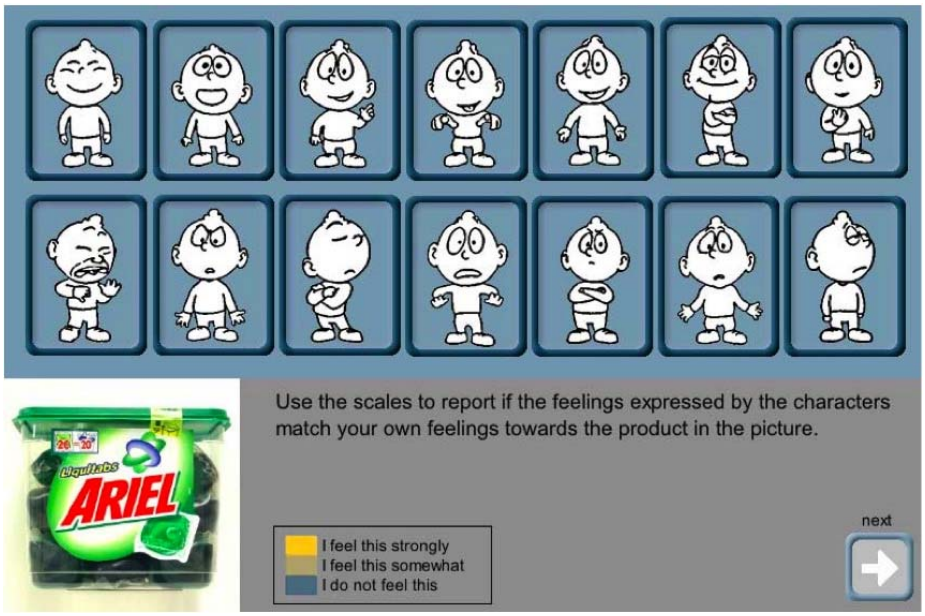


Figure 2.24: PrEmo with 14 emotions

(source from the Design and Emotion Society)

Self-Assessment Manikin (SAM):

Self-assessment Manikin was originally an interactive computer program, and now adds the paper version (Bradley and Lang, 1994). The survey process is firstly making subjects under the stimulus, and then requiring them to appraise their feelings by using three major affective dimensions (valence, arousal and dominance), and each dimension consists five scales (see Figure 2.25). For example, as shown in the top panel of Figure 2.25, the valence dimension includes characters from smiling to frowning.

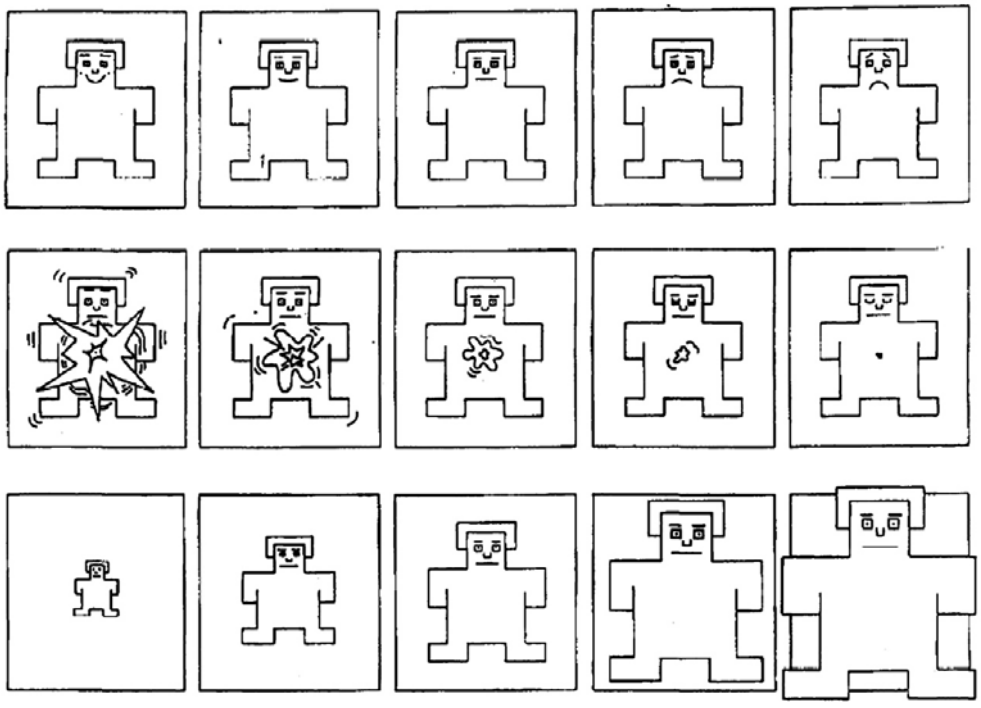


Figure 2.25: Self-assessment Manikin

(Bradley and Lang, 1994)

The limitation of the Self-assessment Manikin can only be used to measure affection along three dimensions and cannot also be used in design development.

Geneva Emotion Wheel (GEW):

The Geneva Emotion Wheel (GEW) was developed by Scherer (Scherer, 2005). The GEW needs the respondent to point out the feeling he or she experienced by choosing

from 20 distinct emotion categories (see Figure 2.26). The 20 emotion categories are arranged in a wheel, and each category has five intensity levels.

The limitation of Geneva Emotion Wheel is that it defines human emotions in 20 emotion categories and each emotion category is demarcated into 6 levels. It is too much to get an accurate and identifiable result in the survey.

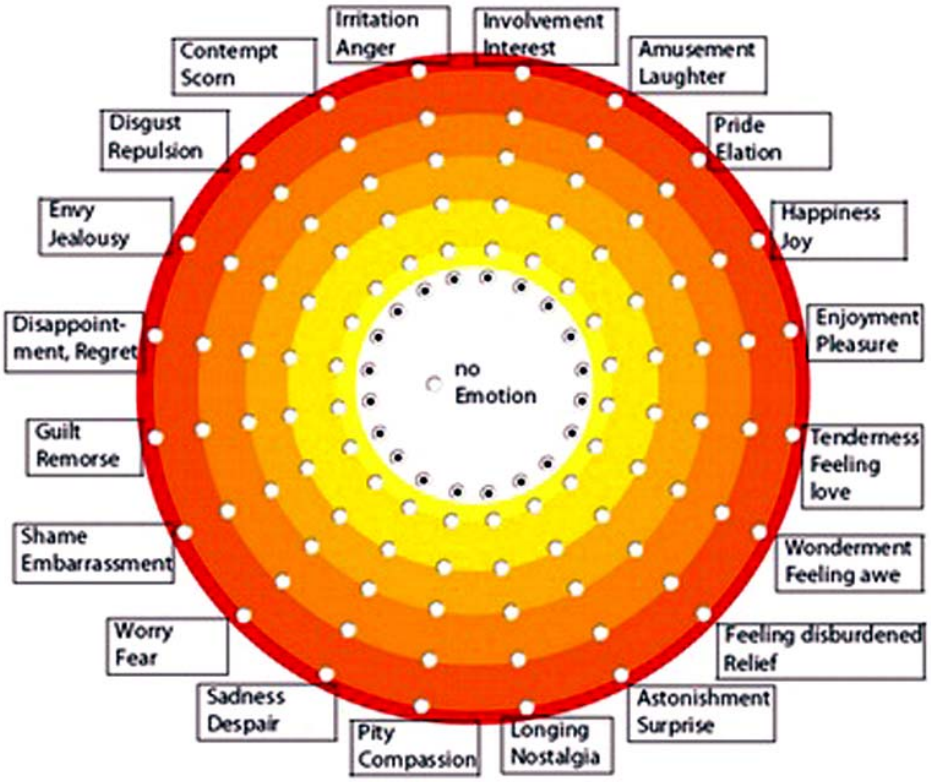


Figure 2.26: Geneva Emotion Wheel

(source from www.wearable.ethz.ch)

PAD (Pleasure, Arousal, Dominance) Emotion Scales:

The foundation of the PAD Emotion Scales is the semantic differential technique. The process needs a questionnaire with 34 pair items of semantic differential scales and companion software. Three main emotion categories (pleasure, arousal and dominance) can be measured by the PAD Emotion Scales. Besides, the method can also calculate the

ranking of basic emotions (Mehrabian, 1996).

The 34 semantic differential scales include 16 pairs of Pleasure-Displeasure scales; 9 pairs of Arousal-Nonarousal scales; and 9 pairs of Dominance-Submissiveness scales.

The limitation of the PAD Emotion Scales is that it provides rather less accurate data to reflect the thinking of people, because the method did not have standard dimensional models of emotions, which is different from other measurement methods.

Differential Emotions Scale (DES):

The Differential Emotions Scale (DES) is developed for distinguishing emotions into validated, discrete categories to avoid multidimensional effect. The DES includes ten emotional categories, and each category consists with three adjectives (see Table 2.4). The ten emotions were identified by Izard (Izard, 1992). They are interest, enjoyment, surprise, sadness, anger, disgust, contempt, fear, shame/shyness, and guilt (Allen, et al, 1988).

Table 2.4: Differential Emotions Scale

1	Interest	Attentive	6	Disgust	Feeling of distaste
		Concentrating			Disgusted
		Alert			Feeling revulsion
2	Enjoyment	Delighted	7	Contempt	Contemptuous
		Happy			Scornful
		Joyful			Disdainful
3	Surprise	Surprise	8	Fear	Scared
		Amazed			Fearful
		Astonished			Afraid
4	Sadness	Downhearted	9	Shame/shyness	Sheepish
		Sad			Bashful
		Discouraged			Shy
5	Anger	Enraged	10	Guilt	Repentant
		Angry			Guilty
		Mad			Blameworthy

Like the Geneva Emotion Wheel, Differential Emotions Scale provides 30 human emotion vocabularies which are too much to get an accurate and identifiable result in the survey, because the understanding for each vocabulary in different person's mind is different.

Emoface:

Emoface was developed by Desmet, and was designed based on the "circumplex of emotions" (see Figure 2.27) (Russell, 1980). Emoface provides 8 male faces and 8 female faces as participants. One or more of the participants describe their feelings. The 16 faces are in an octant, and are arranged from pleasant to unpleasant, and from intense to calm. (Desmet, et al., 2001).

The limitation of Emofaces is that this method can only measure the emotion of pleasantness which is not comprehensive. It cannot measure other emotional expressions which we may feel from the experience. Thus, some relevant emotions may be missing in the survey.

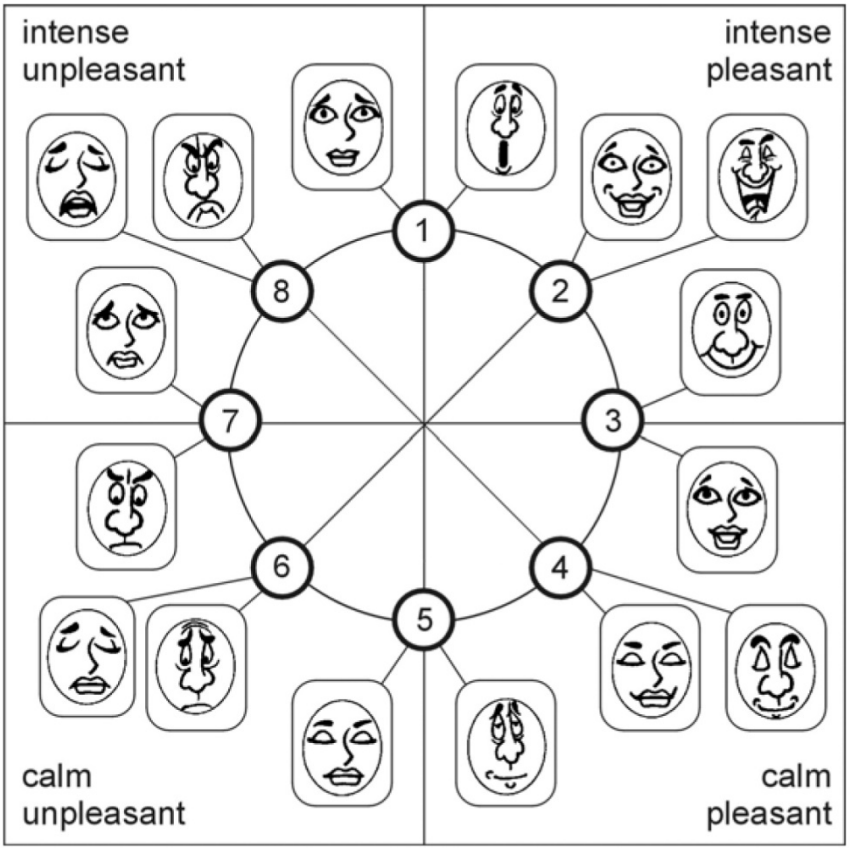


Figure 2.27: Emoface

(source from the Design and Emotion Society)

Emoscope:

Emoscope is a tools group which applies a set of emotional design methods together. It aims to enrich the usability of emotional impact in user experience appraisal process. The Emoscope group includes two approaches: EmoTools and UseTherapist. EmoTools focus on the product. They are incorporated with Emotron (collect emotional data by image methods), Emotracking (collect emotional data by eye tracking), and Pulsetron (collect emotional data by polygraph). UseTherapist focuses on the process of design.

Feeltrack:

Feeltrack is a software which is designed to record the continuous emotional information of people over time. In the test, the participants can move the cursor between two dimensions derived from dimensional theory of Russell (1980). The activation dimension is defined from very passive to very active, and the evaluation dimension is defined from very negative to very positive. (Cowie, et al., 2000)

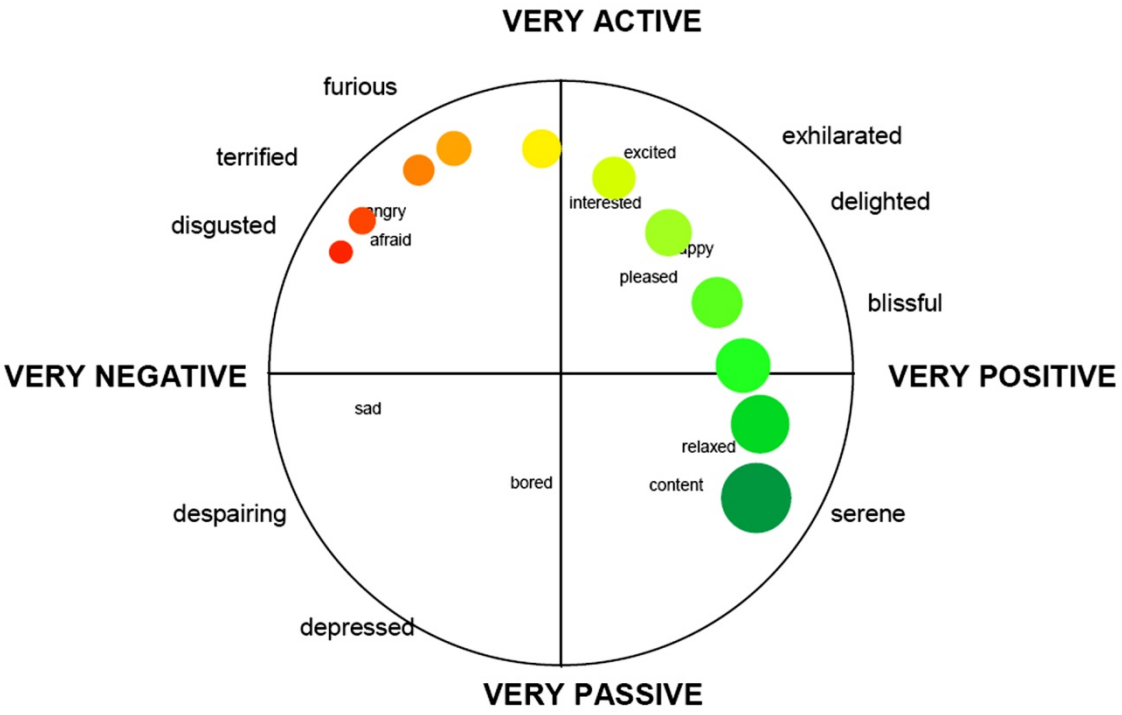


Figure 2.28: Feeltrack example (source from Cowie, et al., 2000)

2.5.2 Defining Product Characteristics

Kansei Engineering (KE):

Kansei Engineering is invented by Professor Nagamachi in the 1970s. It is a consumer oriented technology that translates a consumer's feeling and image of a product into design elements, and has been applied in many fields of product development in Asia (Matsubara and Nagamachi, 1997; Ishihara, et al, 2010). It is also applied in some design

research in Europe (Schütte and Eklund, 2005; Schütte, 2006; Dahlgaard, et al., 2008). Kansei is a Japanese word that means the psychological feeling and image associated with a product. When different people want the same product, there will be many different ideas or images arising in their minds. These ideas or images reflect their expectation for this product, and also become the standard of the product evaluation.

Feeling and image in the mind (Kansei) is an abstract state. This kind of information is difficult to be used in a product development directly. Kansei Engineering technology includes three types: category classification; computer assisted KE system; and KE mathematical modelling. Regarding the methods to measure the customer's feeling (Kansei), KE applied the Semantic Differentials (Osgood et al., 1957), and selected approximately 100 most relevant words from about 800 hundreds customer's feeling words collected from shops and magazines as a Kansei database (Kobayashi et al, 2000). In the first type, category classification breaks down a product into a tree structure of sub-concepts to guide the detail design. A survey or an experiment is conducted to analyse the relations between the consumer's Kansei words and the design characteristics of the product. Common computer assisted technologies is used in the Kansei Engineering that are expert systems (Wang, 2011), artificial neural network and genetic algorithm (Nagamachi, 1995).

Kansei Engineering has provided a practical approach to process affective information for product design, but there are also some problems that need to be solved. Firstly, when selecting Kansei information for KE, the users may not be able to verbalize which product features or areas influence their perception distinctly. Besides, KE cannot deal with individual difference of people's Kansei, because the thinking, feeling and image amongst different people vary generally. Therefore, the Kansei amongst different people is also different.

Image Board:

Image Board is a visual method to understand the emotional experience of respondents for an object, an event or a brand. The materials (images) can source from magazine, photo, advertisement, etc. (McDonagh, et al., 2002).

2.6 Summary and Discussion

Through the literature review, the study further clarified the research objectives and the direction.

Firstly, the future trends of design focus on satisfying the individual emotional needs of the users. As shown in Table 2.2, the relationship between people and design will be "design with/by user", viz. customization. Nowadays, while personalized design is a hot issue in design research, the commercial product design is still largely in brand (cultural) experience design stage. Designers aim to offer their users special experience with quality services in order to get more customers and more profit (for example, Apple, Philips, Starbucks, etc).

Secondly, the difficulty of mass customization design lies in how to identify and satisfy all individual needs within a limited amount of modules. How can we really know users feelings, and which part of product can evoke their positive emotions (such as happiness)? How to cater the preference of people? They are also the main problems in emotion design and present design practice.

Thirdly, among the various emotional theories, cognitive appraisal theory is best used in the current design work. Thus, the user-product cognitive model and other deep studies of this research will also be built on cognitive appraisal theory.

Finally, this chapter has reviewed eight methods of measuring emotional reactions which are introduced by the Design and Emotion Society and have applied in the

current design practices. The main limitation of these methods is how to accurately understand users' feeling and identify which product feature (or which part of product) can arouse a positive emotion.

A basic comparison of the characteristics of the design methods reviewed in this chapter is shown in Table 2.5. According to Table 2.5, there are four methods (GEW, PAD Emotion Scales, DES, and Feeltrace) using emotional words to describe human feelings. However, when we see a vocabulary, no matter it is a noun (e.g. car) or adjective (e.g. happy), different people have different images in their mind. Words in limited categories are difficult to identify a person's real feeling especially for the product details. On the other hand, if the emotional words have too many categories (or levels), it is also difficult to judge the exact and identifiable result of customers (e.g. GEW).

Further, there are another four methods (Promo, SAM, Emoface, and Emoscop) using animations to measure human feelings. Using animations mainly has two limitations. Firstly, it is easier for people to judge positive or negative emotions from an animation, but the same animation in different people may have different meanings and levels, such as enthusiastic, inspired, desiring, appreciative, pleasantly surprised, attracted, content, fascinated, and softened in Promo. It is difficult to achieve an exact and identifiable result during the survey. Secondly, people are easily affected by other things. Vivid animations may arouse respondents' feeling to the illustration, and cause them forget the real feelings about the test product.

At the present, the commonly used measuring methods are applied by survey and questionnaire. The most effective and accurate method to measure the user's feeling is the continuous recording of the participants' instant sensory characteristics. However, these technologies must depend on the special equipments and related software. They are almost limited in laboratory only (e.g. Eye Tracking Technology).

Besides, all methods to measure user emotional reaction cannot be used to identify

product features. Kansei Engineering is a method that can relate human feelings to product features. However, when a number of selected parts are shown to respondents, they may not be able to describe which part can evoke their happiness. Moreover, Kansei Engineering cannot identify the individual feelings.

At last, we can see from Table 2.5, there are only Emoface and Kansei Engineering which can be used to understand user needs, but none of them can be used to identify common needs and personalized needs of users for mass customization design. In addition, there are no methods that can effectively identify which part of a product or what feature can make user to have a positive emotion.

Thus, we still need an effective method to help designers understand what kind of products and which part of product can evoke users' preference, and help designers identify common needs and personalized needs for a product in the early design stage. Furthermore, based on comparison of the existing methods, the new method should also have the following characteristics: easy to use without training and specific knowledge need and can be used in radical innovation and incremental design.

Table 2.5a: Comparison of basic characteristics

Design of Emotion methods	Time required			User involvement		Training required		Specific knowledge needed			Face-to-face administration	
	Short	Medium	Long	Yes	No	Yes	No	Low	Medium	High	Yes	No/ both
PrEmo	X			X			X	X				X
SAM	X			X			X		X	X		X
Emoface	X			X			X	X			X	
GEW	X			X			X	X			X	
PAD Emotion Scales	X			X			X	X				X
DES	X			X			X		X	X	X	
Emoscope		X	X	X		X			X	X	X	
Feeltrace		X	X	X			X		X	X	X	
Kansei Engineering	X			X			X	X				X
Image Boar		X	X		X		X	X				X

Table 2.5b: Comparison of basic characteristics

Design of Emotion Methods	Software		Design strategy		Representation of emotion		Stage of process
	Yes	No	Radical innovation	Incremental changes	Words	Images	
PrEmo	X		X	X		X	Test and evaluate
SAM		X	X	X		X	Test and evaluate
Emoface		X	X	X		X	Understand user/market Test and evaluate
GEW		X	X	X	X		Test and evaluate
PAD Emotion Scales		X	X	X	X		Test and evaluate
DES		X	X	X	X		Test and evaluate
Emoscope	X		X	X		X	Test and evaluate
Feeltrace	X		X	X	X		Test and evaluate
Kansei Engineering	X			X			Explore ideas and concepts Design specification Test and evalutate
Image Boar		X	X	X		X	Understand user/market Test and evaluate

Chapter 3 Methods and Methodologies

3.1 Introduction

Chapter 2 has introduced the development process of human needs, product and the main design shifts since Industry Revolution. It has discussed the relationship between people and design, and has explicated the future trend of customer/user requirements. It has also shown that mass customization can be a new design and development approach suiting the future market and competition.

According to the literature review, it is known that a successful customization process should make a product satisfy the needs of every individual customer. In the present environment of market, the key point of competition is how to exactly identify and satisfy the needs of people. It is not only a problem of mass customization design, but also the main problem in general design activities. Furthermore, in mass customization design, it is impossible for the designers and engineers to meet with every customer to understand his or her needs. Thus, understanding the relationship between different people's feelings and/or thinking and different product features is the main problem of this research.

This chapter will introduce the methods and methodologies used to discover the relationship between people attributes and product features, and to develop a new approach for user preference prediction and evaluation in this research. It mainly includes the following three aspects.

Firstly, a user-product cognitive model will be developed according to cognition psychology, physiology and existing product-emotion research (Desmet and Hekkert, 2002; Norman, 2004; Fenech and Borg, 2007). This model is the base of the study.

Secondly, a quality survey with orthogonal analysis, and an eye tracking experiment are used to investigate the influences and effects of different human attributes on product preference choice.

Thirdly, an artificial neural network model will be built based on the above results. The findings will benefit product designers and engineers to perform personalized design and mass customization design in three stages of a design process: "understand and predict user preference", "explore ideas and concepts", and "evaluate concepts".

3.2 User-Product Cognitive Model

When we see a new product on an advertisement, a magazine, a leaflet, or in a shop, we usually know or predict quickly what it can do and whether we like it. To explore how people perceive and understand a product, we first need to examine how people cognize a product.

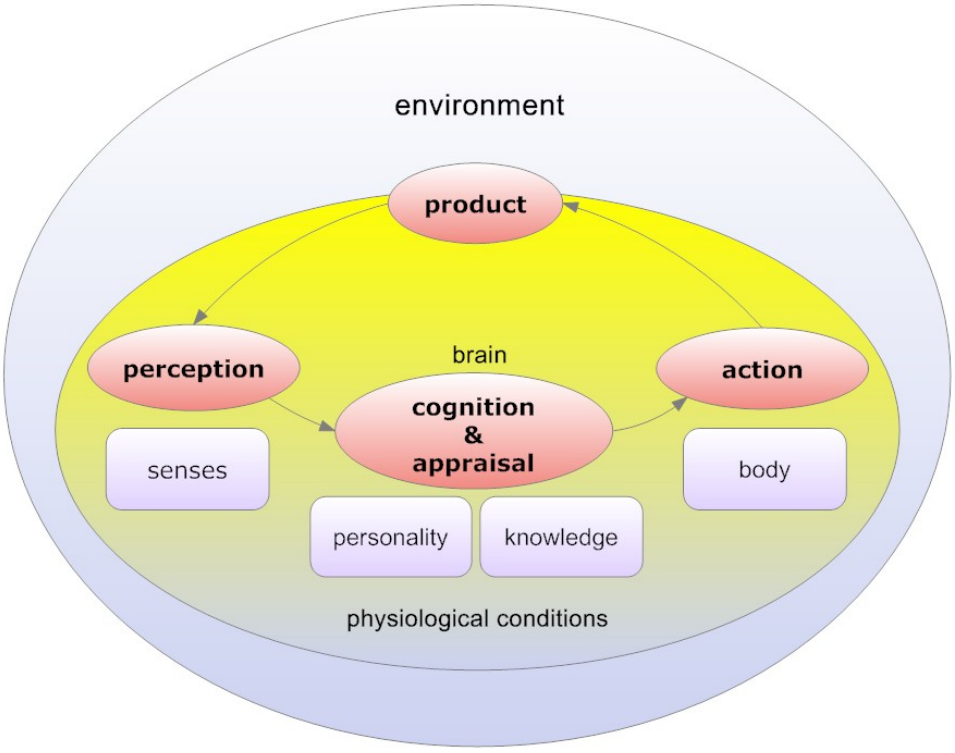


Figure 3.1: User-product cognitive process

As shown in Figure 3.1, we typically experience three steps when we see a product: perceive stimulus (due to product) by senses; cognition and appraisal by the brain; and action by the body (to product) (Arnold, 1960; Plotnik and Kouyoumdjian, 2010).

Firstly, we perceive a product, including its features and performance, through five senses including sight, hearing, touch, smell and taste. Then, the sensory information transmits to the brain. Conversely, our requirements and desires which also are our appraisal standards to a product are reflected as function, shape, colour, material, etc of the product (Figure 3.2).

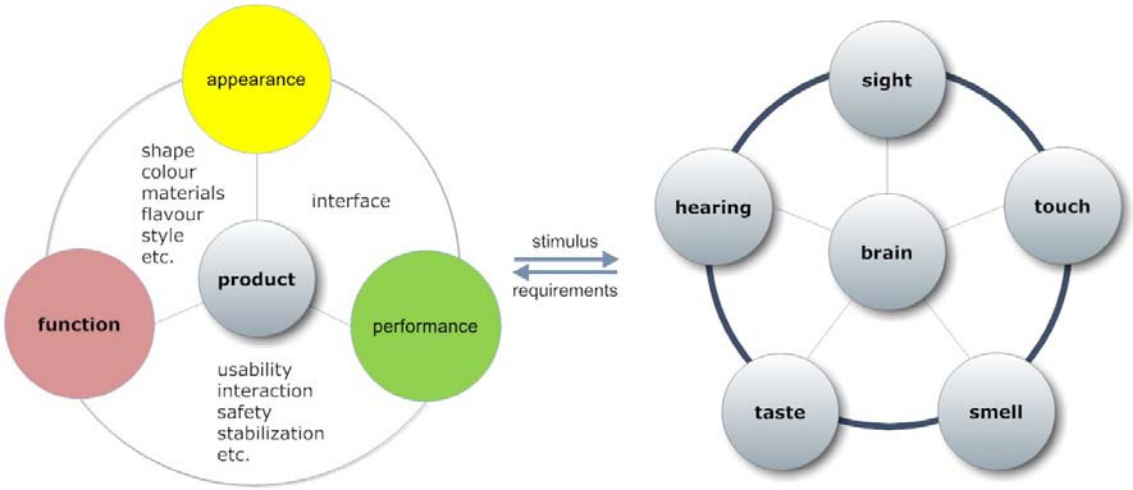


Figure 3.2: Information flow between senses of people and features of products

Secondly, our understandings and decisions are affected by both psychological feeling and knowledge. When different people want the same kind of product, there will be many different ideas or images arising in minds. The reasons for these differences may be very complex, but most of them originate from the past experience. These experiences are stored in the brain as knowledge, and at the same time gradually affect the emotional traits of people. On the other hand, emotion can also affect which part of knowledge will be remembered or be used. According to the definitions and descriptions of different emotional states in Chapter 2, emotional traits and sentiments are two important psychological elements in the product cognition and appraisal stage. They can

influence the formation of various personalities, desires and/or value standards of people, and further affect people's decision and preference choice about a product. Figure 3.3 shows the different aspects of influences when we cognize and appraise a product.

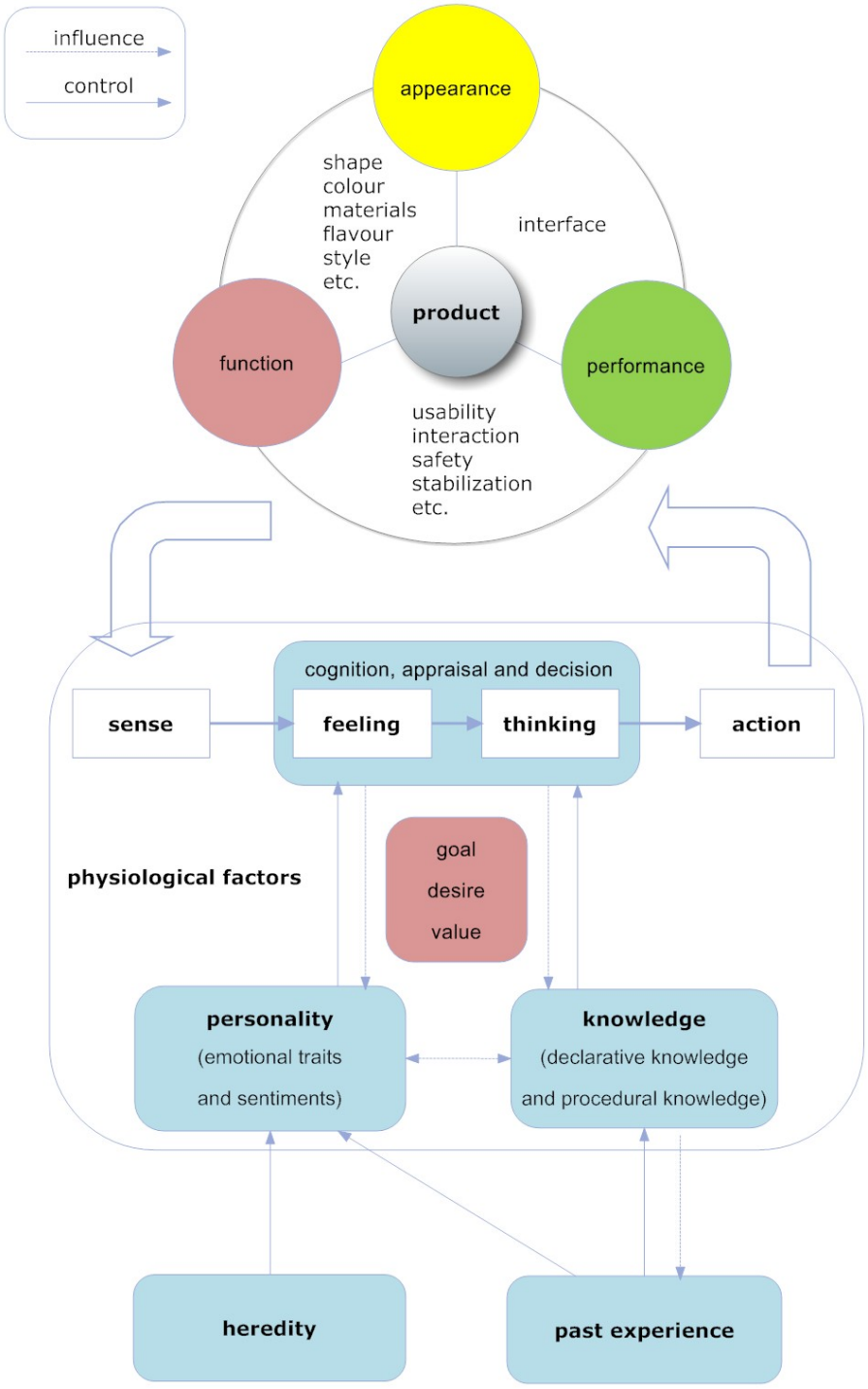


Figure 3.3: Cognition and appraisal of a product

There are two broad types of knowledge: declarative knowledge and procedural knowledge (Cortada and Woods, 2000). Declarative knowledge (knowing what) is the information which concerns the entity or those we can clearly describe, such as a person, an object or an event. Different from declarative knowledge, procedural knowledge (knowing how), also known as imperative knowledge, records a sequence of actions that attain a particular goal, such as using a mobile phone and cooking a dish. In product cognition process, the former is mainly used to represent a product's shape, colour and materials, for example, what a product looks like. The latter, on the other hand, is used to predict and evaluate the functions and interactions of a product, for instance, what functions the product has, and how to use it in everyday life.

In psychology, there are four principles explaining the people's cognition rules. When we need to make judgements and decisions, we typically only employ a small part of the knowledge we could potentially apply. This knowledge may not necessarily be most relevant or reliable, but rather, is always used or come earliest to the mind, and, at the same time, other knowledge may be easily ignored (Robert and Wyer, 2008). Furthermore, when we need to evaluate a product, the bias is easy to occur due to different expectations, feelings or ideas in our minds. If we like a product, we will be inclined to fixate it longer and to notice its advantages.

In addition, besides these knowledge in our minds, there exist other demographic factors which can influence people's knowledge accumulation and decision making, i.e. age and gender. The demographic factors may affect people's aesthetics, feelings and epistemology. Because of this, demographic factors are the basis to distinguish focus groups in design. Besides, some special physiological factors also might affect a person's personality. For example, a person maybe more confident because of his or her beauty or strength; on the contrary a person may have an inferior complex because of disability or weakness.

Finally, according to various goals, desires and value standards of different people, our feelings, and evaluations will lead to different decisions and actions. For example, I want that product, so I will purchase it; I prefer this product, so I will always use it; he does not like it, so he will pay less attention to it.

In conclusion, to integrate Figures 3.1-3.3, a user-product cognitive model is shown in Figure 3.4. The model is built for design research. It provides a connection between the various effect elements of people about human decision making and preference evaluation for products (or product features).

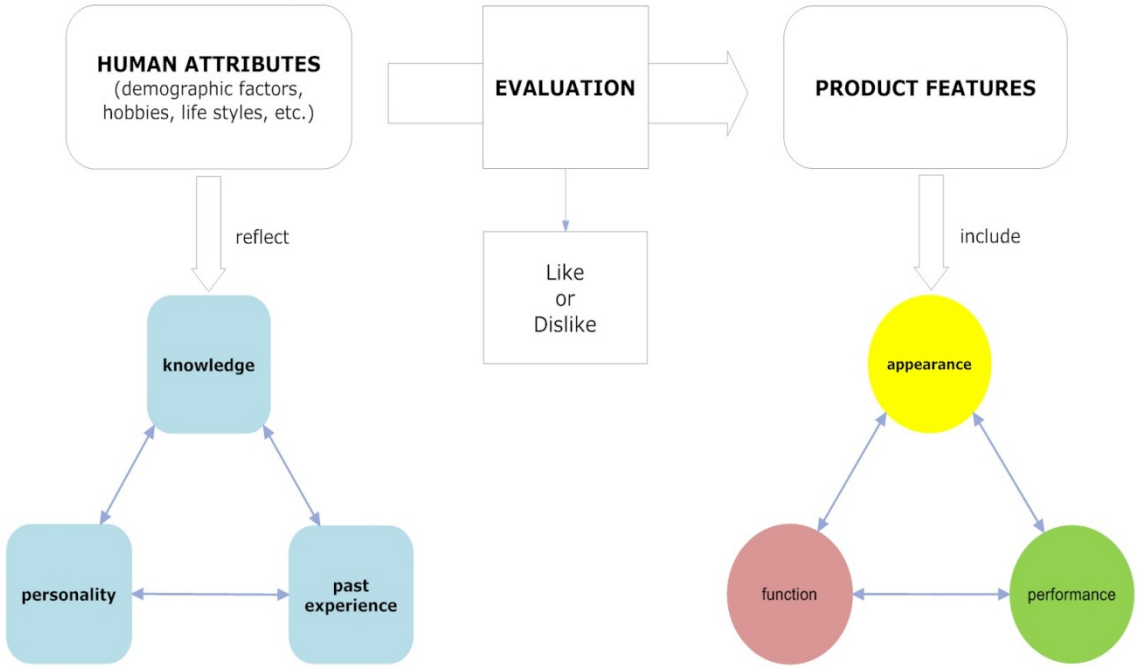


Figure 3.4: User-product cognitive model

The user-product cognitive model includes three sections. They are human attributes, evaluation and product features. Through the above discussion and cognitive appraisal theory, there are three main factors affecting human feelings and decisions including knowledge, personality and past experience. Firstly, knowledge helps us to cognize and to appraise a product's appearance, functions and performance. Personality decides feeling and emotion difference of people. For example, what kind of feelings we want to achieve from a tablet PC? Someone hopes to be encouraged; someone hopes to feel

convenient; someone hopes to feel enjoyment; and someone hopes to feel professional. Finally, according to the past experience, we can judge whether the product can satisfy our desires.

Human attributes can reflect a person's knowledge, personality and past experience. Through building the relationship between human attributes and product features, designers can better understand individual difference of users and identify the customer needs in the early design stage. The user-product cognitive model is the theoretical basis to build the artificial neural network model in a later stage.

3.3 Measurement of Sensory Characteristics

3.3.1 Vision

People cognizing a product depend on five senses (see Figure 3.3). If people want to cognize a thing in a limited time, the most direct and quick way is to observe it. Amongst these senses, we can obtain more information through vision (eyes) than through any other senses (Snowden, et al., 2006). The information involves a product's shape, colour, materials, and style. People can also predict what this product can do, and how to use it by comparing the information and the stored knowledge in the brain. According to this visual information, customers can gain the first impression when they see a product the first time, and judge whether they like them. People can decide whether they like or dislike a product in a momentary time. Khalid (Khalid, 2001) pointed out that "customer needs can then be created very quickly, while other needs are long established". In a typical purchase process, most product information is transferred into brain through vision.

3.3.2 Eye Tracking and Visual Scanning

There are two methods which are used in product design based on vision research, eye tracking and visual scanning.

Eye Tracking: Since the 19th century, psychologists began to analyse human psychological thinking by eye movements. The modern eye tracking technique mainly includes an optical system; pupil centre coordinates extraction system; superimposed system of visual and pupil coordinates; and image data recording and analyzing system. Eye tracking equipment can record the movement information of eyes of users, for example, fixation, saccades, pursuit movement, direction, average velocity, amplitude, size of pupil, and blink. Eye tracking (Vuori, et al., 2004) is a valuable tool for human behaviour (Henderson, et al., 2003) and individual difference research (Galin and Ornstein, 1973). It reveals both physiological actions and behaviour process of the eye. Eye tracking as a design method is widely used in decision making research (Glaholt and Reingold, 2011), and recommender system research (Schmutz, et al., 2009; Castagnos, et al., 2010; Chen and Pu, 2010). However, because of the technical limitations, currently eye tracking can only be applied in the laboratory.

Figure 3.5: Eye tracking device used in the research

(source from SensoMotoric Instruments GmbH)

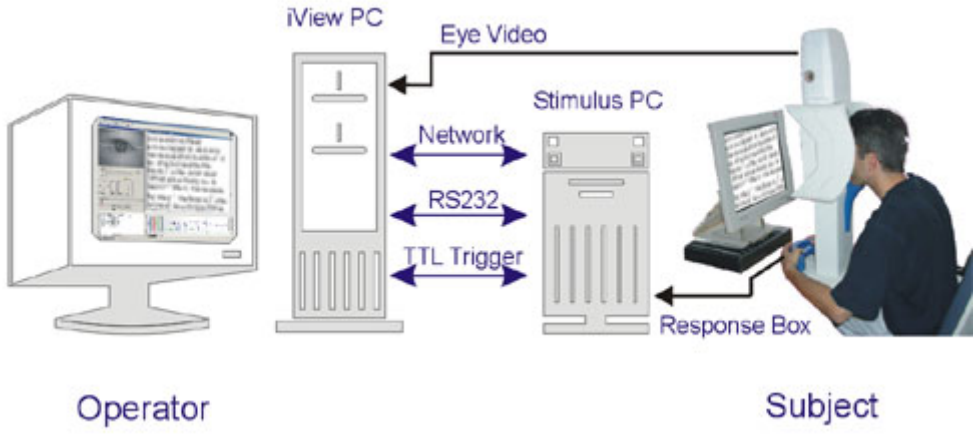


Figure 3.6: Eye tracking device system setting

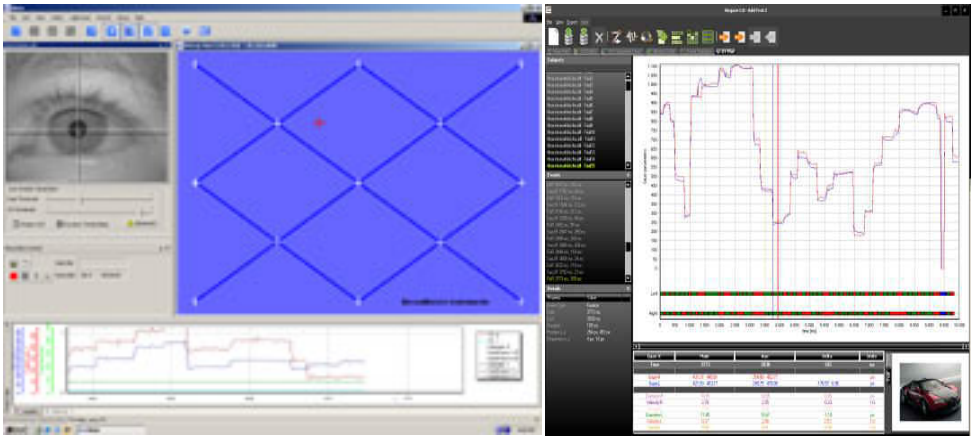


Figure 3.7: Calibration and data analysis

Visual scanning: Similar to the eye tracking, visual scanning is also a method by registering and analyzing the visual information. Its purpose is to identify the most prominent visual features of a product (see Figure 3.8).

Electric Shaver A

	color comb	oval button	dots	LED elements	indicator	separate head
color combination		1	-1	-1	-1	-1
oval button	-1		-1	1	-1	-1
dots	1	1		-1	0	-1
LED elements	1	-1	1		0	0
indicator	1	-1	0	0		1
separate head	1	1	1	0	-1	
sum	3	1	0	-1	-3	-2
relative sum	8	6	5	4	2	3
weight	0,80	0,60	0,50	0,40	0,20	0,30
rank	1	2	3	4	6	5

Figure 3.8: Visual scanning (source from the Design and Emotion Society)

The research aims to survey the people's reactions to different products. Thus, eye tracking technology was selected to employ in this research to help deeply study the customer cognition behaviours.

The research focuses on the cognitive behaviour and preference choice for a number of similar products, but not for different parts of one product. Thus, eye tracking technology was applied in this research.

3.4 Survey for User Preference Choice

3.4.1 Introduction

From the cognition and appraisal model shown in Figure 3.4, different personalities and knowledge backgrounds can affect people's feeling and thinking. In addition, some demographic factors can also influence our cognition and decision. In this research, we define all factors which may affect people's preference choice as the human attributes. Different human attributes can have a varying level of effects on customer cognitive behaviour, preference and purchase decision making. The research of this section aims to explore the influence differences of the various human attributes by using a questionnaire survey with orthogonal analysis.

3.4.2 Aim and Questionnaire Design

This survey aims to compare the influences of customer attributes when customers evaluate whether they like a product using a range of orthogonal arrays.

The survey included twenty different customer attributes in four categories including demographic factors, shape preferences, hobbies, and life styles:

a) Demographic factors: occupation, age, and gender;

b) Shape preferences: round, diamond, and wavy;

c) Hobbies: cooking, party with friends, taking photos for yourself, social (with strangers), shopping, sports, travel, listening music, Internet surfing at home, making plans, playing chess, and pets;

d) Life styles: the time spent in working, and the time spent with family.

Among these human attributes, occupation, age and gender are general demographic factors, which can be gained most easily and accurately. Age (Feller, 2003) and gender (Venkatesh and Agarwal, 2006) are crucial factors and are always used in product marketing research and consumption evaluation. From occupation, we can understand which category of knowledge a person in likely to use and is most conversant with. It means that the person will most likely subconsciously employ this part of the knowledge when he or she needs to judge a thing (Cortada and Woods, 2000). These three demographic factors are the main human attributes in the survey, and further test the cognition differences in the eye tracking experiment.

Shape preferences can reflect a person's psychological experience. People have common understanding of simple shapes, and can associate a series of related sounds, graph and meaning (He and Zhang, 2005). The research uses round, diamond, and wavy shapes to survey the relationship between shape preferences and the feature of product shape (smooth, linear, and streamlined).

Hobbies can mainly reflect a person's personality (emotional traits and sentiments), for example, introvert, extrovert, rational, impulsive, etc. They can also reflect a person's preference, habits and the cognitive bias (Robert and Wyer, 2008). In the following discussion, these sixteen hobbies will be arranged into four groups to analyse their effects on the product preference choice.

From the daily allocation of time, we can predict how many society roles a person usually need to play in the life; which one is the most important; and the life style of a person (Maslow, 1987; Koltko-Rivera, 2006). It helps us to understand the difference of three kinds of people, i.e. career-based people, family-based people and the individual (private-based). The related information can reflect the factors to which they will pay more attention when they need to judge a thing.

Besides, the survey selected 21 different mobile phones, which never launched before and do not have the general mobile phone appearance (participants do not know whether all of them are mobile phone), to study their cognition based on their knowledge and experience. The survey also selected the common digital functions to understand which kind of digital products the participants may know best.

3.4.3 Process

Firstly, a questionnaire survey was designed to collect data. The data will include the twenty human attributes of each participant, and also how they like 21 different types of mobile phones.

Secondly, seven orthogonal arrays were designed to analyse the influences of human attributes on the preference of different product features.

3.4.4 Materials Selection

Digital products as a kind of highly modular product can achieve better product performance by effectively separating the user groups. Digital products are also a kind of products which may achieve mass customization based on the current industrial environment. Mobile phone is a major digital product in the market. It has the characteristics of wide varieties; many possible changes; wide popularization; high frequency of use; and high personalized requirements. Thus, the research has chosen

various mobile phones as the samples for the survey.

The main function of mobile phone is a communication tool. However, different users hope their phones can give them different experiences and performances, e.g. small, direct, interacting, unique, etc. Thus, they may be designed in more than a hundred different shapes, colour surfaces, interactions and attachments. The companies need to segment their target customers to help designers and engineers identify different customer requirements before they brand a new product. We can generally differentiate focus groups according to some demographic factors (i.e. gender, age, etc) and different use environments (entertainment, sports or business).

The study selected 21 mobile phone concept pictures from the Internet. Each participant was presented with these product pictures. All of the participants never saw these products before they completed the questionnaires so their reactions could reflect their natural cognition and decision process. As the study first focused on the preference cognition of consumers, each person in the experiment and the questionnaire survey was asked which product(s) they like most.

All the products selected in this study have not been launched on the market, and do not have any brand marked on them. These help to avoid bias which may be caused by brand or company loyalty.

Comparing the common mobile phone, there are so many concept mobile phones are designed with completely different appearance. I tried to collect various types of mobile phone concepts, including different sizes, shapes, materials, interaction interface and characteristics. Thus, the cognition results of different people may have wide individual differences, and can reflect the knowledge background of the participants more effectively.

In the total 21 products, we will mainly focus on the 6 product concepts (Pictures 1, 2, 6,

9, 15 and 21). They are highlighted with a frame in Figure 3.6. The study employs 21 product choices to help participants to have more comparisons, thus avoiding fuzzy choices. Each product was displayed in the same resolution (300 dpi) and the rendered qualities of the pictures are similar. Every picture only shows limited information about usability. The size would have a small adjustment according to product shape to ensure that participants can see all products clearly. Finally, all product pictures are showed together to the participants on one screen or one piece of paper in a random order.

All the product pictures used in this study are shown in Figure 3.9.

Figure 3.9: 21 digital product concepts

The entire product concepts were collected from Google image search, and selected according to whether it can provide different shapes, colours, materials and interactions to participants.

3.4.5 Hypotheses

The survey and the eye tracking experiment in the next stage were used to test the following hypotheses:

H1: Gender is a crucial factor in consumption evaluation in traditional demography (Venkatesh and Agarwal, 2006) and marketing research. It can affect people's product preference, habits, behaviours (Barletta, 2003) and feelings. Women are good at details and ornament, and pay more attention to fashion and small things. Compared with women, men tend to favour durable (Triplett, 1994) or technical goods. In this research, the study hypothesizes female participants prefer Products 1 and 21 and will fix longer on them. Men would like Products 6 and 9, which appear to have powerful functions.

H2: Similar to gender, age is another important factor in consumption evaluation in traditional demography and marketing research. Particularly for high-tech products and services, age is strongly related to acceptance, adoption and use (Feller, 2003). In this study, Product 6 is completely transparent and very thin, which appears to be most difficult to produce according to current technology. The others are also more advanced than most existing products. Thus, they might be accepted differently by different age groups. For cognitive behaviour, older people should also need a longer time to observe each picture and guess their functions and how to use them. Hypothesis 2 is that age is a significant factor in digital product preference choice.

H3: Occupation is not a general factor in marketing research and rarely used to separate focus group in product design activity. However, occupation can reflect knowledge background of people (such as what kind of things they tend to think about), and further affect cognition behaviours and customer's decision making. Therefore, occupation has been chosen as a factor in this study. Hypothesis 3 is that occupation can influence people's product preference and choice.

H4: Shape preferences can affect person's preference choice. People who like round would prefer the smooth appearance such as Products 1 and 21. People who like diamond would prefer the linear appearance such as Products 6 and 9. People who like wavy would prefer the streamlined appearance such as Products 6 and 15.

H5: Different hobbies can reflect personalities and may influence people to pay attention to different functions. The pictures in Figure 3.9 show different functional feature of the products. For example, Product 1 has sport style, and 21% participants thought it is a phone rather than a medical product (not a mobile phone). 76% participants thought the main function of the Product 6 is communication with surroundings (chat with people or get information). Thus, Hypothesis 5 is that people who like sport would prefer Product 1; people who like communication would prefer Product 6.

H6: Daily schedule can reflect the difference of people's life style. In digital product design, companies usually segment their target user group based on their different life style, for example, business/professional and entertainment or family. Hypothesis 6 is that life style is a significant factor in digital product preference choice.

3.4.6 Participants

A questionnaire survey was conducted in this research, and randomly sampled participants to study the effects of human attributes on customer preference and decision making. The survey was set up both as an online edition and paper edition. In order to avoid large difference from culture, all participants are Chinese from China, UK, US, Malaysia, and Japan. A total of 196 participants from four categories of 12 different occupations completed the survey, and 180 responses are valid. The 12 occupations are classified in four categories according to the level and type of the knowledge associated with each occupation (see Table 3.1). The age ranging from 17 to 58 is divided to four groups: 16-25, 31%; 26-35, 46%; 36-45, 12%; and above 46, 11%. Fifty-nine percent

were female, and forty-one percent were male. Ninety-seven percent of all participants have purchased mobile phones before. Eighty-seven percent of the 180 participants described and hypothesized the functions of the product(s) they like.

Table 3.1: Occupation classification in this study

Knowledge classification	Occupation examples
Macroscopic: people who do these jobs need to notice a bigger societal environment around the world.	manager, finance, marketing
Microscopic: these jobs make employees only need notice at a small range of things.	accountant, sales, service
Skilled: employees need some professional training before they get the job, but rarely or do not need to do further research.	worker, technician, designer
Research/ professional: this kind of work involves learning and exploring science and technology.	professor, lecturer, engineer

3.4.7 Orthogonal Array Design

In this research, there are seven orthogonal arrays which are designed to analyse and determine the influence level of different human attributes. Group separation based on the characteristics of each attribute and the proportion in all population.

Group 1: The first group is demographic factors – occupation, age, and gender. Occupation was chosen as Factor A. there are 12 different kinds of occupations surveyed in this research, and they are classified into 4 levels. Age is Factor B with two levels.

Gender is Factor C with two levels. To study the effects of these factors, an $L_{16}(4\times2^{12})$ array has been chosen in this research which permits 3 factors, A, B and C to be studied (see Table 3.2). The two-factor interactions A×B, A×C, and B×C were also included, and correspond to column 3-5, column 7-9, and column 10 respectively (see Table 3.3).

Table 3.2: Assignment of demographic factors by orthogonal array L_{16} and data

Factor	1st level	2nd level	3rd level	4th level
A: Occupation	A_1= macroscopic	A_2= skilled	A_3= microscopic	A_4= research
B: Age	B_1=under 35	B_2=above 36		
C: Gender	C_1=male	C_2=female		

Continued on next page.

Col. / Group	1	2	6	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	70	10	50	0	20	30
2	1	1	2	55	36	36	9	9	73
3	1	2	1	0	0	0	67	33	0
4	1	2	2	67	0	0	0	0	67
5	2	1	1	36	0	45	9	18	18
6	2	1	2	61	4	48	17	26	30
7	2	2	1	67	44	11	11	11	33
8	2	2	2	50	17	33	0	17	67
9	3	1	1	40	20	60	40	0	40
10	3	1	2	50	8	67	0	42	42
11	3	2	1	40	0	40	0	0	40
12	3	2	2	0	0	33	0	0	100
13	4	1	1	40	70	30	60	40	30
14	4	1	2	30	10	40	30	70	70
15	4	2	1	25	50	17	50	42	25
16	4	2	2	67	33	67	33	33	67

Table 3.3: Columns of interaction effects in orthogonal array (L_{16})

Col. / Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	A	B	A×B			C	A×C			B×C			
1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	2	2	2	2	2	2	2	2
3	1	2	2	2	2	1	1	1	1	2	2	2	2
4	1	2	2	2	2	2	2	2	2	1	1	1	1
5	2	1	1	2	2	1	1	2	2	1	1	2	2
6	2	1	1	2	2	2	2	1	1	2	2	1	1
7	2	2	2	1	1	1	1	2	2	2	2	1	1
8	2	2	2	1	1	2	2	1	1	1	1	2	2
9	3	1	2	1	2	1	2	1	2	1	2	1	2
10	3	1	2	1	2	2	1	2	1	2	1	2	1
11	3	2	1	2	1	1	2	1	2	2	1	2	1
12	3	2	1	2	1	2	1	2	1	1	2	1	2
13	4	1	2	2	1	1	2	2	1	1	2	2	1
14	4	1	2	2	1	2	1	1	2	2	1	1	2
15	4	2	1	1	2	1	2	2	1	2	1	1	2
16	4	2	1	1	2	2	1	1	2	1	2	2	1

Group 2: The second shape is graph preferences – round, diamond, and wavy. Round was chosen as Factor A. Diamond is Factor B, and wavy is Factor C. All the three factors are classified into 2 levels. To study the effects of these factors, an $L_8(2^7)$ array has been chosen in this research which permits 3 factors to be studied (see Table 3.4). The two-factor interactions A×B, A×C, and B×C were also included, and correspond to column 3, column 5, and column 6, respectively.

Table 3.4: Assignment of graph preferences by orthogonal array L_8 and data

Factor	1st level	2nd level
A: Round	A_1= dislike	A_2= like
B: Diamond	B_1= dislike	B_2= like
C: Wavy	C_1= dislike	C_2= like

Col. / Group	1	2	4	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	48	20	48	23	25	40
2	1	1	2	31	13	63	25	50	75
3	1	2	1	53	12	53	35	24	47
4	1	2	2	13	13	63	25	50	50
5	2	1	1	44	31	41	10	18	54
6	2	1	2	47	11	47	0	16	37
7	2	2	1	50	19	31	31	6	56
8	2	2	2	80	0	80	0	0	40

Group 3 to Group 6: Four orthogonal arrays are designed about hobby attributes. There are 16 different kinds of hobbies surveyed in this research, and are classified in 4 groups according to their logical relationships. The attributes in Group 3 include cooking, party with friends, and taking photos for yourself. All of them tend to extroverted and like to communicate with friends. The attributes of Group 4 are listening to music, Internet surfing at home, and shopping which are neutral or tend to introverted. The attributes of Group 5 are sports, making plans, and playing chess. They are logical and rational activities and need patience. The attributes of Group 6 include social (with strangers), travel, and pets. They can reflect who the participants like to communicate: people, nature or animals.

Every attribute factor is classified into 2 levels in the orthogonal array. The $L_8(2^7)$ array has also been chosen to study the effects of hobby factors in this research (see Table 3.5 to Table 3.8). The two-factor interactions A×B, A×C, and B×C were also included, and correspond to column 3, column 5, and column 6, respectively.

Table 3.5: Assignment of group 3 and data

Factor	1st level	2nd level
A: Cooking	A_1= dislike	A_2= like
B: Party with friends	B_1= dislike	B_2= like
C: Taking photos for yourself	C_1= dislike	C_2= like

Col. / Group	1	2	4	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	50	17	67	0	0	17
2	1	1	2	0	33	33	67	67	0
3	1	2	1	42	8	67	25	33	67
4	1	2	2	43	14	71	0	43	57
5	2	1	1	57	14	43	14	43	57
6	2	1	2	33	33	67	33	0	100
7	2	2	1	39	17	61	6	33	28
8	2	2	2	33	13	47	13	20	47

Table 3.6: Assignment of group 4 and data

Factor	1st level	2nd level
A: Listening music	A_1= dislike	A_2= like
B: Internet surfing at home	B_1= dislike	B_2= like
C: Shopping	C_1= dislike	C_2= like

Col. / Group	1	2	4	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	67	50	33	17	17	33
2	1	1	2	50	0	25	0	25	75
3	1	2	1	13	50	13	13	38	50
4	1	2	2	50	19	31	13	44	31
5	2	1	1	33	17	0	50	33	33
6	2	1	2	50	25	58	25	0	67
7	2	2	1	50	20	10	30	10	40
8	2	2	2	46	14	62	16	27	41

Table 3.7: Assignment of group 5 and data

Factor	1st level	2nd level
A: Sports	A_1= dislike	A_2= like
B: Making plans	B_1= dislike	B_2= like
C: Playing chess	C_1= dislike	C_2= like

Continued on next page.

Col. / Group	1	2	4	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	50	11	56	11	17	50
2	1	1	2	33	33	33	22	22	33
3	1	2	1	38	13	63	25	38	50
4	1	2	2	25	25	42	42	17	42
5	2	1	1	56	33	56	0	33	33
6	2	1	2	60	20	60	40	20	40
7	2	2	1	25	0	63	50	13	50
8	2	2	2	52	17	55	14	28	41

Table 3.8: Assignment of group 6 and data

Factor	1^{st} level	2^{nd} level
A: Social (with strangers)	A_1= dislike	A_2= like
B: Travel	B_1= dislike	B_2= like
C: Pets	C_1= dislike	C_2= like

Col. / Group	1	2	4	Results (preference) (%)					
	A	B	C	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	1	0	0	0	33	0	33
2	1	1	2	50	29	39	14	29	39
3	1	2	1	33	0	33	67	0	100
4	1	2	2	47	29	47	6	41	47
5	2	1	1	25	50	50	25	0	50
6	2	1	2	34	10	48	24	31	62
7	2	2	1	25	50	75	0	0	25
8	2	2	2	59	6	53	15	53	53

Group 7: The last group is about life styles – the time spent in working and the time spent with family. Working time was chosen as Factor A. Family time is Factor B. Both of them are respectively classified into 3 levels according to the proportion of the sample size. In addition, if the time which is spent with family is increased, the individual time will be decreased. Thus, Factor B can reflect two aspects of information. To study the effects of these factors, an $L_9(3^4)$ array has been chosen in this research which permits 2 factors to be studied (see Table 3.9). The two-factor interactions A×B and A×C were also included, and correspond to column 3-4.

Table 3.9: Assignment of life styles by orthogonal array L_9 and data

Factor	1st level	2nd level	3rd level
A: Working time	$A_1 \leq 7$ hours	$A_2 = 8$ hours	$A_3 \geq 9$ hours
B: Family time	$B_1 \leq 1$ hour	$B_2 = 3$ or 4 hours	$B_3 \geq 5$ hours

Col. / Group	1	2	Results (preference) (%)					
	A	B	No.1	No.2	No.6	No.9	No.15	No.21
1	1	1	42	17	83	17	25	67
2	1	2	11	33	22	33	56	33
3	1	3	75	0	75	25	0	50
4	2	1	56	22	56	22	22	67
5	2	2	36	14	53	31	28	39
6	2	3	51	20	26	26	20	51
7	3	1	47	26	63	16	32	58
8	3	2	50	20	43	7	10	37
9	3	3	67	11	11	11	44	67

From the above (Tables 3.2-3.9), we can preliminarily observe that the choice difference among the six products is very obvious in some sample groups. For example in the first group of Table 3.9, there are 83% of participants who like

Product 6, but only 17% of participants like Product 9. The percentage difference is larger than 50%. A statistics about percentage difference of attribute groups which is more than 50% is shown as the Figure 3.10.

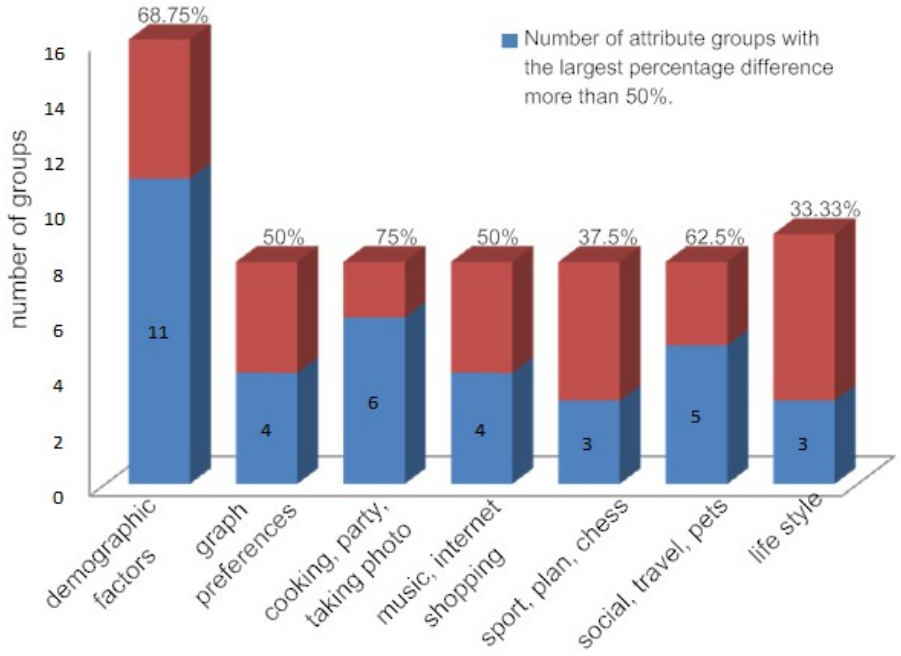


Figure 3.10: Preliminary statistics

From Figure 3.10, we can find that different human attributes have different levels of influence on preference choice for some product features. In the next step, the ANOVA was applied to further study the relationship between different human attributes and product features.

3.5 Eye Tracking Experiment

3.5.1 Introduction

This part of study is to explore the effects of customer attributes on their preference by cognitive behaviour research. An eye tracking experiment with one to one interview was discussed in this section. The way how the potential customers interact with the 21 product pictures, including measurement like fixation time and fixation counts was

studied with an eye tracking experiment. The experiment was used to test Hypotheses 1-3 (demographic factors) introduced above. The experiment examines customers' preference choices and cognitive behaviours through investigating the different behaviours and decisions based on two customer groups for each human attribute, and further test statistically the significance of these differences.

3.5.2 Experiment Process

The questions of the survey were adapted to the eye tracking experiment. In this experiment, there are three pairs of comparison groups based on three human attributes (gender, age and occupation). The participants were recruited from above 180 participants, and they completed the eye tracking experiment first and then filled the questionnaire. The first pair of groups was tested for the gender influence. The participants include ten female and nine male. The second pair of groups was concerned with age attribute. The participants include four people whose ages are below 25, and four above 40. The third pair of groups was tested for occupation influence, and includes eleven participants who have at least 5 years engineering experience including laboratory work (classified as research), and seven participants who have at least 5 years design background (classified as skilled).

Eye tracking was conducted with the non-invasive eye tracking equipment - iView X Hi-Speed 1250 and the analysis software is BeGaze 2.4.175. Each product area was defined as a separate area of interest (AOI) starting from the upper left (Product 1) down to the bottom right (Product 21). Since all of these products belong to the same category (with the same function) and participants never saw them before, the target customers will judge their functions and usability only according to their knowledge and past experiences. Each participant could freely explore the pictures 30 seconds before they began to answer the questions, and then evaluate and choose the product(s) according to the question. Their performance indicators, including eye scan path, fixation time and

fixation count were recorded during the experiment. Figure 3.11 and Table 3.10 show an example of eye tracking. In Figure 3.11, the numbers indicate the sequence of eye movements, and the movement between two numbers without link means saccade.

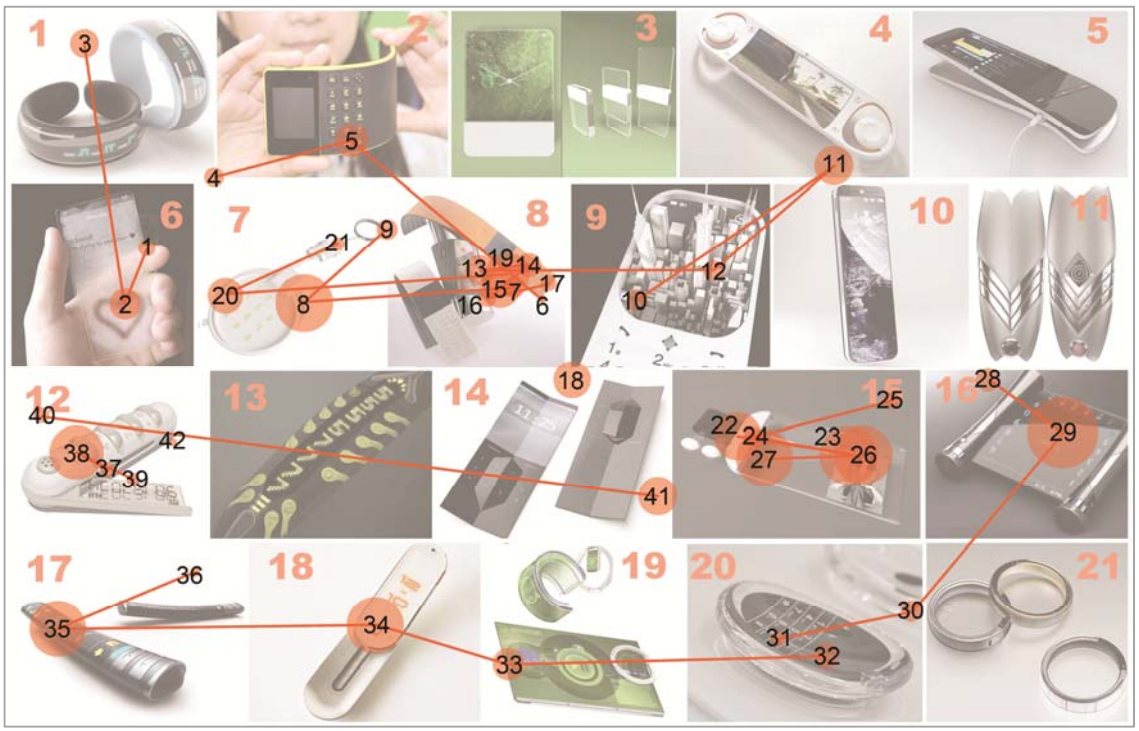


Figure 3.11: Typical scan path

The test is with the question - which product(s) do you expect most?

Table 3.10: Dwell time and fixation count of Figure 3.11

The test is with the question - which product(s) do you expect most?

AOI No. 1-11	1	2	3	4	5	6	7	8	9	10	11
Dwell time (ms)	206	234	0	274	0	362	936	1450	284	0	168
Fixation count	1	1	0	1	0	2	4	8	2	0	1
AOI No. 12-21	12	13	14	15	16	17	18	19	20	21	blank
Dwell time (ms)	816	0	528	1936	506	456	396	220	494	0	132
Fixation count	5	0	2	6	1	2	1	1	3	0	1

As shown in Table 3.10, we can know that the participant fixed at Products 15 and 8 longer than other products, also with higher fixation counts. The questionnaire result

shows that this participant's favourite products are also Products 8 and 15.

Compared with the results from both the experiment and the questionnaire, it can be found that about 75 percent of the products which the participants gazed the longest time are the same as their preference products they actually chosen (they have been told to select which one they like most).

3.6 Artificial Neural Network

3.6.1 Introduction

Common computer technologies used in the Kansei Engineering (mainly Type II) are expert system, artificial neural network (ANN) and genetic algorithm. Amongst these, artificial neural network is widely used to model complex mathematical and logical relationships. ANN as an information processing system is invented based upon the understanding of biological neural systems, and it typically consists of many nonlinear computational elements with certain architecture (Lippmann, 1987). Until now, many researchers have used artificial neural network technology in design process, for example, product conceptualization evaluation (Ventura, et al., 2005; Yu and Yan, 2006; Yan, et al., 2011), product form optimization (Hsu, et al., 2000; Hsiao and Huang, 2001; Hsiao and Tsai, 2005; Chen, et al., 2010), colour optimization (Lin, et al., 2008), and product development (Tallón-Ballesteros and Hervás-Martínez, 2011).

As previously mentioned in Chapter 2, Kansei Engineering has provided a practical approach to process affective information for product design, but it cannot deal with individual difference of people's Kansei. Artificial neural network is used in this research to address the problem about predicting individual customer preference. It can also be used as an evaluation method in design process. Customers evaluate a product in relation to their own attributes. The psychological feeling of individual customer depends obviously upon the product features, but importantly it is also conditional upon the

customer's personality and experiences, which may be termed as customer attributes. Customers evaluate a product in relation to their own attributes. They should generally exhibit complex, nonlinear relations in the customer's evaluation of a product, for which the ANNs will be necessary. It is believed that the ANNs can also provide sufficient capability to address the difference of individual psychological feeling by exploiting the relationship between customer attributes and product design elements, which is presented in this study. This is essentially an extension or generalisation of Kansei Engineering.

3.6.2 Artificial Neural Network Model

When a consumer wants to choose a product, there will be an image arising in his or her mind. This image determines the criteria for judging the product. The factors which affect people to generate an image in his or her mind for making choice are very complex, but most of them originate from the experience information people stored in their brains. Formation of new product requirements is actually based upon these past experience information of their users. The main challenge for mass customization is how to predict and identify the individual customer feeling accurately and objectively without one to one interview in design stage.

This research attempts to integrate the cognitive behaviors into the neural network system. It requires a model to learn and match the relationship between customer attributes and product evaluation (or design elements), and once trained it will be able to predict which product elements and/or features the customer will prefer, thus greatly assist product design. The ANNs model is built based on the user-product cognitive model shown in Figure 3.4.

A three layered feed-forward neural network has been selected, which has the customer attributes as the input layer, the product evaluation as the output layer, plus one hidden layer. The input layer includes the codes for customer attributes including personalities, and the output layer is the code for product evaluations.

The code selection of the input layer focuses on the customer attributes that likely influence the customer cognitive behaviours, which may be related to many disciplines such as perceptual psychology, cognitive psychology and information science.

Figure 3.12 shows a multiple ANNs model. The individual differences are largely attributed to the different experiences of people in their life. Although various kinds of customer attributes can be coded, it has been found difficult to simulate all personalized behaviors of the whole population using one simple ANN. As a consequence, different neural networks are used for each group of customers, with the customer classification determined by self-organizing feature maps (SOFM). Each BP ANN then only models one group of customers, and this has significantly improved the performance. This approach may be generally used in the modeling of complex processes (Yang and Butler, 1994; Zhang, et al., 1997).

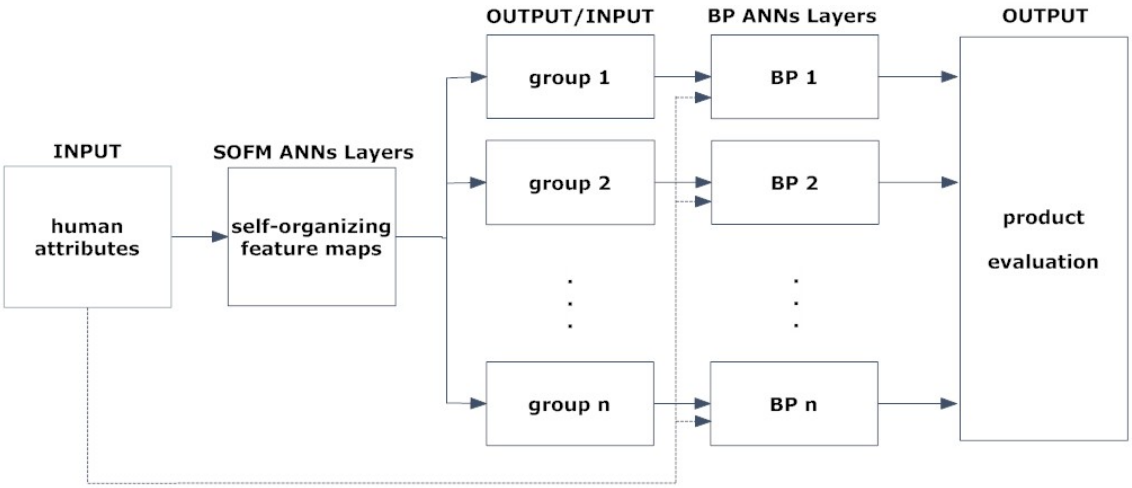


Figure 3.12: User-product ANNs model

3.7 Summary

The research has established user-product cognitive model. People perceive a product's appearance, functions and performance through sense, then cognize and evaluate this product based on knowledge, personality and the past experience, then make judgment

whether they like it or have new desires.

Based on user-product cognitive model, there is a connection between the human attributes and product features. The research makes use of survey, orthogonal analysis, and eye tracking experiment with interview to investigate the significant factors when people cognize a new product.

Finally, an artificial neural network model was built based on user-product cognitive model and the significant factors. This model establishes the relationship between human attributes and product features. It will be a prediction and evaluation tool which can be used in mass customization process. The input layer is human attributes, and the output layer is user group separation or product features.

Chapter 4 Results and Discussions

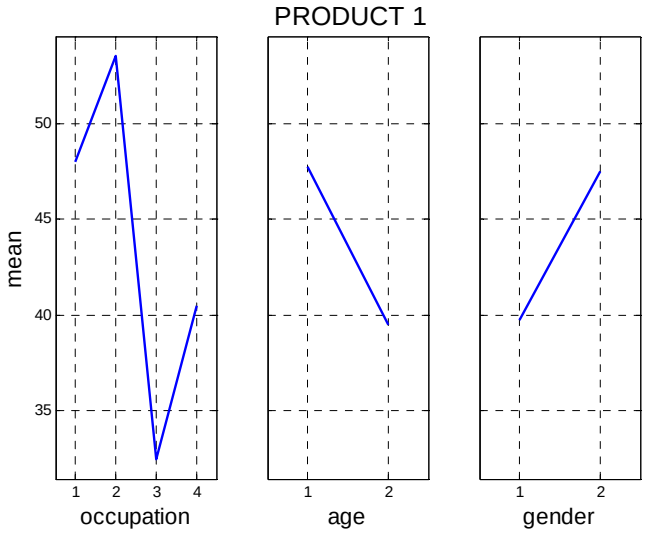
4.1 Introduction

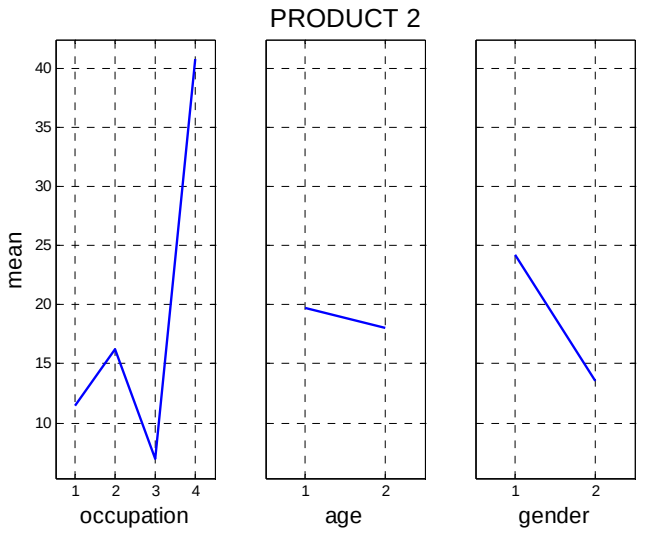
Chapter 3 has introduced the methods and methodologies which were used in this research. This chapter will present the results of orthogonal analysis, eye tracking experiments and artificial neural network.

4.2 Results of Orthogonal Analysis

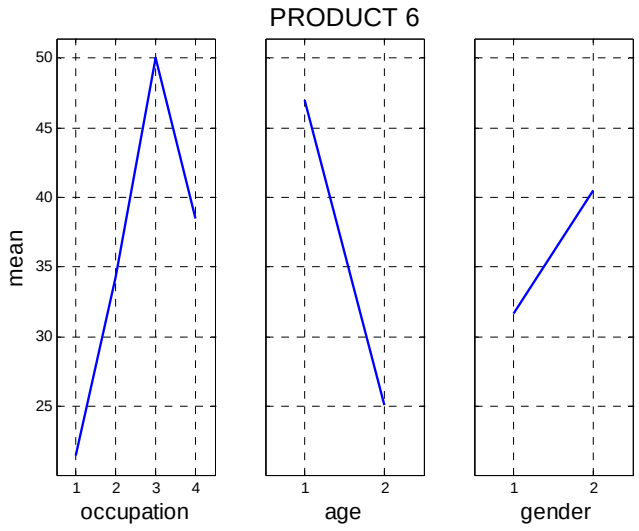
4.2.1 Demographic Factors

Demographic factors are the most significant index in customer and product research. It is also the research emphasis on the human attributes in this study. Performing sixteen groups of surveys (see Table 3.2), the main effect plots were shown in Figure 4.1 (pages 95-97) and the ANOVA results were shown in Table 4.1 (pages 98-100).

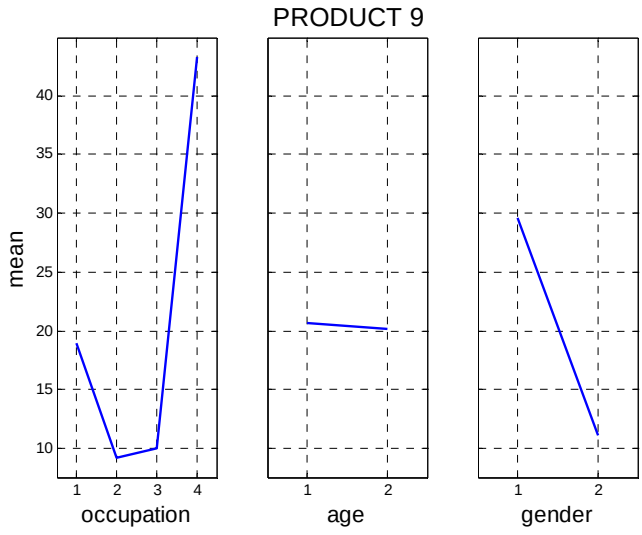



PRODUCT 2
mean
occupation
age
gender


2


PRODUCT 6
mean
occupation
age
gender


6


PRODUCT 9
mean
occupation
age
gender


9

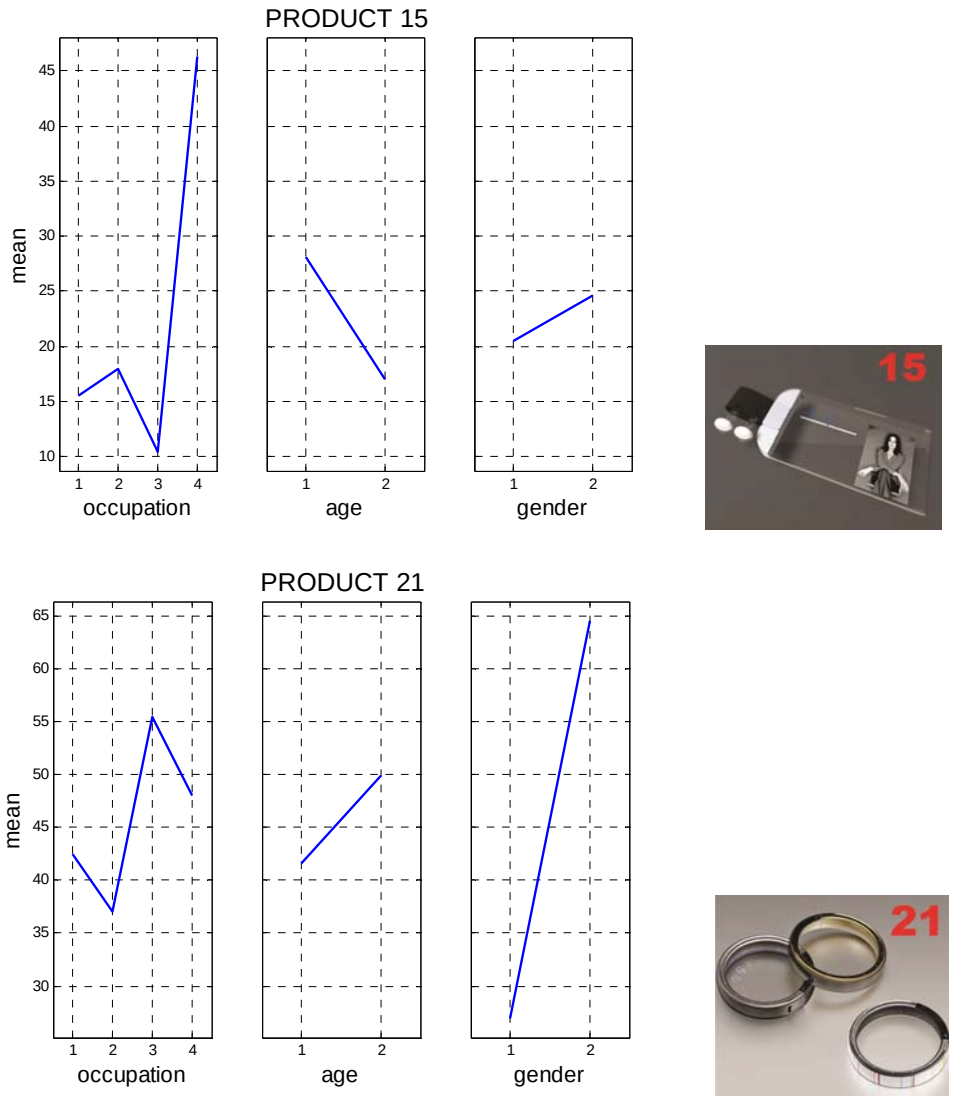


Figure 4.1: Main effect plots of demographic factors

(occupation: 1-macroscopic, 2-skilled, 3-microscopic, 4-research;

age: 1-under 35, 2-above 36; gender: 1-male, 2-female)

Table 4.1: ANOVA of demographic factors (**α_1=0.05, *α_2=0.10)

Product 1				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	994.1	3	331.4	0.30
B	278.7	1	278.7	0.25
A×B	1395.6	3	465.2	0.42
C	230.4	1	230.4	0.21
A×C	916.3	3	305.4	0.28
B×C	113.5	1	113.5	0.10
Error	3288.6	3	1096.2	
Total	7217.2	15		
Product 2				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	2722.1	3	907.4	4.78*
A×B	1533.1	3	511.0	2.69
C	455.8	1	455.8	2.40
A×C	1358.7	3	452.9	2.39
Error	948.6	5	189.7	
Total	7018.3	15		

Product 6

Source	Sum Sq.	d. f.	Mean Sq.	F
A	1646.0	3	548.7	4.53
B	1918.4	1	1918.4	15.84**
A×B	1298.0	3	432.7	3.57
C	314.7	1	314.7	2.60
A×C	783.0	3	261.0	2.16
B×C	226.2	1	226.2	1.87
Error	363.3	3	121.1	
Total	6549.6	15		

Product 9

Source	Sum Sq.	d. f.	Mean Sq.	F
A	3029.1	3	1009.7	3.37*
A×B	1297.7	3	432.6	1.44
C	1351.5	1	1351.5	4.51*
Error	2398.3	8	299.8	
Total	8076.6	15		

Product 15

Source	Sum Sq.	d. f.	Mean Sq.	F
A	3110.9	3	1037.0	12.83**
B	494.1	1	494.1	6.12*
A×B	318.6	3	106.2	1.31
C	66.2	1	66.2	0.82
A×C	1019.8	3	339.9	4.21
B×C	686.1	1	686.1	8.49 *
Error	242.4	3	80.8	
Total	5938.2	15		

Product 21				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	734.4	3	244.8	1.76
B	266.7	1	266.7	1.92
A×B	1586.5	3	528.8	3.81
C	5561.9	1	5561.9	40.07**
A×C	567.4	3	189.1	1.36
B×C	689.3	1	689.3	4.97
Error	416.4	3	138.8	
Total	9822.7	15		

In all participants, there are 43.5% of them who preferred Product 1. It can be seen from the above Figure 4.1 and Table 4.1 that for Product 1, the most significant factor is in occupation. The proportion of the participants who like Product 1 in the skilled occupation group (worker, technician and designer; 53.5%) is more than that in other occupation groups (47.8%, 32.5% and 40.4%), but the ANOVA result shows that the effect of gender, age and occupation factors are not significant. Product 1 has the widest target users based on demographic factors amongst six products. The study hypothesized that the significant factors for Product 1 might be due to other human attributes (e.g. hobbies, life style, etc.), and we explored them in the next section.

In all participants, there are 19.0% of them who preferred Product 2. For Products 2, occupation is a significant factor (F=4.78*). Although the picture emphasizes the photo function of the product, in the survey, 80.0% of the participants thought that Product 2 is a phone, because its form matches their understanding about a phone, for example, screen and number keys. Some participants who like Product 2 said that the material is interesting.

In all participants, there are 36.1% of them who preferred Product 6. For Product 6, as shown in Table 4.1, age is a very significant factor (F=15.84**). The proportion of young people who like it (47.0%) is more than the elder people (25.1%). Besides, the proportion of people who engage in macroscopic occupation (manager, finance and marketing) is less than the proportion in other occupation groups (see Figure 4.1). There are 76% of the participants who thought that the main function of Product 6 is communication, and style or interaction is similar to the existing smart phone (e.g. iPhone). Through the related knowledge about the existing smart phone, they can judge its capability initially. For example, Product 6 may have a lot of different functions, but it may be easy to break and the battery may not be good, because it is very thin.

In all participants, there are 20.4% of them who preferred Product 9. Comparing with the other phones, Product 9 has a normal appearance. It is characterized by showing a strong visual function. Occupation (F=3.37*) and age (F=4.51*) are the significant factors which can influence customer preference choice. There are 70.4% of the participants who thought that Product 9 is phone rather than a 3D map or a 3D video player. The most people who are interested in it are male (29.6%) and those who engage in research occupation (43.3%).

In all participants, there are 22.6% of them who preferred Product 15. For Product 15, as shown in Table 4.1, occupation (F=12.83**) and age (F=6.12*) are significant factors. Product 15 is a phone which has the same style as Product 6. However, for occupation factor, their plots on the 3rd level of occupation (skilled occupation) are obviously different (see Figure 4.2). In addition, there are 69.7% of the participants who thought that it is a digital memory device. Thus, in personalized design and mass customization design, if the detail of a product is changed, the difference can also change people's cognition and feelings.

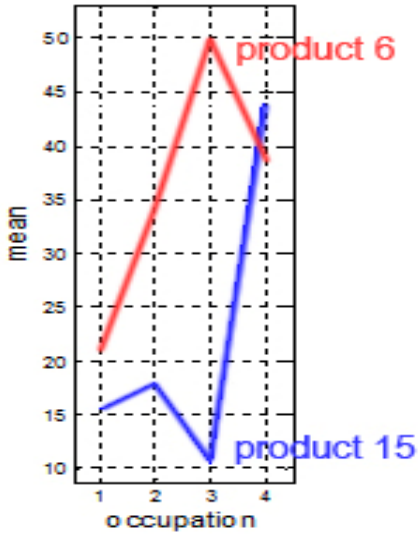


Figure 4.2: Different plots between product 6 and product 15

Finally, in all participants, there are 45.7% of them who preferred Product 21. For Product 21, gender is a very significant factor (F=40.07**). There are 27.3% of the participants who thought that it is an ornament. In addition, generally, the two-factor interaction effects are not significant except for Product 15.

4.2.2 Shape Preferences

Performing eight shape preference groups of surveys, the main effect results of ANOVA are summed up and shown in Table 4.2.

Table 4.2: ANOVA results of shape preferences

("*" means significant, α_2=0.10; "**" means very significant, α_1=0.05)

Product	Round	Diamond	Round × Diamond	Wavy	Round × Wavy	Diamond × Wavy
	F=6.32 *				F=9.14 **	
		F=18.84 **		F=41.64 **	F=20.65 **	
			F=6.20 *			
	F=55.22 **	F=13.31 *		F=30.80 **	F=13.25 *	F=13.31 *
	F=623.45 **	F=44.38 **	F=35.82 **	F=98.13 **	F=189.75 **	
					F=12.15 **	

According to Table 4.2, shape has a more complex influence on customer preference choice. Compared with demographic factors which usually only involve single significant attribute (except Product 6), there are at least two shape factors which can

affect the participants preference for each product.

It can be seen from the above table that for Products 1 and 21, the most significant factor is round and wavy interaction (F=9.14**; F=12.15**); the round and diamond interaction can influence customer preference for Products 6 (F=6.20*). Product 2 is a linear product (rectangular appearance), but its special material also shows a streamlined feature for this product. Thus, for the single human attribute, diamond (F=18.84**) and wavy (F=41.64**) are significant effects for Product 2. Finally, comparing with the other products, Products 9 and 15 have shown various shape features. The significant factors involve smooth, linear, and streamlined elements. Thus, the significant factors of shape preference are also multiple and more complex than the products which have simple shape (e.g. Products 1, 2, 6, and 21).

4.2.3 Hobbies

Product 1: For Product 1, the most significant factors are taking photos (F=10.61**), sports (F=13.0**), travel (F=12.9**) and making plans (F=21.4**). For the people who preferred Product 1, the proportion of the participants who like sports and travel is higher than the proportion of the participants who do not like sports and travel; and the proportion of the participants who like taking photos and making plans is less than the proportion of the participants who do not like taking photos and making plans (see Figure 4.3).

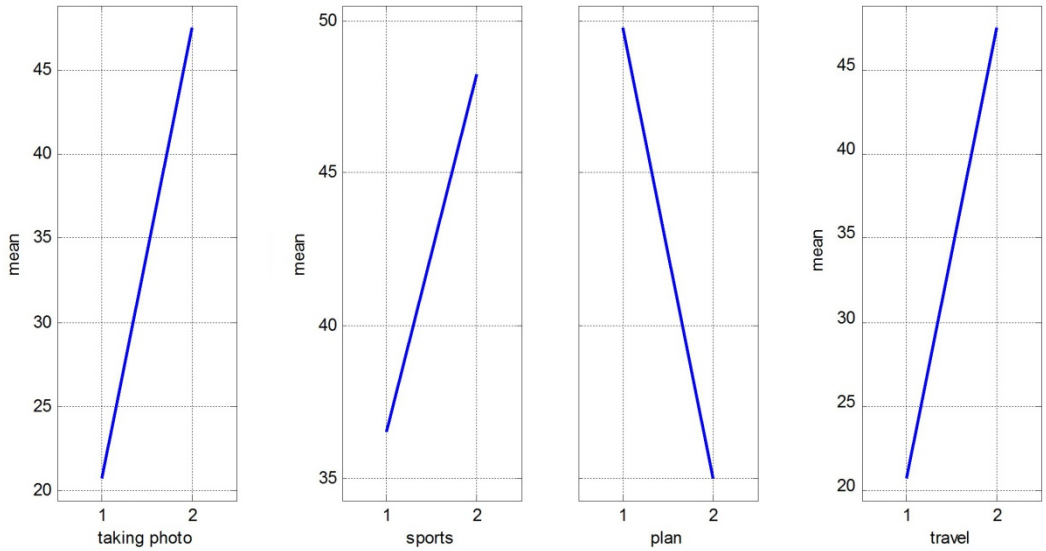


Figure 4.3: Main effects of Product 1 (1 means dislike; 2 means like)

There are 48 participants who tried to describe functions what product 1 might have. 22 of them thought that it is an mp3 or has music function; 12 participants thought that it can show the time; and 10 participants thought that it is a health product for daily health. However, according to the ANOVA results, music is not a significant factor for Product 1. Product 1 shows us a sport style. It is a kind of aesthetic feeling for customers. Both sports and travel are dynamic activities. They can reflect people's personalities and life attitude. Thus, it is an example which can testify that people most likely choose preference product according to their personality styles (feeling resulting from product's appearance) but not the function of the product.

Product 2: According to the ANOVA results, the significant factors of Product 2 include party (F=29.1**), taking photos (F=21.1**), shopping (F=15.1**), social (F=164.5**) and travel (F=32.3**). The most of participants who prefer Product 2 like taking photos (like: 23.6%; dislike: 14.0%) and social (like: 29.1%; dislike: 14.5%). However, some participants who are extroverted (for example, like party and social) said that they did not choose it because they like bright colour, and black is dreary.

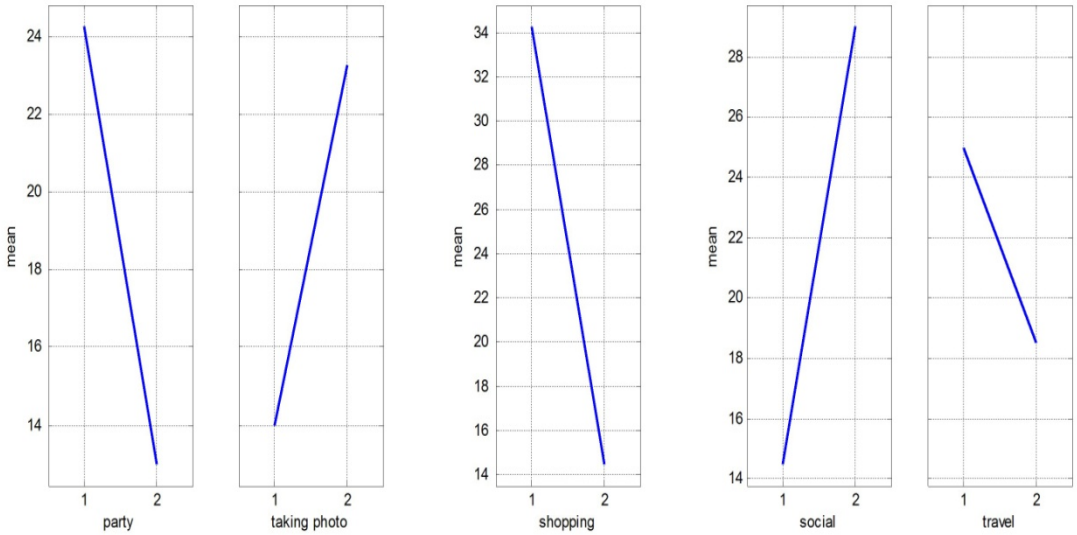


Figure 4.4: Main effects of Product 2 (1 means dislike; 2 means like)

Product 6: The appearance of Product 6 provides a wide scope for function imagination. Based on smart phone, its functions can cover almost all kinds of user groups. The significant factors involve shopping (F=25.9**), sports (F=8.5**), playing chess (F=11.2**), social (F=143.5**), pets (F=63.3**) and travel (F=10.8**). 44.1% of the participants who like shopping preferred Product 6, and only 14.0% of the participants who do not like shopping preferred it. Several participants said that Product 6 looks like the future trend of iPhone; it looks cool or fashionable. In addition, the majority of participants who preferred Product 6 like social (56.6%), pets (52.1%) and travel (46.9%). This result is also consistent with that the most people thought that the main function of Product 6 is communication with surroundings.

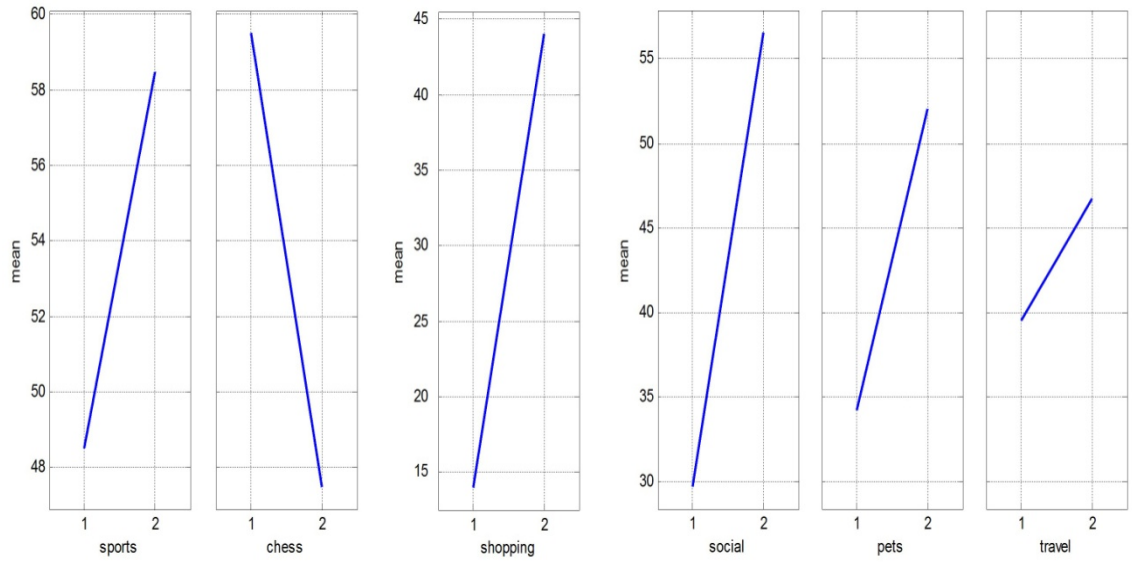


Figure 4.5: Main effects of Product 6 (1 means dislike; 2 means like)

Product 9: For Product 9, the significant factors are listening to music (F=186.9**) and shopping (F=92.7*). 30.2% of the participants who like listening to music preferred Product 9. In addition, gender and shopping have a close relationship. In this survey, there are 71.7% of the female participants who like shopping, and only 22.9% of the male participants like shopping. As shown in Table 4.1, gender is an obvious factor for Product 9 (male: 29.6%; female: 11.2%). 27.3% of the participants who dislike shopping preferred Product 9, and 13.3% of the participants who like shopping preferred Product 9 as preference product. The two pairs of proportion (gender and shopping) are similar.

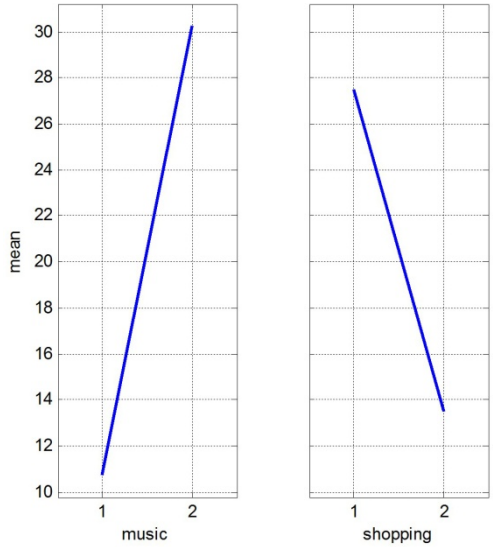


Figure 4.6: Main effects of Product 9 (1 means dislike; 2 means like)

Product 15: For Product 15, the significant factors are pets (F=8.24**) and travel (F=163.6**). Thereinto, travel is the most significant factor for this product (see Figure 4.7). It has been said that the style of Product 15 is similar to Product 6. However, the shape difference caused the participants to have a different judgment about the main function of the two products. Most of them thought that Product 15 is a good digital memory and can show the photos and videos.

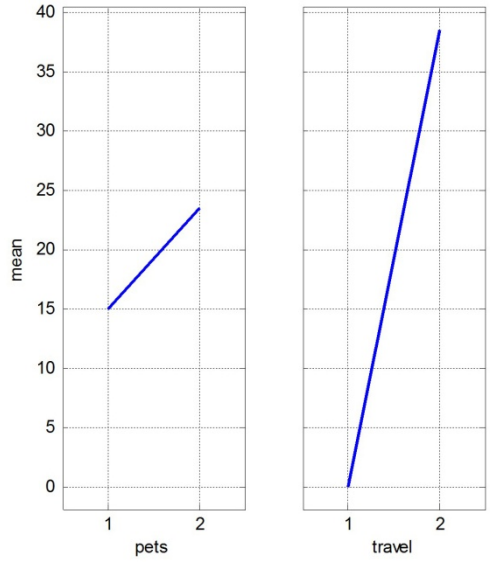


Figure 4.7: Main effects of Product 15 (1 means dislike; 2 means like)

Product 21: For Product 21, the significant factors are cooking (F=13.5**), Internet surfing (F=7.8**) and shopping (F=12.3**). According to the results of this statistics, the proportion of female who like cooking and shopping is more than the proportion of male, and the proportion of female who like Internet surfing is less than the proportion of male. Comparing the above results and the plots of Figure 4.8, it can be seen that for Product 21, gender is the most significant factor. Besides, there are 25% of the participants who thought that Product 21 is a GPS device; and 16% of the participants who thought that it is a timer.

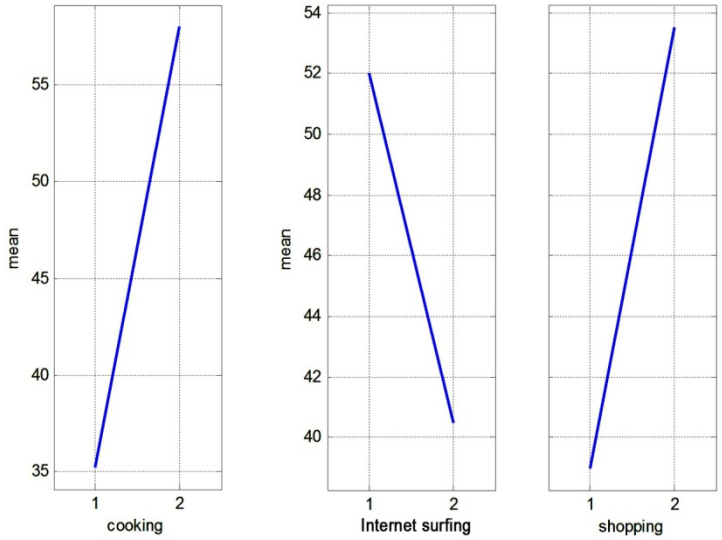


Figure 4.8: Main effects of Product 21 (1 means dislike; 2 means like)

4.2.4 Life Styles

According to the ANOVA results, for products 1, 2 and 21, the most significant factor is family time. The factor of working time can influence customer preference for product 9. In addition, the effect from the two-factor interactions is significant for product 2 and 15. In addition, all factors of life style are not significant for Product 6. In this aspect, Product 6 has the strongest functions to suit any time and any environment in the six products.

Table 4.3: ANOVA results of life styles

("*****" means significant, α_2=0.10; "******" means very significant, α_1=0.05)

Product	Working Time	Family Time	Working Time × Family Time
		F=3.96 *	
		F=26.22 **	F=20.77 **
			
	F=9.88 *		
			F=23.14 *
		F=56.10 **	

4.3 Eye Tracking Experiment Results

In all of the human attributes, demographic factors are easier and more concrete to use in the early user and product survey. For demographic factors, the research employed an eye tracking experiment to study the relationship between human attributes and product preference choice from the perspective of cognitive behaviours. Among three pairs of experimental groups, the most significant difference is shown in the occupation pair. A pair of examples are shown in the following.

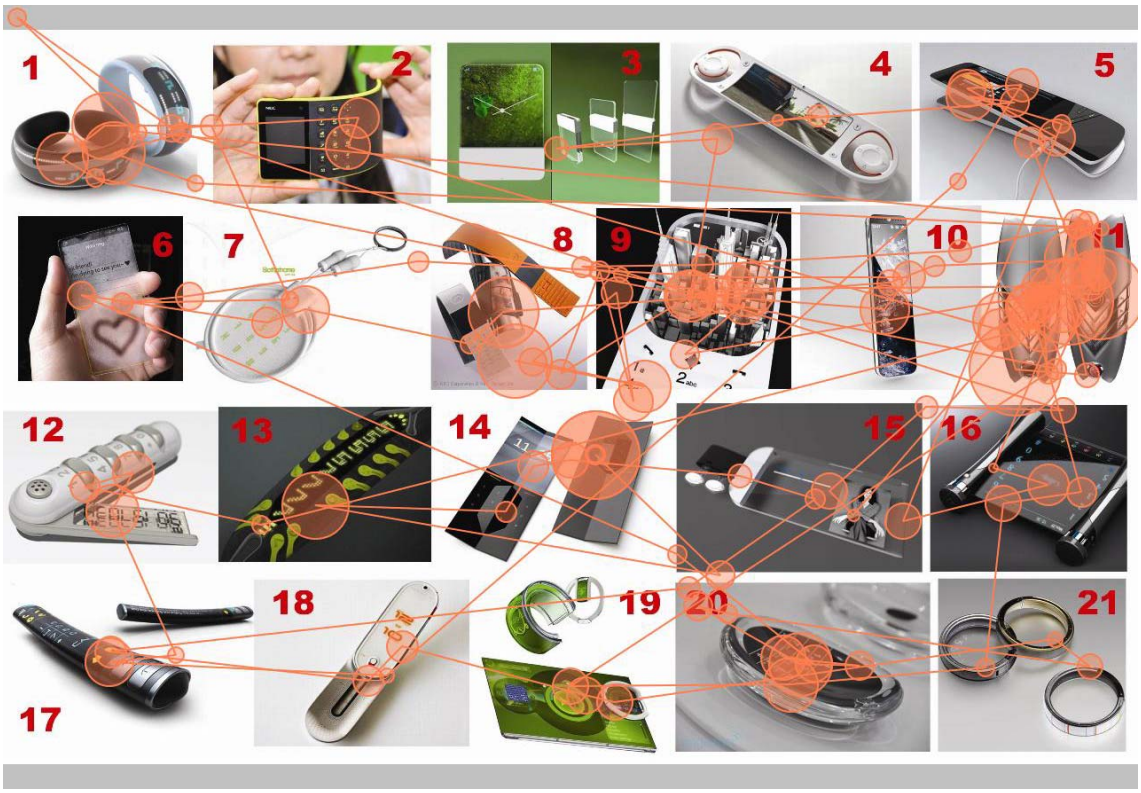


Figure 4.9: Typical scan path of an engineer, male participant

(The test is with the question - which product(s) do you expect most?)

Table 4.4: Dwell time and fixation count of Figure 4.9

(The test is with the question - which product(s) do you expect most?)

AOI No. 1-11	1	2	3	4	5	6	7	8	9	10	11
Dwell time (ms)	2116	624	164	494	1958	342	842	1732	3487	1120	7460
Fixation count	8	2	1	3	8	2	4	6	13	5	25
AOI No. 12-21	12	13	14	15	16	17	18	19	20	21	blank
Dwell time (ms)	944	604	1330	1136	1110	702	564	832	2328	458	1122
Fixation count	3	2	4	6	5	3	3	3	8	3	6

Figure 4.10: Typical scan path of a designer, male participant

(The test is with the question - which product(s) do you expect most?)

Table 4.5: Dwell time and fixation count of Figure 4.10

(The test is with the question - which product(s) do you expect most?)

AOI No. 1-11	1	2	3	4	5	6	7	8	9	10	11
Dwell time (ms)	280	272	2493	114	676	2569	110	0	0	266	262
Fixation count	1	1	9	1	3	8	1	0	0	1	1
AOI No. 12-21	12	13	14	15	16	17	18	19	20	21	blank
Dwell time (ms)	0	0	0	2683	254	0	0	270	474	404	468
Fixation count	0	0	0	12	1	0	0	1	2	2	2

From the above figures and tables, the engineer participant (see Figure 4.9 and Table 4.4) used a total of 30347 ms to decide which one(s) he expects most, and the answer is that he likes Products 1 and 11. The designer participant (see Figure 4.10 and Table 4.5) used 11127 ms to decide which one(s) he expects most, and the answer is that he likes Products 6 and 15.

From the cognition process, most engineer participants observed every picture carefully, and need a longer time to think. Relatively, the designer participants tend to make decision very quickly, and scan in a limited space.

In order to assess the effects of different human attributes, t-tests were conducted on the three attributes (gender, age and occupation) with the results presented in Table 4.6. A significance level of 0.1 was used for all statistical tests.

Table 4.6: Analysis of t-test table

Source	Gender	Age	Occupation
Mean	1130/927	1474/1196	1293/647
Variance	2.95E+05/2.36E+05	1.41E+06/6.59E+05	4.90E+05/8.40E+04
Observations	21	21	21
Pearson correlation	0.47	0.45	0.19
d.f.	20	20	20
t stat	1.75	1.17	4.20
P (T≤t) one-tail	0.05	0.13	2.22E-04
t critical one-tail	1.33	1.33	1.33
P (T≤t) two-tail	0.09	0.26	4.44E-04
t critical two-tail	1.72	1.72	1.72

According to the analysis results, occupation can most significantly affect cognition behaviours. Traditionally, we think that age is an important factor which can affect experience and knowledge accumulation, and that older people have more experience than young people, whereas young people learn and accept new things better than older people. However, in this experiment, the influence of age on cognition behaviour and decision making is not significant. There are several possible reasons. Firstly, engineers, researchers, lecturers and designers account a large proportion of participants. Engineers, researchers and lecturers belong to professional occupation. They are good at adapting to new science and high technology. Designer is a career which always touches new things. It can also prove occupation is the most significant amongst the three factors in knowledge cognition and preference choice. Secondly, the participants' age ranges from 23 to 56. Its effect would not be obvious as we live in a society with great product diversification and knowledge globalization.

In order to verify whether occupation factor can weaken gender effect, we performed another t-test analysis, as shown in Table 4.7.

Table 4.7: Analysis of t-Test table for two pairs gender groups

Source	Gender (engineer)	Gender (designer)
Mean	1138/1422	723/547
Variance	7.01E+05/5.95E+05	1.47E+05/1.20E+05
Observations	21	21
Pearson correlation	0.53	0.21
d.f.	20	20
t stat	1.66	1.76
P (T≤t) one-tail	0.06	0.05
t critical one-tail	1.33	1.33
P (T≤t) two-tail	0.11	0.09
t critical two-tail	1.72	1.72

As shown in the result, the fourth kind of occupation (research/professional) can weaken gender effect (1.66<1.75). Occupations which are related to aesthetics or arts can increase the effect of gender factor, but is limited (1.76>1.75).

Furthermore, for the cognitive behaviour, the most prominent difference is that the average of the engineering group's fixation time (27149 ms) is much longer than the design group's fixation time (13592 ms) when they make a decision about which product(s) they like.

4.4 Discussions

4.4.1 Gender

According to the above results, gender has limited influence on people's product preference and choices. Furthermore, this effect may be easily weaken by occupation factor. When a product has a special shape, especially ornaments or fashion products, gender will become a significant factor. For example, through the survey, Product 21 is

one of the popular products amongst 21 products. About 64.4% of female participants prefer this product, compared with only 27.1% male participants. Two of male participants gave us the reason why they prefer this one: it looks very pretty and they can give to their partners as a present. Thus, it seems to suggest that the appearance is more important than its real function when the participants evaluate this product. For Products 6 and 15, the percentages of female participants who like them (40.5% and 24.6%) are also a little more than the male participants (31.7% and 20.5%), although the gender effect on them is not statistically significant.

In addition, the male participants prefer Products 2 and 9 more than the female participants, especially Product 9 (a high-tech 3D map). Compared with the female participants, there are 2 times male participants who like this product. It supports well the belief that men generally prefer goods with more technical features. The ANOVA result shows that gender factor can affect people's preference for Product 9, but is not significant on Product 2.

Hence, Hypothesis 1 was partly supported in digital product design. In this study, female participants prefer Product 1 and Product 21. For Product 21, they fixate at it longer than male participants (female: 634 ms and male: 353 ms). Men like Product 9, which is technical and appears to have powerful functions.

4.4.2 Age

According to the t-test result, amongst the participants, there was no significant difference between the two age groups (below 25 and above 40). Further it can be found there was no significant differences for age groups (from 16 to 56), except for Product 6.

Increasingly customers appear to pursue personality and self value. These new needs reflect that customers are interested in fashion, uniqueness and sophistication. The elder people also like to try new digital products, even though they are sometimes not sure

about their functions. The difference in accepting new mobile phone products is not significant between different ages. Additionally, the age influence will be continuously weakened by increasing customer needs and product diversification in the next few years. Hence, for the ages between 16 and 56 years old, age is not an important factor in digital product choice. Hypothesis 2 should therefore be rejected.

4.4.3 Occupation

From the results shown in Figure 4.1, Tables 4.1 and 4.6, the effect of occupation is most significant in the three attributes. Occupation can generally reflect a person's knowledge background and thinking habit, and further, these knowledge and thinking habit can affect a person's cognition behaviours and decision making.

As far as people's preference is concerned, participants in different occupations appear to be biased towards different product features (Table 4.8). We tried to explain this result according to the level and/or type of the knowledge associated with each occupation, and the features of each product. As shown in Table 4.8, Products 1 and 21 have similar shapes which are like bracelets. But interestingly, the ranks of the proportion of people who like them in the four study groups are reversed. Based upon the picture, the most distinct difference is their materials. The former looks easy to use, and the latter is more advanced and delicate. Amongst four groups of occupations, the macroscopic and skilled focused more on usability (like Product 1); the professional focused on technology (like Products 2, 9 and 15); and the microscopic biased towards ornaments and/or fashion goods (like Products 6 and 21).

Table 4.8: Choice proportion and rank

Product No. / Occupation	Percentage of people who like the product (%)					
	1	2	6	9	15	21
Macroscopic	47.8②	11.6	21.6④	18.9	15.6	42.3③
Skilled	53.5①	16.4	34.4	9.4④	18.0	37.2④
Microscopic	32.5④	7.1④	50.0①	10.0	10.4④	55.4①
Research/professional	40.1③	40.8①	38.3	43.3①	46.25①	47.9②

In cognition behaviour aspect, the two groups have also shown significant difference (Table 4.6). Relatively long time in a career (greater than 5 years) can affect and reflect a person's personality. People who do research work tend to be more careful, serious and cautious. Compared with this, people who have jobs close to aesthetics and/or fashion tend to have stronger emotional ability. In the experiment, engineer needs a longer time to make decision (mean 27149 ms, and 1293 ms for each product) than the time taken by designer (mean 13592 ms, and 647 ms for each product). When they meet a new product with advanced or complex functions, like Product 9, engineers use much longer time (mean 3557 ms) to evaluate its functionality and usability, whereas designers only spend a mean 459 ms on it. On the other hand, designers fixate longer time at product with fashionable shape, for example Product 15 (mean 1313 ms).

The type of knowledge likely to be used by different occupations primarily belongs to procedural knowledge and is commonly used in daily work and life. Based upon the principles of cognition psychology introduced above, when people see a product they have never seen before, they are likely to use this type of knowledge to judge what the product can do and how to interact with it. According to the above results, Hypothesis 3 should be accepted. Occupation is a significant factor influencing human's cognition behaviours and customer's decision making.

4.4.4 Shape Preferences

According to the survey, there are 55.2% of the participants who like round shape and preferred Product 1 (simple smooth appearance) and the effect is significant. There are 56.7% of the participants who like diamond shape and preferred Product 6 (simple linear appearance); and 22.9% of the participants who like diamond shape and preferred Product 9 (linear appearance with complex 3D feature) and the effect is significant. There are 28.9% of the participants who like wavy and preferred Product 15 (linear and streamlined appearance) and the effect is significant.

Basically, the results support Hypothesis 4. Shape preferences can affect person's preference choice. For simple shape appearance, the effect is more significant. However, when we approach a design, the information about people shape preference is difficult to collect, and the difficulty will increase with the increasingly complex level of the shape.

4.4.5 Hobbies

From the survey results, hobbies can reflect a person's personality (introverted and extroverted). But more importantly, different hobbies can also reflect the demographic factors of people. Through analyses of a person's hobbies, we can judge his or her life style (e.g. like sports – focus on health), knowledge (e.g. knowledge about sports, taking photo, or playing chess), gender (e.g. shopping), and who he or she may like communication with (e.g. social, pets and travel), and further predict what the person like and/or need. Thus, Hypothesis 5 can be accepted.

4.4.6 Life Style

According to the above analysis, besides Product 6, daily schedule is a factor for people's preference choice, especially the proportion of family time and individual time.

However, comparing with the influence from the other categories of human attributes, the influence level of life time is limited. In other words, life style mainly reflects people's personalities rather than their functional needs. For example, when we need to design a business phone, designer usually thinks that how many actions a business person can do with a phone. At the present, most digital products have multiple functions which can cover the most needs of people. Thus, Hypothesis 6 should be accepted. Life style is an influence factor in digital product preference choice, but it is not very significant in product feature design (appearance design).

4.5 Artificial Neural Network

4.5.1 Inputs

As shown in Figures 3.4 and 3.12, to build this artificial neural network may involve many disciplines such as perceptual psychology, cognitive psychology and information science. The code selection of the input layer focuses on the customer attributes that likely influence the customer cognitive behaviours, which include demographic factors, graph preferences, hobbies, life styles and others (for example, past using experience of a product). Many factors or attributes can affect a customer's preference, and the following attributes have been chosen according to the previous investigation. They are demographic factors which include gender, occupation, and age; shape preferences which include round, diamond, and wavy; hobbies which include cooking, party with friends, taking photos for yourself, listening to music, Internet surfing at home, shopping, sports, making plans, playing chess, social (with strangers), travel, and pets; life styles which include the arrangements of working and family time; and others which show how often the participants use a mobile phone and what functions they use in daily life. All the attributes are coded and normalized within [0 1]. Table 4.9 shows the code of all input factors for artificial neural network system.

Table 4.9: Code of input factors

category	**factor**	**level**				
demographic factors	gender	male =0	female =1			
	age	16-25 =0.25	26-35 =0.5	36-45 =0.75	>46 =1	
	occupation	macroscopic =0	skilled =0.25	microscopic =0.5	research =0.75	student =1
graph preferences	round	dislike =0	like =1			
	diamond					
	wavy					
hobbies	cooking	very dislike =0	dislike =0.25	general =0.5	like =0.75	very like =1
	party					
	photo					
	music					
	Internet					
	shopping					
	sports					
	plans					
	chess					
	social					
	travel					
	pets					
life styles	working	unemployed =0	less =0.25	general =0.5	long =0.75	
	life	less =0	general =0.5	more =1		
other	using frequency	very frequent =0	frequent =0.25	general =0.5	infrequent =0.75	very infrequent =1

4.5.2 Process

The survey carried out in this research has generated 180 valid responses. 24 different kinds of personalized customer attributes are obtained from the survey. 21 most important attributes shown in Table 4.9 are selected in the input layer.

The human differences not only consist in different human attributes, but also consist in different logical processes. Thus, firstly a Self-organizing feature maps (SOFM) neural network is used to classify different groups of customers. 180 customers have been classified as 4 groups, each group of customers are modeled with a different Backpropagation neural network. For example, one group has 60 customers. 21 customer attributes are used in the Backpropagation neural network.

The research used MATLAB neural network toolbox to carry out the modeling. The SOFM learns to classify inputs according to how they are grouped in the input space. The inputs differ from competitive layers in that neighbouring neurons in the self-organizing map learn to recognize neighbouring sections of the input space. In this research, the inputs of SOFM are different attribute groups. Each group means a person, and the outputs are four groups. The study created the self-organizing map network with the function *newsom*. The neural network is trained up to 2000 epochs.

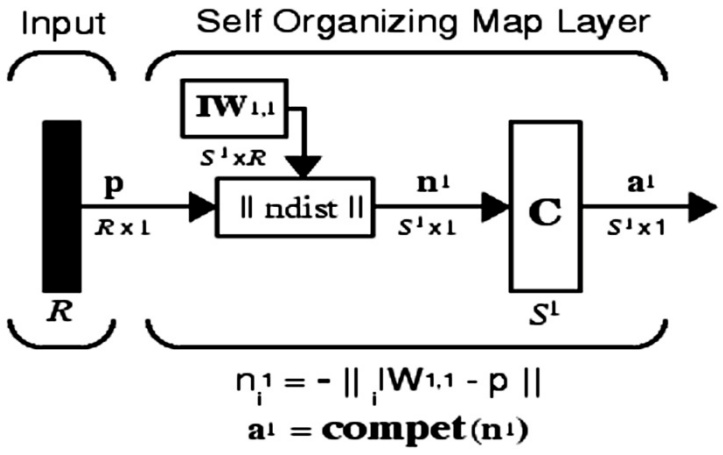


Figure 4.11: The architecture of SOFM

Backpropagation (BP) is the generalization of the Widrow-Hoff learning rule to multiple-layer networks and nonlinear differentiable transfer functions. An elementary neuron with R inputs is shown in Figure 4.12. Each input is weighted with an appropriate w. The sum of the weighted inputs and the bias forms the input to the transfer function f. Neurons can use any differentiable transfer function f to generate their output.

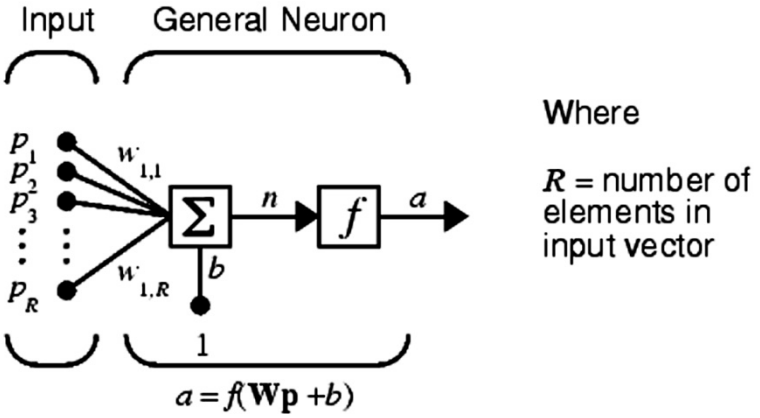


Figure 4.12: The architecture of an elementary neuron

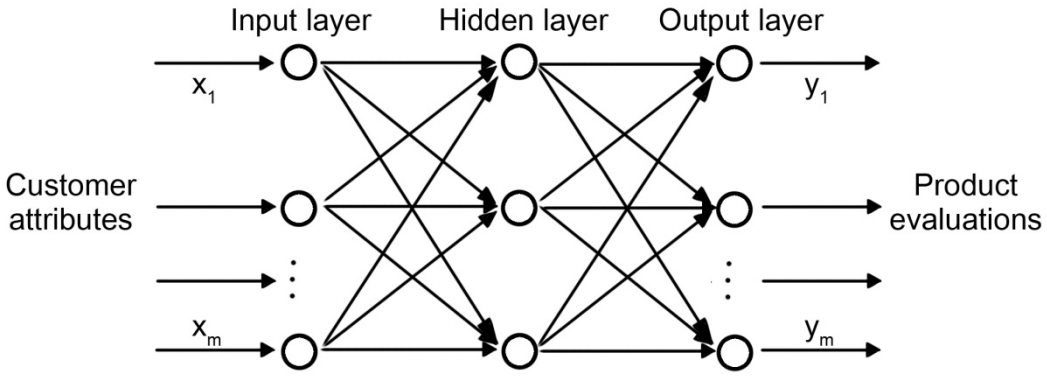


Figure 4.13: Backpropagation neural network model of relationship between customer attributes and product evaluation

4.5.3 Outputs

As the study first focused on the preference cognition of consumer, each person in the survey was asked which product(s) they like most.

There are 6 products used in this experiment. For the data accuracy, each participant was presented with 21 product pictures. Since all these products belong to the same category (with the same function), the target customers will only choose the product(s) which they like. A 6 bit binary code is used to represent the customer preference(s), 1 if the corresponding design is liked, and 0 otherwise. For example, if a participant likes all 6 products (i.e. Products 1, 2, 6, 9, 15, and 21), the result will be coded 111111; if a participant does not like any of the 6 products, the result will be coded 000000.

4.5.4 Results

The output layer of the neural network has 6 neurons and there are 20 neurons in the hidden layer. Pairs of customer attribute and product evaluation codes will be trained using Levenberg-Marquardt algorithm. The learning rate is set as 0.1 and the neural network is trained up to 2000 epochs.

An example of the typical training is shown in Figure 4.14. In the BP group, 35 out of 55 customers have been randomly used for training. After the learning has finished, the remaining 20 out of 55 customers that was not used in the training was used to test the generalisation and prediction ability of the ANNs. With the ANNs trainings repeated 10 times, a success rate chart of results is given in Figure 4.15, which indicates a success rate of approximately 80%, and the average success rate is 73.4%. The best success rate of the experiment during the research is approximately 87%.

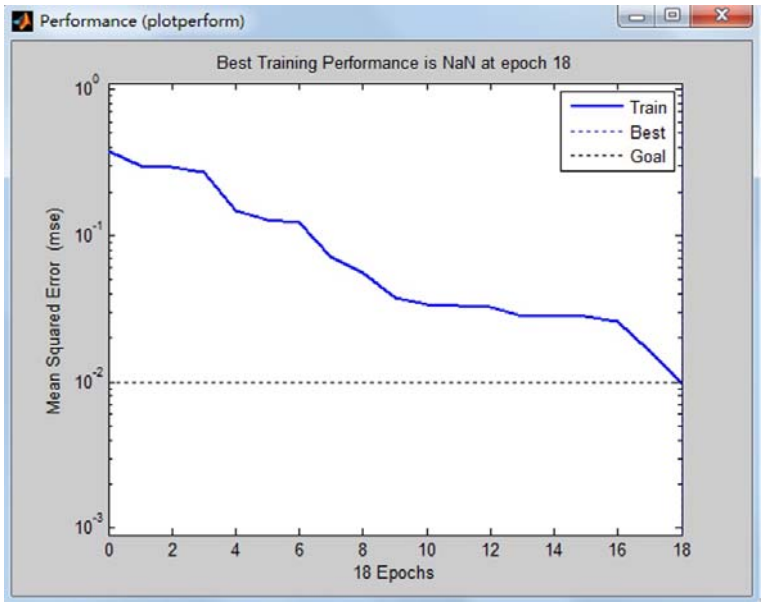


Figure 4.14: ANNs test results example

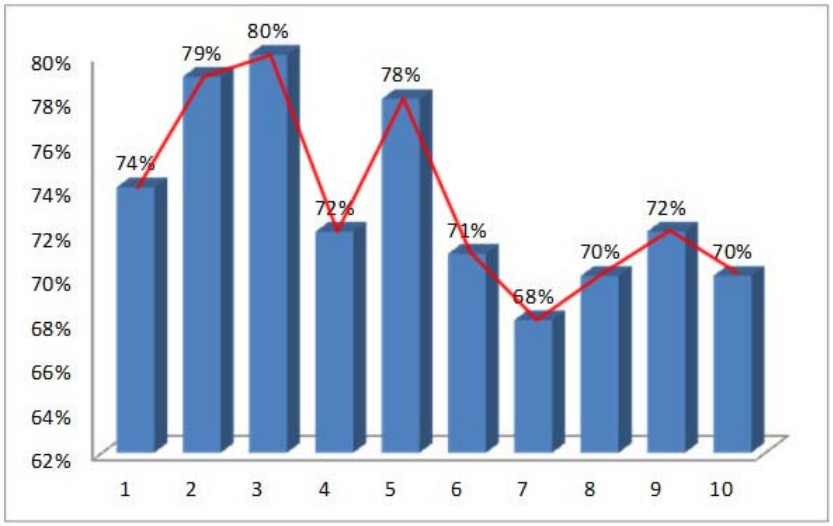


Figure 4.15: Success rate

4.5.5 Summary

This section discussed the relationship between impact factors (customer attributes) of individual difference and product evaluations, and presented a novel information processing method using artificial neural networks. It aims to discover regularity which exists between customer attributes and product evaluations, and use this regularity in design activities. The initial results have established the feasibility and the success of

this method. From the results, we can see that artificial neural network system can potentially well simulate the cognitive process of people and replace designers' face to face interview with their customers in mass customization.

However, the success rate of this prediction and evaluation model is not stable. The reasons are: firstly, the model needs a more accurate data representation and training algorithm; secondly, the model needs more samples to test the practicability and the effectiveness of the codes in the inputs layer.

In conclusion, the new neural network model developed is essentially an extension of Kansei Engineering technology. It can be used to predict and/or evaluate new product concepts based upon customer attributes. It has great potential to model the relationship between customer personality and product preference, and to assist personalized customization in product design.

Chapter 5 Embryonic Form of Product Mass Customization

5.1 Introduction

As mentioned before, in the fiercely competitive environment of the marketplace, companies have been seeking opportunities to expand their product lines and to increase their product offerings with different product performance. They hope that large product variety can stimulate sales and generate additional revenue (Ho and Tang, 1998). Initially various product choices help them improve sales and bring in more attractive offerings. However, as the variety keeps increasing, the cost will be too high with diminishing returns and benefits (Jiao, et al., 2007; Wortmann, et al., 1997). Faced with such a dilemma, companies must find the balance between variety numbers and manufacture cost, i.e. the level of customisation should be optimised according to product type, customer needs, and product value and manufacture cost.

The future trend of added value for a product will be user added value. Mass customization is a good solution which can provide enough variety product choices for customers, and create personalized value according to the special individual requirements. An effective mass customization process can help companies optimise product types, product value, and manufacture cost.

5.2 Case Study – Mobile Phone

5.2.1 Customization Marketing

Nowadays, people have increasingly strong desires to express their personalities and originalities, for example, dressing style, home style, gift, name card, or even

curriculum vitae. There are three types of customization forms which exist in the market.

The first type is one to one customization service. It is a traditional customization form, and its characteristic is that the designer provides one to one (or face to face) design service for one customer. Most of these products are made by hand. The final product usually is unique, and the price normally is much higher than the price of the general products. The traditional customization is a kind of high-end consumer behaviour. Typical customized products are interior, clothes, jewelry, etc.

The second type is one customer customizes a small quantity of products. The products can be anything, for example, 500 gifts, office supplies, etc. The customers normally are organizations and companies, or customize products for a special event. In essence, it still belongs to mass production.

The third type is mass customization which also is the key of this research. The difference from the first type is that designers do not provide one to one design service, but provides enough various modular choices to customers to finish the design; the customization price is cheaper than the price of the traditional customization; the product is not made by hand. The difference from the second type is that a customer usually only customize one product. It needs that designers can accurately identify the common needs and personalized needs of all potential users.

In addition, the level of mass customization depends on the related manufacturing level. For example, we want to customize a business card. Because the technology is well advanced and mature, we can customize all parts of the business card, from material and shape of paper to graphic content. However, for most industrial products, customization service only limits in part of product features, such as colour, internal configuration (e.g. digital products), and interior materials (e.g. car).

We can believe that the future industrial mass customization will achieve a level similar to a business card. However, according to the existing manufacturing level, mass customization needs effective methods to identify common needs and personalized needs of all potential users, and to judge the variety and amount of product modules in the early design stage.

5.2.2 Personalized Mobile Phone in China

There are many small and medium-sized manufacturing enterprises in south of China, which can produce personalized or customization mobile phones with a small quantity (see Figure 5.1). In China, the mobile phone produced in these small and medium-sized factories is called cottage mobile phone. These cottage mobile phones only focus on appearance change and mature functions, and are produced with a lower cost. As shown in Figure 5.1, the price of them are between £50 and £100.

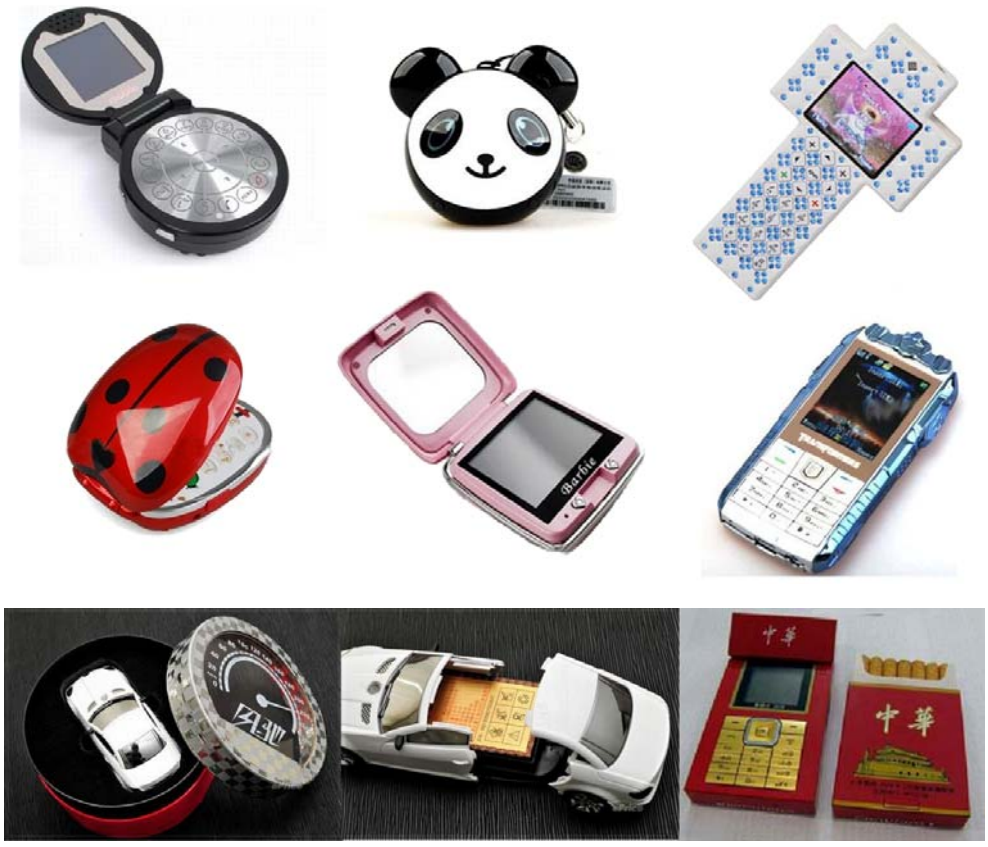


Figure 5.1: Personalized mobile phone in China

Cottage product is a special mass production. The characteristics are that manufacture companies are of small-scale production and low cost operation. Initially, they do not have brand. Through integrating the advantages of supply chains, some of them have developed their own brands (see Figure 5.2). In 2007, the market share of cottage mobile phone has reached 25%, and exported one hundred million mobile phones (Xu, et al., 2009).

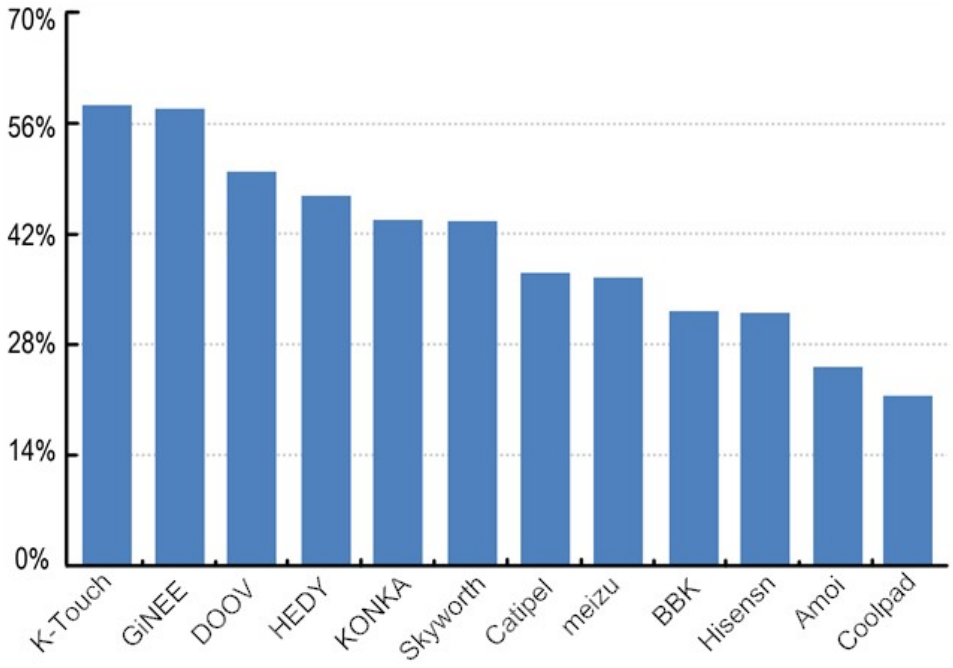


Figure 5.2: 2010 brand perception survey of cottage mobile phone

(Data source from Internet Consumer Research Center (ZDC), China)

Some researchers think that the reasons for the success of this business model are the network subdivision (Wu and Zhang, 2009), satellite platform district (Huang and Chen, 2006), and industrial clusters (Luo and Zhao, 2009). Most cottage mobile phone companies do not have technological research and development ability, but they know how to gain useful resources through the integration of the network supply chain (see Figure 5.3). The companies are in the network with mutual cooperation and interdependence, and share the technology and information.

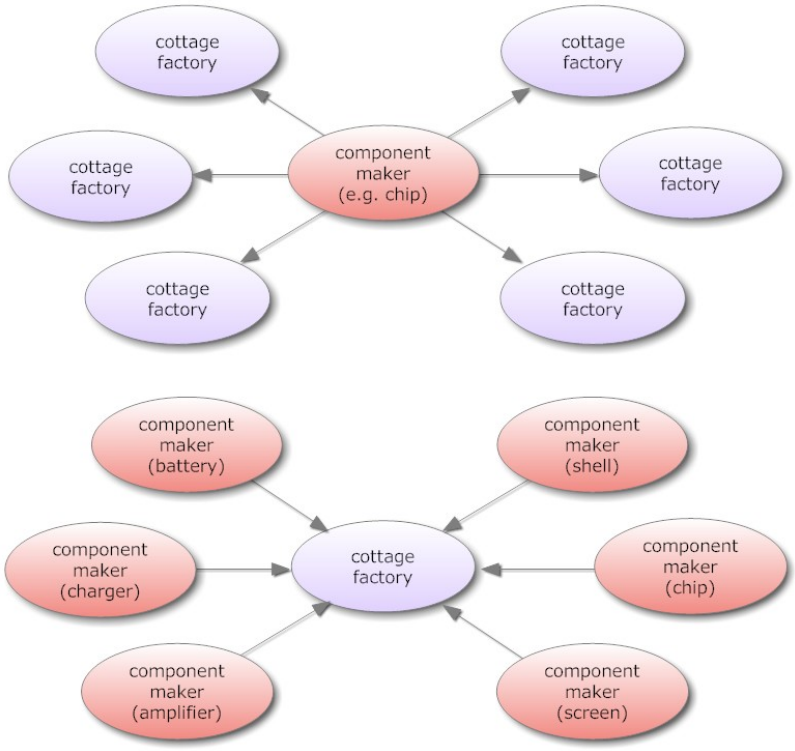


Figure 5.3: Network supply chain (Xu, et al., 2009)

In addition, the cluster effect brings enormous creativity and flexible manufacture ability which help the cottage companies realize to satisfy personalized and rapidly changing customer needs. According to the survey (Xia, 2008), the Chinese mobile phone companies launch an average of two new phone models every year. In 2007, Samsung launched 47 new mobile phone models; Nokia launched 34 new mobile models; Sony Ericsson launched 19 new mobile models. However, the survey shows that a daily average of 3-5 new cottage mobile models entered the market. The developments of these cottage companies usually do not involve new technology (e.g. main board). They are just limited to the increase of the additional features and change appearance to meet the changing and personalized consumer needs.

5.3 Model Formulation

A product mass customization design process is shown in Figure 5.4, based on the existing product design processes and the personalized manufacturing.

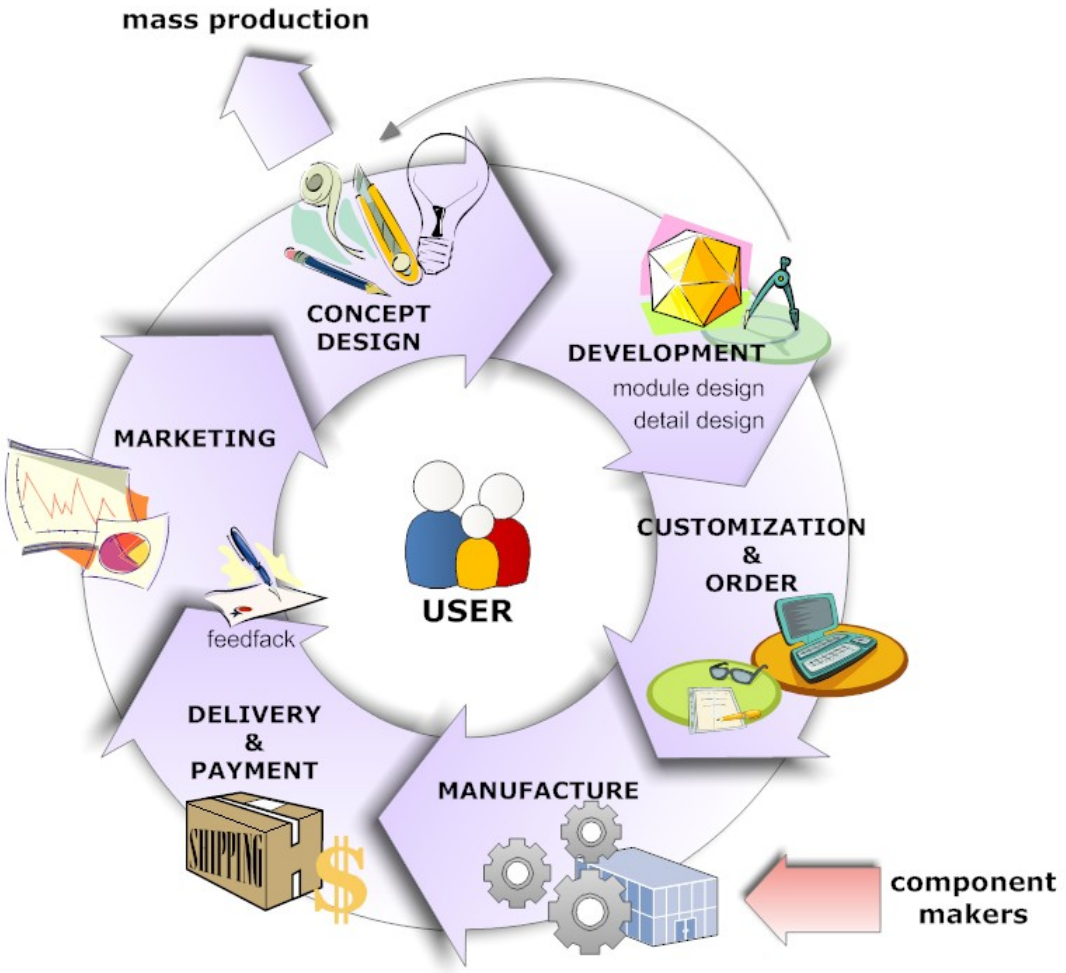


Figure 5.4: Product mass customization design process formulation

Figure 5.4 depicts an integrated framework for customisation design circle and process. It emphasizes the customer focus of all the business activities and continual improvement of design process.

Not every kind of product suits customization design. So the mass customization design process should have a compound structure which allows free change between standard design and customization design. In this process, there are more than one approaches to achieve the final concept. Figure 5.5 shows a model of the mass customization design process, including the key stages such as information research (marketing research), conceptual design, design development and evaluations. The study focuses on the

research stage, i.e. how to identify customer needs in mass customization design.

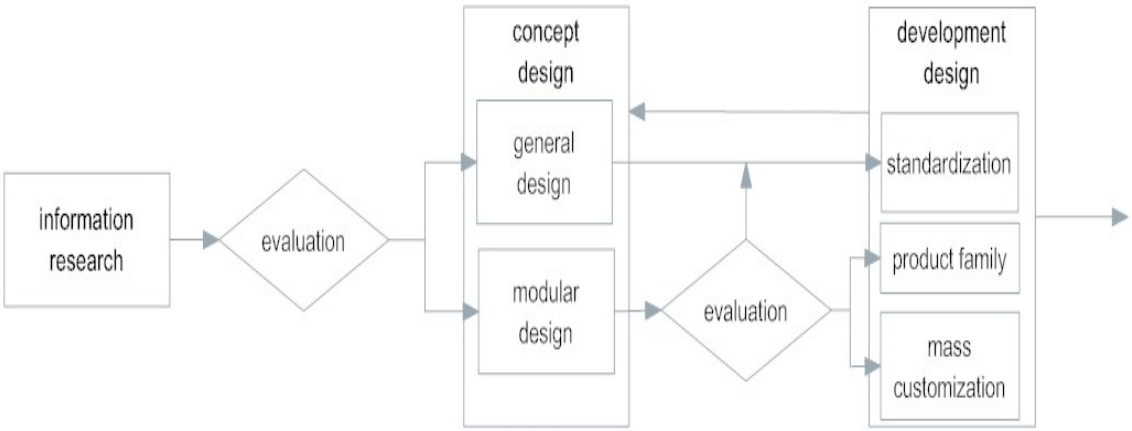


Figure 5.5: Model of mass customization design process

5.3.1 Information Research in Mass Customization Design Process

Any product or service is developed by starting from capturing real customer needs, and then transforming these needs into a target specification. This is very important and will ultimately guide the whole design process. In most design processes, the first stage usually is marketing research and is a business-based activity. Designer gets the target specification from marketing department. But sometimes, the marketing needs cannot reflect full expectation of target users because of considerations due to profits and competitive advantages. This deviation may cause design problems. In the mass customization design process, the information research focuses on human research to understand users and their needs (Figure 5.6).

Figure 5.6: Stages of design information research

The objectives and potential advantages of information research are:

- To avoid possible subjective prejudice of designers and the bias in the goal-directed information collection;
- To forecast market opportunities;
- To reuse the information and knowledge in other design projects.

I. **Mission statement:** This is a design brief to lay out requirements from all stakeholders, broad constraints, purpose of business and/or challenges, and target customers. For instance, the purpose may be seeking a new market opportunity, importing a new technology or updating an existing product/service or for a special application.

II. **Discover:** This is for exploring perceived appearance and reasons based upon 5W+H (namely when, where, who, what, why and how). At this stage, designers will start to re-analyse the information from marketing department. The work focuses on target customers and gathers raw data through observation, interview and survey.

III. **Understand:** This is for interpreting customer needs. The understand process needs to sort out and interpret the data, reveal all explicit and latent/hidden customer needs.

IV. **Indentify:** This is for filtering the information and organizing the needs into 4 hierarchies (must have, should have, could have and will not have), and getting final product/service/system functions and features.

V. **Target specifications/structure requirements:** Customer language is translated to design language, generating the research output (target specification).

5.3.2 Expanded Substages

Stages II to IV together can be further expanded as shown in Figure 5.7, including function maximizing and function filtering stages.

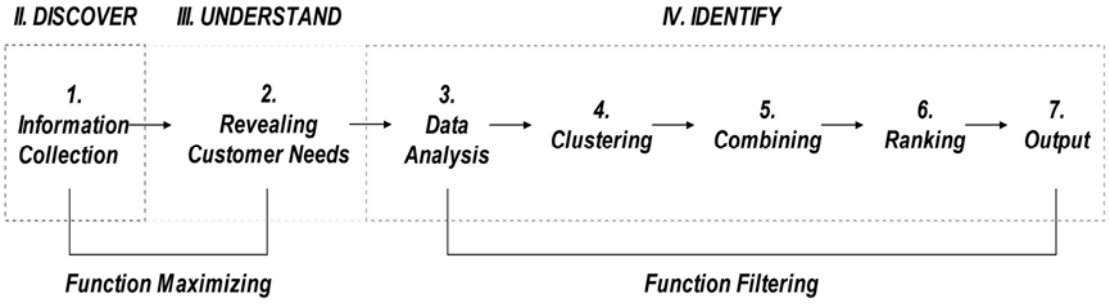


Figure 5.7: Expanded substages of design information research

Information collection: This is a function maximizing stage. Any general marketing/design research methods can be used in this step to collect any kind of information.

Revealing customer needs: Still in the function maximizing stage, to suppose all the possible scenes which target customers may meet and all functions which target customers may need.

Before enter the function filtering stage, we need to build target personas models to help us filter functions successful. Because the potential customers of mass customization are all of the population, and customer needs involve common needs and plenty of various personalized needs, the existing “personas” method which is for mass production does not suit to mass customization.

People within the population have a range of different personalities, past experiences, wants and opinions. Customization design aims to satisfy self value of customer. Everyone is unique, but mass product customization design cannot build persona model

for everyone. Here, the research will introduce a qualitative method to identify customer needs for mass customization in the Section 5.3.3.

Data analysis: This is the start of function filtering stage. According personas model, to assort the all functions into 4 hierarchies. There are must have, should have, could have and will not have.

Clustering: To cluster the same level functions together and to remove the group of "will not have".

Combining: To combine function choices for the people in different modules. In this step, we can get whole kinds of functional combinations of a product/service for whole population, and we also can choose doing design for a certain kind of customers, for example a certain age. The research data can be reused in other design projects which belong to a same category.

Ranking: Optimizing combination. The final result should satisfy mission statement first.

Output: This is the end of function filtering stage.

5.3.3 "Extreme" Personas Models Analysis

According to results of the survey, knowledge background, gender, age and personality decide status of a people and the product/service function he/she needs.

Personalities are formed in different growing environments. It can be separated to four elements: occupation, life-style, social environment and nature. Social environment and nature are change slowly, and have a strong regional. Thus, the research focus on impacts of occupation and life-style here.

Extreme Point:

"Extreme" personas models mean building pairs of completely opposite personalities, for example, extremely extroverted (i.e. extroversion in all time) and extremely introverted (i.e. introversion in all time). In fact, no one is extroverted in all time. Sometimes the extroverted people also need quiet environment.

Assume all personalities are gray with different saturations. Thus, a pair of "pole" personas models can be represented as colours: white and black. Namely the other personas models belong to the set of gray and the saturation between 0 % and 100 %, and have (100-x) % characteristics from white and x % characteristics from black (see Figure 5.8).

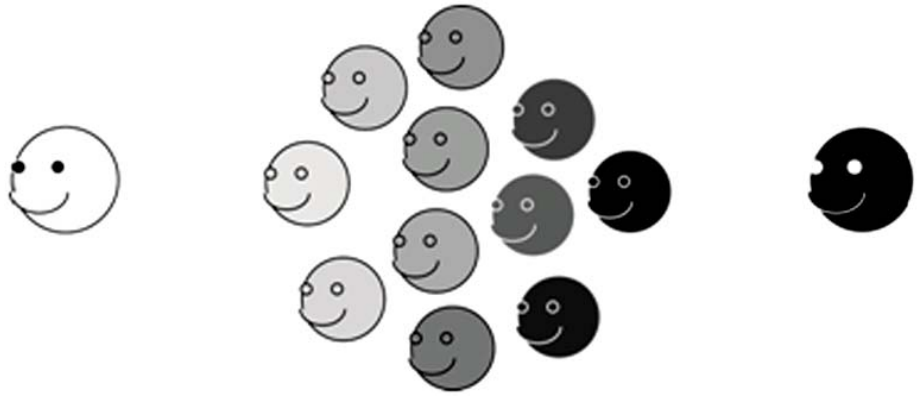


Figure 5.8: "Extreme point" colour model

Categorising method:

Based on the survey, for the real products, the differences of gender and age are foreseeable. The need difference of gender mainly reflect in the ornamental needs and technological desires. The need difference of age mainly reflect in the physiologic factors. The need differences of gender and age exist in all kinds of products. Through analysing the effects of the four factors on preference choice, knowledge background and personality are most important, and then is gender, and the last is age. Thus,

knowledge background and personality are identified as two key factors in the extreme personas map.

Through the simulation of various attributive classifications, the final extreme personas map is as follow:

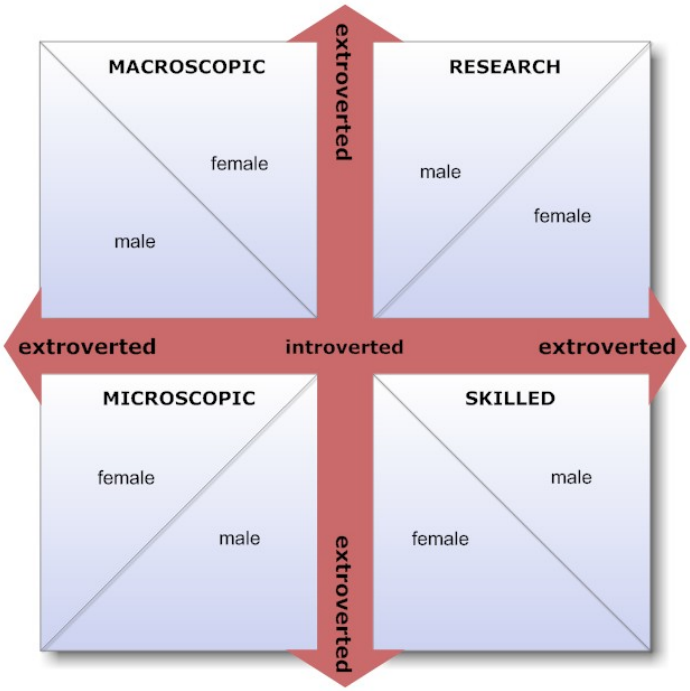


Figure 5.9: Extreme personas map

The map shows 16 kinds of extreme personas, which include: 1) macroscopic knowledge with extroverted personality (male); 2) macroscopic knowledge with extroverted personality (female); 3) macroscopic knowledge with introverted personality (male); 4) macroscopic knowledge with introverted personality (female); 5) microscopic knowledge with extroverted personality (male); 6) microscopic knowledge with extroverted personality (female); 7) microscopic knowledge with introverted personality (male); 8) microscopic knowledge with introverted personality (female); 9) skilled knowledge with extroverted personality (male); 10) skilled knowledge with extroverted personality (female); 11) skilled knowledge with introverted personality (male); 12) skilled knowledge with introverted personality (female); 13) research knowledge with extroverted personality (male); 14) research knowledge with

extroverted personality (female); 15) research knowledge with introverted personality (male); 16) research knowledge with introverted personality (female).

Table 5.1: Main characteristics of extreme personas map

Software	No
Design strategy	Radical innovation/ Incremental changes
Representation of emotion	Words/ Images
Stage of process	Understand user/market Explore ideas and concepts Design specification
Time required	Short/ Medium
User involvement	No
Training required	No
Specific knowledge needed	No

Method comparison:

Mobile phone users have rapidly increased in recent years. Most people have had or used more than one mobile phones. It is usually to see people using mobile phones in different environments and with various functions. People cognize a mobile phone from its appearance, functions (e.g. hardware, software, and network services), and performance (e.g. interaction, service provider information and quality) (Palen, et al., 2000).

Mobile phone technology is accelerating in recent years and covers multiple technical components, for example, various hardware and software, modern wireless communication technology, and mobile commerce (Wu and Wang, 2005). The different methods to study user acceptance of mobile technology include Technology Acceptance Model (Davis 1989; Legris et al., 2003), Human-Centered Design process (Norman, 1998; Ketola, 2002), Human-Computer Interaction (Kallio and Kekäläinen, 2004).

However, as mentioned before, the rate of new technology development has been lagging behind the user needs changing. There is a huge demand for personalized products in the market. The current technologies have already satisfied most user needs. Re-design and re-combination existing resources can bring enormous creativity and flexible manufacture ability to meet the increasing personalized needs of people, add profits for companies, and save time for new technology development.

The existing innovation methods focus only on one target group (not all population) and cannot identify individual differences. The main advantage of extreme personas map is that can help designer understand individual difference of different user groups, identify common needs and personalized needs, optimize the number of design modules, and suit mass customization.

Figure 5.10 shows an example of concept mobile phone case studies. The blue points mean 16 kinds of extreme personas. The data distribution is based on the survey results of this research. For example, according to the survey, there are 53.5% skilled participants who like Product 1. It is the highest proportion in all the groups, so using a bigger photo to represent it. There are 40.9% research participants who like Product 2, but this proportion in the other groups are lower than 20%. Thus, Product 2 is only shown in Research area, which means that this style, material, or interaction is preferred only in research group (with research knowledge background).

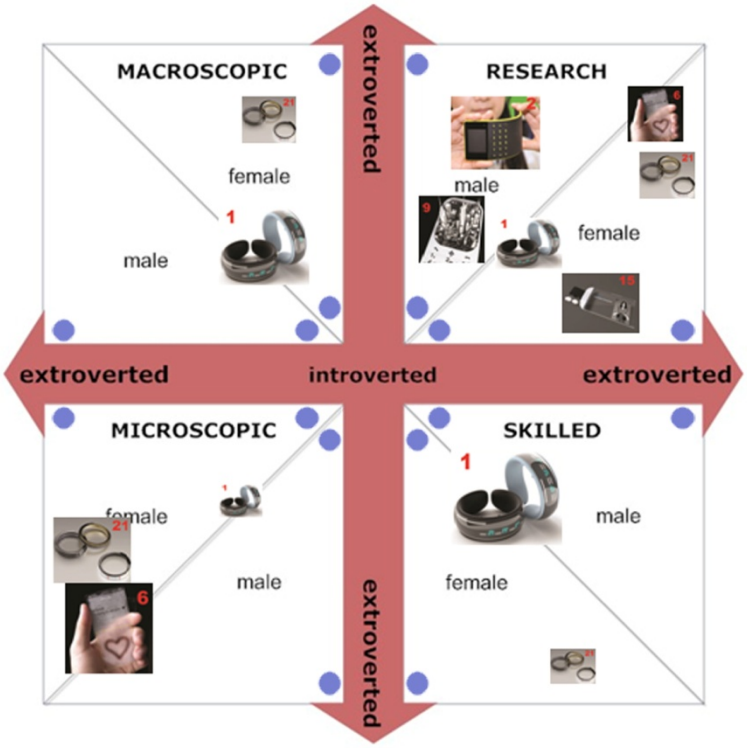


Figure 5.10: Extreme personas map example

5.3.4 Conceptual Design and Design Development

Following the detailed needs identification and analysis performed at the design information research stage, target specification can be produced and evaluated against the initial mission statement and design brief. The conceptual design aims to develop an integrated conceptual model of the product. Various aspects should be considered, including internal (e.g. structural and key parameters), operational (e.g. different modes and interfaces) and environmental. In particular, the proposed design framework emphasizes the identification and justification of general and modular design, based upon the consideration of the component value and its manufacturing cost. This aims to balance and optimise the level of customisation since too much customisation may incur unnecessarily high cost. In general, three categories of design will be needed, i.e. standardization, product family and mass customization, which will be addressed further in the design development stage to produce detailed product design.

5.4 Summary

This chapter has introduced customization market environment and manufacture environment. A small batch mass production and manufacturing network supply chain provide feasible solution for product mass customization. A case study showed the small and medium sized manufacturing companies use the network subdivisions, satellite platform districts, and industrial clusters to build industrial supply chains and produce personalized mobile phones with a small quantity in China. In addition, the research has developed a model formulation, an information research process and an extreme personas map methods for product mass customization.

Chapter 6 Conclusions

6.1 Introduction

This research has investigated the product mass customization design method based on individual differences and existing manufacturing environment. To achieve this goal, the connection between human attributes and product features were developed. From this, it became clear how to identify common needs and personalized needs of all population in early design stage. The extreme personas map was formed which can help existing design methods to be used in mass customization.

6.2 Research Summary

Mass customization design offers several advantages:

- Satisfying the consumer needs better and embodying consumer self values;
- Reducing waste of resources and protecting the environment;
- Saving storage place;
- Reducing the product investment risk.

Although innovation design has been widely discussed and has become increasingly popular for various reasons, this research argues for going back to basics of user feeling. Innovation design itself is not the aim; rather it is the means to achieve effective and good design to satisfy the increasingly changing customer needs, especially the psychological needs. The criteria for successful innovation design must still be the quality and values it offers to the customers, which lies essentially in the understanding of human needs and translating this understanding and knowledge into real products.

This research presents a theoretical framework and related methods for product

innovation design and balanced or optimised customization. According to this framework, customers have entered the central stage of the design process, they can directly influence the design, realising their own values and brands carrying their own personalities. In addition, based on this framework, manufacture companies can maximize the existing strengths, and use industry chain to improve their market competitiveness.

6.3 Contributions of the Research

This research has four key contributions:

Firstly, the research has studied customer preference from perspective of human attributes and cognition, and used orthogonal array, design of experiment (DOE) and eye tracking technology in product design study. The results have:

a) Established the relationship between human attributes and product features, which can help designers understand the differences of various customer groups. The differences involve the way of thinking and emotional traits.

b) Identified different levels of various influence factors which can affect people's cognition and preference choice based on vision.

c) Revealed that knowledge is the most direct and significant influence factor for cognition when we evaluate a product.

Secondly, the research has summed up product development process, design development process, and human needs hierarchy, and identified user needs hierarchy and added value hierarchy when we evaluate a product. The research has advanced added value hierarchy to support that the future trend of customer desires is to demonstrate self value, and mass customization is a good way to realize user added value and to increase companies' market competitiveness.

Thirdly, the research has developed a novel conceptual framework model for product mass customization based on existing business and manufacturing environment, and provided an “extreme personas map” method which can be used in early design stage of mass customization. The new method was built based on the existing design methods and the results of the first contribution. The advantages of this method are that:

a) The method can be used for product case studies, and product innovation. It can be used for both radical innovation and incremental design.

b) The method is easy to use and the focus group includes all of the population. The results of information research can be reused in the future design of the same or similar kind of products.

c) Comparing with the existing methods (Table 2.5), through the use of the personas map, it is easy for the designers to understand what features different people like; to identify common needs and personalized needs; and to optimize the number of design modules.

d) Any existing design methods can be used in this map to identify needs of any specified user group.

Fourth, the research has built an artificial neural network model to simulate customer preference choosing process. The model made the connection between people attributes and product features directly in the design stage. The results will benefit designers to predict customer’s preference and to identify their potential needs objectively. It can be used to identify the needs of a group people or an individual, and also can be used to evaluate a product in the early design stage.

6.4 Suggestions for Further Research

Based upon the research results, in order to develop more effective and applied tools for mass customization design and evaluation, the following future works are proposed:

1) Carry out the second survey based on the results of the first survey to make human attributes and product features more targeted and wider (e.g. which sports the participant like, yoga or football which can reflect the difference of personalities).

2) Conduct a quantitative survey and cognitive behaviour experiment to generate more samples. It can help to determine the coefficients of artificial neural network and the relationship between various human attributes.

3) Improve or develop better training algorithms for artificial neural network to achieve higher accuracy and stability.

4) Re-arrange the sequence/positions of the photos in the eye tracking experiment and analyse whether or not it influences the cognitive behaviours and preference decisions of the participants.

5) Validate the results (human attributes – product preference survey or cognitive behaviour experiment) under different culture background (e.g. different countries).

6) Put the framework in practice to guide a real product mass customization design.

7) As an integrated innovation framework, the research has covered many disciplines, e.g. behaviour psychology, cognitive psychology, physiology (vision research), statistics, design methods and process, manufacturing supply chain, and artificial neural network. Due to the limitation of time and scope, the research cannot cover all these in great depths. It is possible to extend the research in many of these aspects.

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Appendix A: Questionnaire

此问卷旨在学术研究，您的答案和隐私将不会被公开。谢谢！

This questionnaire will be used for academic research. All your answers and personal information will be made absolutely confidential. Your assistance will be greatly appreciated. Thank you.

第一部分: 个人信息/Part 1: Personal details

请在选项中打勾。Please fill "✓" in the box.

1. 性别/Gender: ☐ 男/male ☐ 女/female

2. 年龄/Age: ☐16-25 ☐26-35 ☐36-45 ☐ 46 以上/above 46

3. 家乡/Hometown: _____ 现居住地/Current residence: _____

4. 职业/Occupation: _____

5. 工作日, 你一般有多少时间用于工作, 家庭, 个人和睡眠?/During work days, how many hours do you usually spend in working, family activities, individual time and sleeping?

小时/Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14
工作时间 Working time	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
家庭时间 Family time	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
个人时间 Individual time	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

第二部分: /Part 2:

1. 在下列选项中, 你经常使用的电子功能有哪些? (多项选择)/Which of the following functions do you usually use in your daily life? (Multiple choices)

☐ 通话/phone ☐ 信息/message ☐ 邮件/mail ☐ 时钟/clock

☐ 日历/calendar ☐ 音乐/music ☐ 图片/photos ☐ 照相机/camera

☐ 记事本/notes ☐ 计算器/calculator ☐ 游戏/games ☐ 地图/map

☐ 浏览器/browser ☐ 天气/weather ☐ 股票/stocks ☐ 录音/voice record

☐ 其它/others: _____

2. 你喜欢下列哪种形状的饰品? (多项选择)/Which shape of ornament do you like? (No more than 3 choices)

☐ 圆形/round ☐ 菱形/diamond ☐ 波浪形/wavy

3. 请选择你对下列活动的喜好程度/Please make the choices which closely represent you.

	非常不喜欢 Strongly Dislike	不喜欢 Dislike	一般 Neutral	喜欢 Like	非常喜欢 Strongly Like
烹饪/Cooking	☐	☐	☐	☐	☐
朋友聚会/Party with friends	☐	☐	☐	☐	☐
听音乐/Music	☐	☐	☐	☐	☐
运动/Sports	☐	☐	☐	☐	☐
在家上网/Internet surfing at home	☐	☐	☐	☐	☐
自拍/Taking photos for yourself	☐	☐	☐	☐	☐
养宠物/Pets	☐	☐	☐	☐	☐
旅游/Travel	☐	☐	☐	☐	☐
购物/Shopping	☐	☐	☐	☐	☐
社交/Social	☐	☐	☐	☐	☐
定计划/Making Plans	☐	☐	☐	☐	☐
下棋/Playing chess	☐	☐	☐	☐	☐

4. 你购买过以下哪些电子产品? (多项选择)/Which of the following digital products have you purchased before? (Multiple choices)

☐ 桌式计算机/desk PC ☐ 便携式计算机/laptop ☐ 上网本/netbook

☐ 移动存储 flash drive/hard drive ☐ 手机/mobile phone ☐ mp3/mp4 player

☐ 游戏机/game machine ☐ 录音笔/voice recorder ☐ PDA

☐ 数码摄像机/digital camcorder ☐ 数码相机/digital camera ☐ GPS

5. 图中汇集了多种产品的概念设计, 请选择你最期待的产品有哪些？(最多选择 3 项)/There are various kinds of product concepts as shown in the picture. Please choose which product(s) do you expect most? (No more than 3 choices)

Appendix B: Results of Orthogonal Analysis - Demographic Factors

A: Occupation; B: Age; C: Gender

Product 1				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	994.1	3	331.4	0.30
B	278.7	1	278.7	0.25
A×B	1395.6	3	465.2	0.42
C	230.4	1	230.4	0.21
A×C	916.3	3	305.4	0.28
B×C	113.5	1	113.5	0.10
Error	3288.6	3	1096.2	
Total	7217.2	15		

Percentage of people who like Product 1 in following group:							
Macroscopic	47.8%	Skilled	53.5%	Microscopic	32.5%	Research	40.4%
Under 35	47.8%	Above 36	39.4%				
Male	39.8%	Female	47.3%				

Product 2 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	2722.1	3	907.4	4.78*
A×B	1533.1	3	511.0	2.69
C	455.8	1	455.8	2.40
A×C	1358.7	3	452.9	2.39
Error	948.6	5	189.7	
Total	7018.3	15		

Percentage of people who like Product 2 in following group:							
Macroscopic	11.6%	Skilled	16.4%	Microscopic	7.1%	Research	40.9%
Under 35	19.9%	Above 36	18.1%				
Male	24.3%	Female	13.6%				

A: Occupation; B: Age; C: Gender

Product 6 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	1646.0	3	548.7	4.53
B	1918.4	1	1918.4	15.84**
A×B	1298.0	3	432.7	3.57
C	314.7	1	314.7	2.60
A×C	783.0	3	261.0	2.16
B×C	226.2	1	226.2	1.87
Error	363.3	3	121.1	
Total	6549.6	15		

Percentage of people who like Product 6 in following group:							
Macroscopic	21.6%	Skilled	34.4%	Microscopic	50.0%	Research	38.3%
Under 35	47.0%	Above 36	25.1%				
Male	31.7%	Female	40.5%				

Product 9 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	3029.1	3	1009.7	3.37*
A×B	1297.7	3	432.6	1.44
C	1351.5	1	1351.5	4.51*
Error	2398.3	8	299.8	
Total	8076.6	15		

Percentage of people who like Product 9 in following group:							
Macroscopic	18.9%	Skilled	9.4%	Microscopic	10.0%	Research	43.3%
Under 35	20.7%	Above 36	20.1%				
Male	29.6%	Female	11.2%				

A: Occupation; B: Age; C: Gender

Product 15 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	3110.9	3	1037.0	12.83**
B	494.1	1	494.1	6.12*
A×B	318.6	3	106.2	1.31
C	66.2	1	66.2	0.82
A×C	1019.8	3	339.9	4.21
B×C	686.1	1	686.1	8.49 *
Error	242.4	3	80.8	
Total	5938.2	15		

Percentage of people who like Product 15 in following group:							
Macroscopic	15.6%	Skilled	18.0%	Microscopic	10.4%	Research	46.3%
Under 35	28.1%	Above 36	17.0%				
Male	20.5%	Female	24.6%				

Product 21 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	734.4	3	244.8	1.76
B	266.7	1	266.7	1.92
A×B	1586.5	3	528.8	3.81
C	5561.9	1	5561.9	40.07**
A×C	567.4	3	189.1	1.36
B×C	689.3	1	689.3	4.97
Error	416.4	3	138.8	
Total	9822.7	15		

Percentage of people who like Product 21 in following group:							
Macroscopic	42.3%	Skilled	37.2%	Microscopic	55.4%	Research	47.9%
Under 35	41.6%	Above 36	49.8%				
Male	27.1%	Female	64.4%				

Appendix C: Results of Orthogonal Analysis - Shape Preferences

A: Round; B: Diamond; C: Wavy

Product 1 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	720.7	1	720.7	6.32*
A×B	353.6	1	353.6	3.10
A×C	1042.0	1	1042.0	9.14 **
Error	456.3	4	114.1	
Total	2572.6	7		

Percentage of people who like Product 1 in following group:			
Dislike Round	36.3%	Like Round	55.2%
Dislike Diamond	42.6%	Like Diamond	48.9%
Dislike Wavy	48.7%	Like Wavy	42.8%

Product 2 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	118.4	1	118.4	33.70**
A×B	25.6	1	25.6	7.28
C	261.7	1	261.7	74.48**
A×C	129.8	1	129.8	36.95**
B×C	11.8	1	11.8	3.37
Error	7.0	2	3.5	
Total	554.4	7		

Percentage of people who like Product 2 in following group:			
Dislike Round	14.2%	Like Round	15.0%
Dislike Diamond	18.4%	Like Diamond	10.8%
Dislike Wavy	20.3%	Like Wavy	8.9%

A: Round; B: Diamond; C: Wavy

Product 6 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
C	776.5	1	776.5	6.20*
A×C	123.0	1	123.0	0.98
B×C	178.6	1	178.6	1.43
Error	500.9	4	125.2	
Total	1579.0	7		

Percentage of people who like Product 6 in following group:			
Dislike Round	56.6%	Like Round	49.9%
Dislike Diamond	49.8%	Like Diamond	56.7%
Dislike Wavy	43.4%	Like Wavy	63.1%

Product 9 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	563.2	1	563.2	55.22**
B	135.7	1	135.7	13.31*
C	314.2	1	314.2	30.80**
A×C	135.1	1	135.1	13.25*
B×C	135.7	1	135.7	13.31*
Error	20.4	2	10.2	
Total	1304.4	7		

Percentage of people who like Product 9 in following group:			
Dislike Round	27.2%	Like Round	10.4%
Dislike Diamond	14.6%	Like Diamond	22.9%
Dislike Wavy	25.0%	Like Wavy	12.5%

A: Round; B: Diamond; C: Wavy

Product 15 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	1472.6	1	1472.6	623.45**
B	104.8	1	104.8	44.38**
A×B	84.6	1	84.6	35.82**
C	231.8	1	231.8	98.13**
A×C	448.2	1	448.2	189.74**
Error	4.7	2	2.4	
Total	2346.8	7		

Percentage of people who like Product 15 in following group:			
Dislike Round	37.1%	Like Round	10.0%
Dislike Diamond	27.2%	Like Diamond	19.9%
Dislike Wavy	18.2%	Like Wavy	28.9%

Product 21 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	78.9	1	78.9	1.51
A×B	69.0	1	69.0	1.32
A×C	633.6	1	633.6	12.15**
B×C	122.5	1	122.5	2.35
Error	156.5	3	52.2	
Total	1060.5	7		

Percentage of people who like Product 21 in following group:			
Dislike Round	53.0%	Like Round	46.7%
Dislike Diamond	51.4%	Like Diamond	48.3%
Dislike Wavy	49.3%	Like Wavy	50.5%

Appendix D: Results of Orthogonal Analysis - Hobbies (Group 3)

A: Cooking; B: Party with Friends; C: Taking photos for yourself

Product 1 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	99.2	1	99.2	1.38
A×B	348.2	1	348.2	4.84
C	763.9	1	763.9	10.61**
B×C	602.8	1	602.8	8.37*
Error	216.0	3	72.0	
Total	2030.1	7		

Percentage of people who like Product 1 in following group:			
Dislike Cooking	33.6%	Like Cooking	40.7%
Dislike Party	35.1%	Like Party	39.2%
Dislike Taking photos	46.9%	Like Taking photos	27.4%

Product 2 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	253.1	1	253.1	29.10**
A×B	11.9	1	11.9	1.37
C	183.7	1	183.7	21.11**
B×C	136.9	1	136.9	15.74**
Error	26.1	3	8.7	
Total	611.7	7		

Percentage of people who like Product 2 in following group:			
Dislike Cooking	18.2%	Like Cooking	19.4%
Dislike Party	24.4%	Like Party	13.2%
Dislike Taking photos	14.0%	Like Taking photos	23.6%

A: Cooking; B: Party with Friends; C: Taking photos for yourself

Product 6				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	165.2	1	165.2	0.80
A×B	198.4	1	198.4	0.96
A×C	179.9	1	179.9	0.87
Error	828.8	4	207.2	
Total	1372.3	7		

Percentage of people who like Product 6 in following group:			
Dislike Cooking	59.5%	Like Cooking	54.3%
Dislike Party	52.4%	Like Party	61.5%
Dislike Taking photos	59.3%	Like Taking photos	54.5%

Product 9 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	619.5	1	619.5	2.65
C	586.4	1	586.4	2.51
B×C	1324.5	1	1324.5	5.66*
Error	935.5	4	233.9	
Total	3465.9	7		

Percentage of people who like Product 9 in following group:			
Dislike Cooking	22.9%	Like Cooking	16.6%
Dislike Party	28.6%	Like Party	11.0%
Dislike Taking photos	11.2%	Like Taking photos	28.3%

A: Cooking; B: Party with Friends; C: Taking photos for yourself

Product 15 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	272.2	1	272.2	1.20
A×C	2190.6	1	2190.6	9.66**
Error	1134.4	5	226.9	
Total	3597.2	7		

Percentage of people who like Product 15 in following group:			
Dislike Cooking	35.7%	Like Cooking	24.0%
Dislike Party	27.4%	Like Party	32.4%
Dislike Taking photos	27.4%	Like Taking photos	32.4%

Product 21 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	1037.7	1	1037.7	13.47**
A×B	4505.0	1	4505.0	58.49**
C	158.0	1	158.0	2.05
A×C	966.6	1	966.6	12.55**
Error	231.1	3	77.0	
Total	6898.3	7		

Percentage of people who like Product 21 in following group:			
Dislike Cooking	35.1%	Like Cooking	57.9%
Dislike Party	43.5%	Like Party	49.6%
Dislike Taking photos	42.1%	Like Taking photos	51.0%

Appendix E: Results of Orthogonal Analysis - Hobbies (Group 4)

A: Listening music; B: Internet surfing at home; C: Shopping

Product 1				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	215.0	1	215.0	1.09
A×B	558.9	1	558.9	2.83
Error	988.8	5	197.8	
Total	1762.6	7		

Percentage of people who like Product 1 in following group:			
Dislike Music	44.8%	Like Music	44.8%
Dislike Internet surfing	50.0%	Like Internet surfing	39.6%
Dislike Shopping	40.6%	Like Shopping	49.0%

Product 2 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	229.0	1	229.0	4.48
A×B	85.4	1	85.4	1.67
C	772.9	1	772.9	15.12**
A×C	879.3	1	879.3	17.20**
Error	153.4	3	51.1	
Total	2119.8	7		

Percentage of people who like Product 2 in following group:			
Dislike Music	29.7%	Like Music	19.0%
Dislike Internet surfing	22.9%	Like Internet surfing	25.8%
Dislike Shopping	34.2%	Like Shopping	14.5%

A: Listening music; B: Internet surfing at home; C: Shopping

Product 6 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	99.1	1	99.1	1.41
A×B	99.1	1	99.1	1.41
C	1819.7	1	1819.7	25.90**
A×C	1245.5	1	1245.5	17.73*
B×C	53.3	1	53.3	0.76
Error	140.5	2	70.3	
Total	3457.2	7		

Percentage of people who like Product 6 in following group:			
Dislike Music	25.5%	Like Music	32.6%
Dislike Internet surfing	29.2%	Like Internet surfing	28.9%
Dislike Shopping	14.0%	Like Shopping	44.1%

Product 9 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	784.2	1	784.2	186.90**
B	54.0	1	54.0	12.88
A×B	175.4	1	175.4	41.81*
C	389.1	1	389.1	92.74*
A×C	63.1	1	63.1	15.03
B×C	94.8	1	94.8	22.60
Error	4.2	1	4.2	
Total	1564.8	7		

Percentage of people who like Product 9 in following group:			
Dislike Music	10.4%	Like Music	30.2%
Dislike Internet surfing	22.9%	Like Internet surfing	17.7%
Dislike Shopping	27.3%	Like Shopping	13.3%

A: Listening music; B: Internet surfing at home; C: Shopping

Product 15				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	345.8	1	345.8	2.21
B	233.6	1	233.6	1.50
B×C	290.8	1	290.8	1.86
Error	624.6	4	156.2	
Total	1494.9	7		

Percentage of people who like Product 15 in following group:			
Dislike Music	30.7%	Like Music	17.6%
Dislike Internet surfing	18.8%	Like Internet surfing	29.6%
Dislike Shopping	24.4%	Like Shopping	23.9%

Product 21 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	262.4	1	262.4	7.78**
C	413.6	1	413.6	12.26**
B×C	1069.1	1	1069.1	31.69**
Error	134.9	4	33.7	
Total	1879.9	7		

Percentage of people who like Product 21 in following group:			
Dislike Music	47.4%	Like Music	45.3%
Dislike Internet surfing	52.1%	Like Internet surfing	40.6%
Dislike Shopping	39.2%	Like Shopping	53.5%

Appendix F: Results of Orthogonal Analysis - Hobbies (Group 5)

A: Sports; B: Making plans; C: Playing chess

Product 1 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	269.7	1	269.7	12.99*
B	445.0	1	445.0	21.44**
A×B	40.5	1	40.5	1.95
A×C	455.0	1	455.0	21.92**
B×C	87.4	1	87.4	4.21
Error	41.5	2	20.8	
Total	1339.1	7		

Percentage of people who like Product 1 in following group:			
Dislike Sports	36.5%	Like Sports	48.1%
Dislike Making plans	49.7%	Like Making plans	34.8%
Dislike Playing chess	42.0%	Like Playing chess	42.5%

Product 2				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	231.5	1	231.5	2.32
C	186.5	1	186.5	1.87
Error	498.4	5	99.7	
Total	916.4	7		

Percentage of people who like Product 2 in following group:			
Dislike Sports	20.5%	Like Sports	17.6%
Dislike Making plans	24.4%	Like Making plans	13.7%
Dislike Playing chess	14.2%	Like Playing chess	23.9%

A: Sports; B: Making plans; C: Playing chess

Product 6 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	201.7	1	201.7	8.53**
C	263.8	1	263.8	11.15**
A×C	201.7	1	201.7	8.53**
Error	94.6	4	23.7	
Total	761.9	7		

Percentage of people who like Product 6 in following group:			
Dislike Sports	48.3%	Like Sports	58.3%
Dislike Making plans	51.1%	Like Making plans	55.5%
Dislike Playing chess	59.0%	Like Playing chess	47.5%

Product 9				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	407.9	1	407.9	1.95
B×C	624.0	1	624.0	2.98
Error	1045.3	5	209.1	
Total	2077.2	7		

Percentage of people who like Product 9 in following group:			
Dislike Sports	25.0%	Like Sports	25.9%
Dislike Making plans	18.3%	Like Making plans	32.6%
Dislike Playing chess	21.5%	Like Playing chess	29.4%

Product 15				
Source	Sum Sq.	d. f.	Mean Sq.	F
A×B	101.7	1	101.7	1.40
Error	435.7	6	72.6	
Total	537.4	7		

Percentage of people who like Product 15 in following group:			
Dislike Sports	23.3%	Like Sports	23.4%
Dislike Making plans	23.1%	Like Making plans	23.6%
Dislike Playing chess	25.0%	Like Playing chess	21.6%

A: Sports; B: Making plans; C: Playing chess

Product 21				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	87.0	1	87.0	3.45
C	90.8	1	90.8	3.60
A×C	66.4	1	66.4	2.63
Error	100.8	4	25.2	
Total	345.0	7		

Percentage of people who like Product 21 in following group:			
Dislike Sports	43.8%	Like Sports	41.2%
Dislike Making plans	39.2%	Like Making plans	45.8%
Dislike Playing chess	45.8%	Like Playing chess	39.1%

Appendix G: Results of Orthogonal Analysis - Hobbies (Group 6)

A: Social with strangers; B: Travel; C: Pets

Product 1 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	374.5	1	374.5	3.38
C	1432.0	1	1432.0	12.91**
Error	554.6	5	110.9	
Total	2361.1	7		

Percentage of people who like Product 1 in following group:			
Dislike Social	32.6%	Like Social	35.8%
Dislike Travel	27.4%	Like Travel	41.1%
Dislike Pets	20.8%	Like Pets	47.6%

Product 2 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	424.0	1	424.0	164.52**
C	83.1	1	83.1	32.26**
A×C	2511.8	1	2511.8	974.54**
Error	10.3	4	2.6	
Total	3029.3	7		

Percentage of people who like Product 2 in following group:			
Dislike Social	14.5%	Like Social	29.1%
Dislike Travel	22.2%	Like Travel	21.3%
Dislike Pets	25.0%	Like Pets	18.6%

A: Social with strangers; B: Travel; C: Pets

Product 6 (**α_1=0.05, *α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	1418.8	1	1418.8	143.49**
B	626.1	1	626.1	63.32**
C	106.8	1	106.8	10.80*
A×C	737.2	1	737.2	74.55**
B×C	263.3	1	263.3	26.63**
Error	19.8	2	9.9	
Total	3171.9	7		

Percentage of people who like Product 6 in following group:			
Dislike Social	29.9%	Like Social	56.6%
Dislike Travel	34.4%	Like Travel	52.1%
Dislike Pets	39.6%	Like Pets	46.9%

Product 9 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	396.6	1	396.6	2.34
A×B	440.5	1	440.5	2.60
C	544.3	1	544.3	3.22
A×C	1096.9	1	1096.9	6.49*
Error	507.4	3	169.1	
Total	7217.2	15		

Percentage of people who like Product 9 in following group:			
Dislike Social	30.0%	Like Social	16.0%
Dislike Travel	24.2%	Like Travel	21.8%
Dislike Pets	31.3%	Like Pets	14.8%

A: Social with strangers; B: Travel; C: Pets

Product 15 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	148.9	1	148.9	8.24**
C	2953.9	1	2953.9	163.56**
B×C	148.9	1	148.9	8.24**
Error	72.2	4	18.1	
Total	3323.9	7		

Percentage of people who like Product 15 in following group:			
Dislike Social	17.4%	Like Social	21.0%
Dislike Travel	14.9%	Like Travel	23.5%
Dislike Pets	0.0%	Like Pets	38.4%

Product 21 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A×B	1473.4	1	1473.4	5.90*
A×C	946.1	1	946.1	3.79
Error	1249.3	5	249.9	
Total	3668.8	7		

Percentage of people who like Product 21 in following group:			
Dislike Social	54.9%	Like Social	47.5%
Dislike Travel	46.2%	Like Travel	56.3%
Dislike Pets	52.1%	Like Pets	50.3%

Appendix H: Results of Orthogonal Analysis – Life Styles

A: Working time; B: Family time

Product 1 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	1532.0	2	766.0	3.96*
Error	1160.0	6	193.3	
Total	2692.0	8		

Percentage of people who like Product 1 in following group:			
Working time≤7hs	42.6%	Family time≤1h	48.2%
Working time=8hs	47.7%	Family time=3-4hs	32.4%
Working time≥9hs	54.7%	Family time≥5hs	64.4%

Product 2 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	274.5	2	137.2	26.22**
A×B	435.0	4	108.7	20.77**
Error	10.5	2	5.2	
Total	720.0	8		

Percentage of people who like Product 2 in following group:			
Working time≤7hs	16.7%	Family time≤1h	21.7%
Working time=8hs	18.7%	Family time=3-4hs	22.4%
Working time≥9hs	19.1%	Family time≥5hs	10.4%

A: Working time; B: Family time

Product 6				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	1687.8	2	843.9	7.64
A×B	2432.3	4	608.1	5.51
Error	710.7	2	355.4	
Total	4830.8	8		

Percentage of people who like Product 6 in following group:			
Working time≤7hs	60.2%	Family time≤1h	67.3%
Working time=8hs	44.7%	Family time=3-4hs	39.4%
Working time≥9hs	39.2%	Family time≥5hs	37.3%

Product 9 (*α_2=0.10)				
Source	Sum Sq.	d. f.	Mean Sq.	F
A	416.3	2	208.2	9.88*
A×B	173.4	4	43.3	2.06
Error	42.2	2	21.1	
Total	631.9	8		

Percentage of people who like Product 9 in following group:			
Working time≤7hs	25.0%	Family time≤1h	18.2%
Working time=8hs	26.2%	Family time=3-4hs	23.5%
Working time≥9hs	11.2%	Family time≥5hs	20.6%

Product 15 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	139.1	2	69.5	3.14
A×B	2047.2	4	511.8	23.14**
Error	44.2	2	22.1	
Total	2230.5	8		

Percentage of people who like Product 15 in following group:			
Working time≤7hs	26.9%	Family time≤1h	26.3%
Working time=8hs	23.3%	Family time=3-4hs	31.1%
Working time≥9hs	28.7%	Family time≥5hs	21.5%

A: Working time; B: Family time

Product 21 (**α_1=0.05)				
Source	Sum Sq.	d. f.	Mean Sq.	F
B	1202.3	2	601.1	56.10**
A×B	216.2	4	54.0	5.04
Error	21.4	2	10.7	
Total	1439.9	8		

Percentage of people who like Product 21 in following group:			
Working time≤7hs	50.0%	Family time≤1h	63.7%
Working time=8hs	52.3%	Family time=3-4hs	36.3%
Working time≥9hs	53.7%	Family time≥5hs	56.0%

Appendix I: Eye Tracking Example - Original Data of Figure 3.12

[BeGaze]
Converted from: C:\Program Files\SMI\Experiment Suite 360\Experiment Center 2\Results\ designer1F \ designer1F - designer1F -1.idf
Date: 04.10.2010 14:56:08
Version: BeGaze 2.4.175
Sample Rate: 500
Subject: designer1F
Description: Run1

Table Header for Fixations:
Event Type Trial Number Start End Duration Location X Location Y Dispersion X Dispersion Y Avg. Pupil Size X Avg. Pupil Size Y

Table Header for Saccades:
Event Type Trial Number Start End Duration Start Loc.X Start Loc.Y End Loc.X End Loc.Y Amplitude Peak Speed Peak Speed At Average Speed Peak Accel. Peak Decel. Average Accel.

Table Header for Blinks:
Event Type Trial Number Start End Duration

Table Header for User Events:
Event Type Trial Number Start Description

Table Header for Trigger Line Events:
Event Type Trial Number Start Duration Port Status

UserEvent 1 1 34043559234 # Message: pic1.jpg
Fixation L 1 1 34043559910 34043677937 118027 138.63 367.91 15 7 26.93 26.97
Fixation R 1 1 34043559910 34043677937 118027 154.00 361.80 13 9 27.46 26.00
Saccade L 1 1 34043677937 34043711940 34003 141.36 365.36 114.36 429.99 2.07 142.99 0.35 60.76 59077.51 -54497.90 36500.95
Saccade R 1 1 34043677937 34043715940 38003 157.19 363.20 117.05 409.37 2.37 153.00 0.32 62.26 62362.89 -49418.76 33033.14
Fixation L 1 2 34043711940 34043921985 210045 113.95 430.31 4 10 27.00

26.89
Fixation R 1 2 34043715940 34043919988 204048 112.96 413.35 8 8 27.94
26.08
Saccade R 1 2 34043919988 34043963996 44008 109.12 414.32 70.62 110.22
7.08 294.77 0.41 160.99 133151.32 -112474.61 89370.32
Saccade L 1 2 34043921985 34043961995 40010 115.36 427.22 59.31 101.20
7.38 357.00 0.70 184.39 130810.63 -141307.33 99299.05
Fixation R 1 3 34043963996 34044212042 248046 67.66 111.62 12 19 27.89
25.70
Fixation L 1 3 34043973995 34044180042 206047 67.26 136.01 9 32 27.03
26.45
Blink L 1 1 34044196042 34044378079 182037
Blink R 1 1 34044212042 34044346079 134037
Fixation R 1 4 34044346079 34044512117 166038 219.72 218.53 12 28 29.07
26.61
Fixation L 1 4 34044378079 34044510116 132037 236.19 279.71 6 23 27.88
27.14
Saccade L 1 3 34044510116 34044544116 34000 236.35 286.19 375.17 229.71
3.64 241.23 0.41 107.01 105050.74 -101352.07 73390.97
Saccade R 1 3 34044512117 34044540117 28000 219.32 223.50 376.61 210.93
3.67 261.27 0.50 131.17 111262.76 -104239.18 78374.11
Fixation R 1 5 34044540117 34044778171 238054 379.30 225.56 16 21 29.87
27.08
Fixation L 1 5 34044544116 34044778171 234055 391.42 238.71 27 13 29.86
28.05
Saccade L 1 4 34044778171 34044848190 70019 400.01 240.58 603.77 413.98
7.71 392.27 0.26 110.06 172837.79 -153065.40 69309.18
Saccade R 1 4 34044778171 34044842180 64009 382.79 225.85 579.60 439.26
7.74 414.01 0.28 120.96 178413.04 -163110.77 77735.86
Fixation R 1 6 34044842180 34044898198 56018 580.32 440.76 12 16 30.00
28.00
Fixation L 1 6 34044848190 34044900199 52009 606.25 418.42 4 11 30.00
29.88
Blink R 1 2 34044898198 34045074237 176039
Blink L 1 2 34044900199 34045078237 178038
Blink R 1 3 34045074237 34045332290 258053
Blink L 1 3 34045078237 34045366300 288063
Fixation R 1 7 34045332290 34045522337 190047 554.08 448.39 11 40 30.00
27.96
Fixation L 1 7 34045366300 34045522337 156037 574.02 404.51 13 17 30.00
29.72
Saccade L 1 5 34045522337 34045558347 36010 567.67 405.30 336.84 412.31
5.27 286.70 0.44 146.21 128020.34 -119709.65 90763.51
Saccade R 1 5 34045522337 34045558347 36010 559.77 450.30 308.93 438.55

5.63 309.26 0.50 156.45 137623.88 -118745.01 93737.84
Fixation L 1 8 34045558347 34045958429 400082 338.77 422.04 20 19 30.05 28.90
Fixation R 1 8 34045574352 34045956428 382076 340.42 447.07 18 11 30.57 28.74
Saccade R 1 6 34045956428 34045988439 32011 334.70 445.12 436.61 368.28 2.95 182.76 0.50 92.24 79970.16 -71547.23 56543.27
Saccade L 1 6 34045958429 34045992437 34008 335.20 428.63 430.07 340.03 2.99 173.07 0.47 87.92 76290.09 -72851.43 54278.66
Fixation R 1 9 34045988439 34046130466 142027 425.92 365.43 15 11 28.89 26.44
Fixation L 1 9 34045992437 34046130466 138029 431.63 338.28 15 6 29.17 28.04
Saccade L 1 7 34046130466 34046244492 114026 438.49 338.73 601.29 349.24 19.24 491.29 0.26 168.76 165997.47 -127771.93 61877.59
Saccade R 1 7 34046130466 34046244492 114026 428.03 368.40 599.63 362.36 24.47 620.62 0.26 214.57 221357.22 -168319.36 80178.79
Blink L 1 4 34046264493 34046438533 174040
Blink R 1 4 34046268492 34046430529 162037
Fixation R 1 10 34046430529 34046576572 146043 721.47 429.19 9 33 28.00 26.08
Fixation L 1 10 34046438533 34046576572 138039 713.92 419.41 11 37 29.58 28.68
Saccade L 1 8 34046576572 34046620576 44004 716.45 424.31 929.48 264.96 6.20 299.82 0.41 140.98 132437.90 -113385.46 84517.66
Saccade R 1 8 34046576572 34046620576 44004 723.75 430.19 959.21 237.17 7.51 336.33 0.41 170.62 149704.29 -133200.54 99114.26
Fixation L 1 11 34046620576 34046894636 274060 936.61 266.52 19 13 30.82 28.91
Fixation R 1 11 34046620576 34046892633 272057 957.11 259.98 6 27 28.97 26.75
Saccade R 1 9 34046892633 34046924641 32008 959.96 258.93 795.53 395.11 4.78 307.72 0.56 149.19 132761.88 -117033.61 93131.82
Saccade L 1 9 34046894636 34046938641 44005 935.73 263.68 805.15 374.08 4.77 282.53 0.36 108.48 121060.54 -109174.35 69478.55
Fixation L 1 12 34046938641 34047084678 146037 800.93 385.82 15 15 30.18 29.01
Fixation R 1 12 34046940641 34047086678 146037 804.23 387.54 24 12 30.00 27.79
Saccade L 1 10 34047084678 34047124686 40008 806.72 389.12 523.17 380.90 6.43 311.71 0.45 160.78 140023.05 -123824.72 95183.85
Saccade R 1 10 34047086678 34047124686 38008 800.20 387.52 507.42 388.73 6.54 312.52 0.47 172.04 139275.43 -119098.43 96366.33
Fixation L 1 13 34047138687 34047340731 202044 537.51 385.27 23 16 30.02

28.78
Fixation R 1 13 34047158695 34047340731 182036 529.36 387.94 6 5 30.53
28.84
Saccade L 1 11 34047340731 34047362733 22002 539.34 387.96 603.98 383.96
1.31 108.98 0.55 59.57 43526.75 -37295.56 25872.01
Saccade R 1 11 34047340731 34047362733 22002 531.30 388.33 600.60 385.70
1.42 118.48 0.55 64.63 48224.89 -37049.78 27563.26
Fixation L 1 14 34047362733 34047526768 164035 591.12 379.56 20 8 28.93
27.94
Fixation R 1 14 34047362733 34047526768 164035 584.21 383.57 23 11 29.17
27.26
Fixation L 1 15 34047546778 34047824833 278055 559.17 404.09 13 30 28.26
27.19
Fixation R 1 15 34047558782 34047812835 254053 554.96 417.67 11 27 28.77
26.94
Blink R 1 5 34047812835 34047984872 172037
Blink L 1 5 34047824833 34047996881 172048
Fixation R 1 16 34047984872 34048130909 146037 538.51 440.73 13 39 29.41
27.99
Fixation L 1 16 34047996881 34048122907 126026 544.60 416.51 13 41 29.95
29.71
Saccade L 1 12 34048122907 34048156908 34001 539.78 427.76 615.23 397.91
1.90 124.18 0.59 55.75 46426.28 -51062.90 33063.81
Saccade R 1 12 34048130909 34048156908 25999 544.55 453.96 619.96 403.28
2.07 147.37 0.54 79.45 58026.58 -59915.37 42429.50
Fixation L 1 17 34048156908 34048260937 104029 613.48 400.12 4 10 30.58
29.37
Fixation R 1 17 34048156908 34048272937 116029 617.10 396.35 22 18 30.10
28.29
Blink L 1 6 34048260937 34048779047 518110
Blink R 1 6 34048272937 34048761047 488110
Blink L 1 7 34048785047 34049091120 306073
Blink R 1 7 34048809055 34049059110 250055
Fixation R 1 18 34049059110 34049177139 118029 216.06 559.30 8 38 31.81
31.58
Saccade L 1 13 34049091120 34049123120 32000 161.92 552.65 175.57 586.23
1.08 70.65 0.44 33.74 14460.44 -21276.25 11327.09
Fixation L 1 18 34049123120 34049173139 50019 186.49 603.88 15 35 31.00
29.40
Saccade L 1 14 34049173139 34049223147 50008 187.74 615.96 127.70 721.18
2.81 98.05 0.40 56.22 40707.79 -25195.18 22215.65
Saccade R 1 13 34049177139 34049219149 42010 218.03 543.18 196.10 600.13
1.40 50.48 0.38 33.29 19026.23 -13926.73 10728.43
Blink R 1 8 34049223147 34049829278 606131

Blink L 1 8 34049227148 34049729259 502111
Fixation R 1 19 34049829278 34050147351 318073 623.49 550.53 15 40 32.09 30.55
Fixation L 1 19 34049877286 34050131340 254054 618.63 517.51 20 65 32.28 33.76
Blink L 1 9 34050131340 34050677462 546122
Blink R 1 9 34050147351 34050773487 626136
Blink L 1 10 34050677462 34050791488 114026
Saccade L 1 15 34050797489 34050827503 30014 578.28 394.52 576.22 437.29 1.00 49.40 0.53 33.28 15819.93 -17257.28 12268.99
Saccade R 1 14 34050855510 34050885506 29996 594.62 476.25 582.25 396.29 1.88 113.63 0.47 62.80 38933.54 -45764.74 31595.10
Saccade L 1 16 34050857506 34050885506 28000 585.37 435.97 566.49 382.26 1.28 75.77 0.50 45.54 31615.39 -25791.82 21265.01
Fixation L 1 20 34050885506 34051197580 312074 566.41 390.81 21 15 31.40 30.45
Fixation R 1 20 34050885506 34051197580 312074 579.29 403.64 19 11 31.10 29.24
Saccade L 1 17 34051197580 34051239591 42011 563.35 389.97 234.17 402.72 7.54 346.78 0.43 179.53 155922.50 -140829.66 107309.00
Saccade R 1 15 34051197580 34051237591 40011 587.69 402.31 219.25 415.14 8.16 375.26 0.50 204.03 165410.29 -143849.60 113000.75
Fixation L 1 21 34051239591 34051483644 244053 249.16 413.69 19 19 27.61 26.66
Fixation R 1 21 34051253589 34051485644 232055 261.07 412.25 20 15 28.76 27.55
Saccade L 1 18 34051483644 34051517653 34009 251.17 413.90 369.33 353.59 3.10 200.97 0.41 91.10 85456.80 -82673.22 59783.75
Saccade R 1 16 34051485644 34051513661 28017 257.58 408.90 380.22 364.70 3.02 214.38 0.50 107.76 91236.55 -88778.09 64990.17
Fixation R 1 22 34051513661 34051597664 84003 384.02 363.65 11 8 28.00 25.74
Fixation L 1 22 34051517653 34051603666 86013 375.71 353.48 14 11 26.93 25.95
Blink R 1 10 34051597664 34051757700 160036
Blink L 1 11 34051603666 34051787710 184044
Fixation R 1 23 34051757700 34051825720 68020 252.06 343.15 9 30 27.00 25.15
Saccade L 1 19 34051823720 34051893728 70008 234.49 347.85 811.81 546.56 15.87 509.07 0.31 226.64 224999.55 -182412.94 116114.40
Saccade R 1 17 34051825720 34051903736 78016 246.25 345.41 844.81 585.54 16.43 544.42 0.23 210.64 241364.04 -166931.34 104927.71
Fixation L 1 23 34051893728 34052221802 328074 822.99 562.83 20 26 27.90 27.61

Fixation	R	1	24	34051903736	34052221802	318066	829.01	578.03	21	27	27.64	26.23									
Saccade	L	1	20	34052221802	34052259817	38015	830.84	566.19	939.23	570.62	3.37	209.50	0.37	88.68	90250.43	-78127.88	53283.46				
Saccade	R	1	18	34052221802	34052265812	44010	829.74	584.74	952.42	585.56	3.65	200.38	0.32	82.84	87697.41	-71276.97	48300.93				
Fixation	L	1	24	34052259817	34052671911	412094	947.20	583.38	13	20	28.72	28.57									
Fixation	R	1	25	34052265812	34052673912	408100	957.32	604.35	19	30	27.95	27.37									
Saccade	L	1	21	34052671911	34052709912	38001	947.62	583.22	836.19	550.99	2.65	122.55	0.42	69.70	53989.80	-45149.91	35142.28				
Saccade	R	1	19	34052673912	34052705912	32000	953.67	612.95	848.31	581.57	2.49	138.53	0.44	77.85	60698.97	-53729.86	42557.66				
Fixation	R	1	26	34052705912	34052837941	132029	847.11	579.62	27	10	28.95	27.70									
Fixation	L	1	25	34052709912	34052835941	126029	840.81	562.90	8	15	29.02	28.86									
Saccade	L	1	22	34052835941	34052871949	36008	841.55	563.36	1010.52	525.92	3.95	231.70	0.50	109.71	99130.53	-87787.54	68487.48				
Saccade	R	1	20	34052837941	34052869949	32008	840.06	576.40	1025.61	524.62	4.28	251.68	0.50	133.63	112384.85	-99382.97	79343.99				
Fixation	R	1	27	34052869949	34052947959	78010	1004.93	526.45	24	9	28.62	27.03									
Fixation	L	1	26	34052871949	34052973968	102019	995.12	522.88	24	5	29.75	29.22									
Blink	R	1	11	34052947959	34053126006	178047															
Blink	L	1	12	34052973968	34053113995	140027															
Saccade	L	1	23	34053113995	34053142004	28009	944.72	536.39	952.53	590.57	1.08	70.76	0.36	38.48	5928.72	-26628.96	12556.57				
Fixation	R	1	28	34053126006	34053554096	428090	977.73	598.99	16	41	27.86	26.68									
Fixation	L	1	27	34053142004	34053552096	410092	964.33	583.02	24	18	28.71	28.32									
Saccade	L	1	24	34053552096	34053582106	30010	972.22	589.54	852.09	576.08	2.74	181.53	0.53	91.29	77338.78	-73716.25	55260.60				
Saccade	R	1	21	34053554096	34053582106	28010	972.96	598.36	854.47	593.46	2.65	184.22	0.50	94.54	75603.00	-70382.92	53622.78				
Fixation	L	1	28	34053582106	34053970190	388084	853.51	587.99	24	26	30.16	29.41									
Fixation	R	1	29	34053582106	34053986188	404082	867.72	594.59	23	21	28.96	27.94									
Blink	L	1	13	34053986188	34054402280	416092															
Blink	R	1	12	34053986188	34054342272	356084															

Saccade R 1 22 34054360273 34054386281 26008 1049.63 513.24 1137.49 510.07
1.98 139.91 0.54 76.01 52814.42 -54857.19 38846.03
Fixation R 1 30 34054386281 34054572328 186047 1131.30 536.80 17 53 28.54
28.42
Fixation L 1 29 34054402280 34054570326 168046 1115.28 496.44 25 74 30.71
32.15
Saccade L 1 25 34054570326 34054594328 24002 1117.27 535.65 1228.68 571.91
2.34 186.88 0.58 97.56 77672.36 -58545.55 45368.60
Saccade R 1 23 34054572328 34054596328 24000 1137.14 558.39 1202.02 598.54
1.59 122.74 0.58 66.08 48833.39 -42368.23 30803.59
Fixation R 1 31 34054596328 34055114438 518110 1197.50 592.09 18 29 28.30
28.60
Fixation L 1 30 34054608328 34055114438 506110 1200.58 555.77 19 25 30.56
30.39
Saccade L 1 26 34055114438 34055178467 64029 1199.38 546.77 1024.83 764.19
7.77 397.60 0.28 121.39 175062.58 -151351.03 74024.45
Saccade R 1 24 34055114438 34055158447 44009 1198.08 575.97 1056.64 746.63
5.71 305.28 0.41 129.80 130976.68 -121399.36 80606.15
Fixation L 1 31 34055178467 34055310485 132018 1029.84 758.63 8 11 28.83
29.00
Fixation R 1 32 34055178467 34055318485 140018 1041.56 764.43 19 29 27.39
27.44
Saccade L 1 27 34055310485 34055354499 44014 1029.84 758.92 875.37 768.49
3.89 215.94 0.50 88.47 87254.82 -83868.21 55972.45
Saccade R 1 25 34055318485 34055362493 44008 1034.67 763.76 901.83 769.55
4.10 234.63 0.36 93.24 99504.43 -89510.31 57321.46
Fixation L 1 32 34055354499 34055448511 94012 878.39 788.07 14 32 29.00
29.85
Fixation R 1 33 34055362493 34055436520 74027 894.45 769.46 15 7 28.35
27.92
Blink R 1 13 34055436520 34055670558 234038
Blink L 1 14 34055448511 34055680557 232046
Saccade R 1 26 34055674558 34055706567 32009 931.54 769.34 923.05 808.85
0.90 40.57 0.38 28.25 10550.10 -10852.25 8069.03
Saccade L 1 28 34055684567 34055728578 44011 905.38 719.58 908.96 799.30
1.74 64.77 0.36 39.61 21486.21 -18305.22 15034.29
Fixation R 1 34 34055706567 34055908612 202045 921.30 806.40 27 17 26.62
26.41
Fixation L 1 33 34055728578 34055908612 180034 906.40 811.08 18 19 28.18
27.93
Saccade L 1 29 34055908612 34055966624 58012 909.54 812.90 562.58 818.24
8.99 365.06 0.34 154.94 158767.46 -132254.26 88940.86
Saccade R 1 27 34055908612 34055952623 44011 933.82 812.26 541.48 832.82
9.09 388.97 0.45 206.61 171607.97 -155402.07 118392.51

Fixation L 1 34 34055966624 34056186682 220058 545.22 819.29 26 28 28.56 29.03
Fixation R 1 35 34055966624 34056188677 222053 551.84 824.64 24 15 28.87 28.15
Saccade L 1 30 34056186682 34056224685 38003 551.88 817.74 389.75 783.70 3.82 205.55 0.37 100.56 87377.05 -80441.54 59374.92
Saccade R 1 28 34056188677 34056238687 50010 553.46 823.20 418.48 816.15 4.26 234.07 0.32 85.24 101657.27 -88499.90 50591.15
Fixation L 1 35 34056224685 34056620770 396085 395.26 775.32 23 34 25.03 25.82
Fixation R 1 36 34056238687 34056620770 382083 399.57 804.59 33 22 25.97 25.47
Saccade L 1 31 34056620770 34056672778 52008 393.32 769.38 20.98 772.23 8.75 327.75 0.38 168.19 142031.68 -114917.82 91287.38
Saccade R 1 29 34056620770 34056666780 46010 387.51 794.23 27.26 821.41 8.40 322.18 0.48 182.52 142533.91 -133525.66 99638.66
Fixation R 1 37 34056666780 34057068872 402092 42.37 810.36 22 29 24.84 24.74
Fixation L 1 36 34056672778 34057068872 396094 37.99 779.67 30 34 23.47 24.96
Saccade L 1 32 34057068872 34057110881 42009 42.64 772.05 188.60 707.24 3.84 214.72 0.38 91.33 88626.14 -77322.21 55756.21
Saccade R 1 30 34057068872 34057108872 40000 40.06 797.13 177.93 746.30 3.57 217.22 0.40 89.32 91259.51 -85220.41 58799.61
Fixation R 1 38 34057108872 34057176893 68021 178.34 745.64 9 8 25.12 24.06
Fixation L 1 37 34057110881 34057170900 60019 192.03 714.82 6 24 24.27 24.37
Blink L 1 15 34057170900 34057436944 266044
Blink R 1 14 34057176893 34057398937 222044
Fixation R 1 39 34057398937 34057598985 200048 115.03 642.81 15 53 26.99 26.00
Saccade L 1 33 34057450955 34057494964 44009 75.13 563.49 99.60 626.61 1.49 54.89 0.27 33.79 21213.63 -15745.75 12397.55
Fixation L 1 38 34057494964 34057598985 104021 112.30 634.61 18 11 26.27 26.69
Saccade L 1 34 34057598985 34057634991 36006 112.18 636.65 74.19 613.40 1.36 74.37 0.39 37.73 30101.64 -25870.04 19522.70
Saccade R 1 31 34057598985 34057625003 26018 121.21 645.82 58.45 602.81 1.67 107.73 0.54 64.01 45938.89 -42105.16 32578.29
Fixation R 1 40 34057625003 34057999076 374073 71.07 601.01 24 24 27.82 26.96
Fixation L 1 39 34057634991 34058001082 366091 77.92 615.35 15 18 26.15 27.69

Saccade R	1	32	34057999076	34058025074	25998	81.04	589.28	146.62	656.63	
2.03	149.84	0.62	78.25	63938.97	-57827.43	42237.47				
Saccade L	1	35	34058001082	34058037083	36001	68.32	619.47	137.18	646.05	
2.41	162.74	0.33	66.83	64594.27	-59803.31	38622.97				
Fixation R	1	41	34058025074	34058125102	100028	141.64	648.79	11	16	26.94
26.36										
Fixation L	1	40	34058037083	34058113096	76013	141.65	645.56	7	8	25.84
26.95										
Blink L	1	16	34058113096	34058605206	492110					
Blink R	1	15	34058125102	34058471176	346074					
Fixation R	1	42	34058471176	34058603203	132027	109.42	604.58	19	32	27.35
26.67										
Saccade R	1	33	34058603203	34058655213	52010	113.89	615.78	56.34		565.12
2.90	128.11	0.27	55.72	55356.30	-45463.97	27254.13				
Saccade L	1	36	34058605206	34058653212	48006	77.00	593.05	37.41		574.16
2.32	110.54	0.29	48.35	33314.89	-33801.12	18616.67				
Fixation L	1	41	34058653212	34058753241	100029	37.19	574.40	17	6	27.02
27.90										
Fixation R	1	43	34058655213	34058753241	98028	56.61	558.18	3	10	28.02
27.88										
Saccade L	1	37	34058753241	34058809256	56015	48.36	574.39	741.17		670.04
16.36	524.04	0.43	292.05	227321.56	-196646.02	147789.32				
Saccade R	1	34	34058753241	34058809256	56015	56.83	553.97	740.47		655.23
16.24	537.75	0.36	289.96	240237.53	-158941.40	140445.88				
Fixation L	1	42	34058809256	34059083304	274048	734.35	664.48	28	19	28.04
28.19										
Fixation R	1	44	34058821247	34059091313	270066	739.46	669.91	34	33	27.47
26.44										
Blink L	1	17	34059083304	34059403379	320075					
Blink R	1	16	34059091313	34059393378	302065					