

**The effects of individual differences
on mobile phone
users' operational behaviour**

A thesis submitted for the degree of Doctor of Philosophy

By

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Abstract

Mobile handset technology has improved greatly in recent decades. Improvements in hardware and software conduce the importance of the handset as a computer. Whilst the mobile phone industry and researchers emphasise understanding users from sociological aspects, such as services, usage habits, functionalities and so forth; this research aims to seek the variables that impact upon users' interactions with the phone from the root-individual differences.

For the purpose of placing mobile phone users at the core of the interface design process, the individual differences of gender, cognitive style and user experience were applied as the main variables in this research. Accordingly, to examine individuals' differences and their operational behaviour with phone interfaces, the effects of cognitive style and user experience present stronger impact on the user performance than gender. The two factors were then investigated with regard to individuals' operational behaviour with phone interfaces.

This research then developed categories to link the theoretical attributes of cognitive style and phone users' practical operational behaviour. Furthermore, the impact of cognitive style on the users' operational behaviour was also connected to individuals' problem solving ability. Meanwhile, the effect of user experience was investigated with a novel methodology-Taxonomy of Experience. The results revealed necessary elements that the users cared about the most, and these differed from the interface design guidelines of phone industry.

This PhD thesis presents the application of the triangulation method to explore the variables that impact upon individuals' interaction with mobile phone interfaces, specially concerned with mobile phone interface design from a psychological perspective, and provides a deeper understanding of users for future design events. More importantly, this research delivered the concept of understanding users before conducting design.

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CHAPTER 1 INTRODUCTION

Overview

In recent decades, mobile handset technology has improved greatly. In handsets of old, users were limited to a numeric keypad and monochromatic displays; whereas modern phones combine touch screens, QWERTY keypads and colourful icons. The improvement of the hardware affects the way in which people use their phones, such as the gesture of operating the phone, input data and so forth. Because the screen is larger, the functional structure is simpler and more wide-ranging than a phone with a basic numeric keypad. Apple, the computer manufacturer launched its first mobile phone, the iPhone, along with the concept of 'applications' in 2007. The company's innovation in the field of touch screen phone operation started a new competition in the phone market. As this research has proceeded, the concept of the application has been applied to different platforms, such as Android and Symbian. Meanwhile, more and more program developers devote numerous types of ideas to develop applications that can be downloaded and operated with mobile handsets. Whilst the phone industry addresses the capability of hardware and platforms, program developers emphasise the usability of applications; this research is more concerned with the role of the interface in mobile handsets. More importantly, to understand how individuals interact with phone interfaces, what factors affect individuals' operational behaviour, and how these factors reflect on the users' interaction process with phone interfaces. According to Norman (1998), seven stages of actions are necessary to process an intention to reach a goal (Figure 1-1). This PhD thesis thus applied a mobile phone task to Norman's seven stages of actions in chapter 2, involving individual differences for understanding users' operational behaviour with phone interface. In terms of users' different interaction behaviour, this research attempts to establish a guideline to identify users' differences and to provide solutions for designing phone interface for different users.



Figure 1-1 Norman's seven stage action (Norman, 1998; adapted from Wang, Young and Love, 2011).

This research firstly reviews literature and previous studies; and then research questions arose. According to the results gained when the questions were answered, hypothesis of this research were therefore established. The exploration process also explores the link between cognitive style and individuals' problem solving ability. This PhD thesis not only provides solutions to interface design, but also involves psychology in design; more importantly, it provides an alternative aspect in the design process - to keep user concerns at the core.

1.1 Research background

Interface is a crucial component to help users and machines communicate with each other. Since Apple launched the iPhone in 2007, phone manufacturers seem to have followed its interface design. Although the interfaces of mobile phones have a lot in common, users still complain about the difficulties of operating a device. Based on the intended outcome of providing better design solutions for mobile phone interfaces, this research places users at the core of interface design process. It is thus essential to be concerned with how an individual interacts with an interface, and how individual differences impact upon users' operational behaviour with interfaces.

1.1.1 Interaction design process

Interaction design processes normally include three to four steps; however, there might not be a straight line from creating an idea to producing a concrete product (Löwgren and Stolterman, 2004). With different researchers, the paths taken in the design process might vary, such as a) to identify users' needs and requirements, to meet those requirements through alternative designs, to present the designs by

interactive versions, and to evaluate the design (Sharp et al., 2007), b) analysis, design, realization (Rakers, 2001), or c) understanding users, developing prototype designs, evaluation (Jones and Marsden, 2006). The process might alternate between different steps according to consumers' needs, business objectives, or the designer's working pattern until the goal is accomplished (see Figure 2-1).

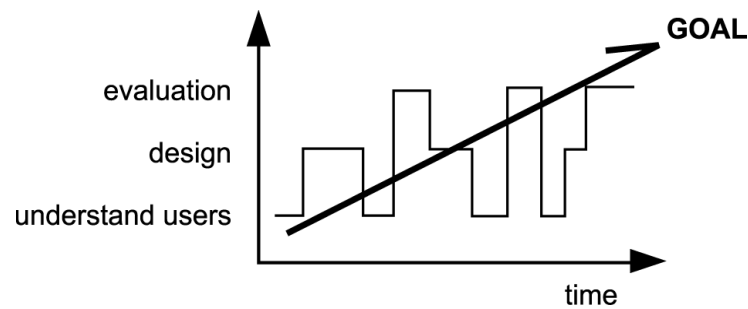


Figure 1-2 Interface design process (adapted from Wang, Young and Love, 2011, p.286)

During the design process, industrial designers, engineers and user representatives work together, and ideas might appear, fail, or be replaced by better concepts among the process.

Understanding users is important in the design process. The design director of Nokia, Antti Kujala, mentions that the step with the greatest priority in the design process at Nokia is the observation of people's behaviour and communication patterns by anthropologists and psychologists (Nokia, 2009). Though part of the knowledge of users can be obtained from biologists, psychologists, sociologists and anthropologists; experiments and field studies are essential for understanding humans' ability and the design itself (Jones and Marsden, 2006, p.96).

Furthermore, the concept of 'interaction design' has been applied in human-machine interface design in recent decades. Interaction design is not only involved in understanding users' requirements producing a design as a solution to satisfy the users' requirements and evaluating the design; but also to focus on users and their goals whilst operating an interface (Sharp, Rogers and Preece, 2007).

In terms of the discussion above, concerning users' requirements, placing users at the core of design process, which are crucial for completing a design. Thus, how to understand users becomes the priority in the design process.

1.1.2 Users' interaction with an interface

According to Dix (1998), the interaction framework can be illustrated as in Figure 1-3. Four major components of an interactive system include the system, the user, the input and the output, which have their own languages. The output and input were presented on an interface. In the interaction circle, four steps translate the meanings to the four components. In terms of a user's goal, the task was articulated and input to the system via an interface; the input language was then translated to the system, and the outcomes were presented on the interface; followed by the user's observation of the task and the evaluation of whether the results were coherent with the user's original goal.

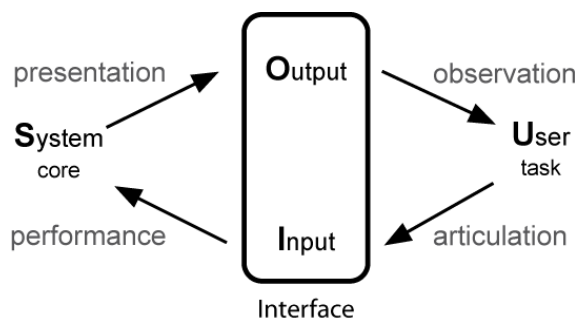


Figure 1-3 Translations between components of interaction framework (adapted from Dix, 1998, p.107)

The framework presents the general interaction process when humans interact with a system. This research aims to involve the element of individual differences, and then establish a linkage between theoretical individual differences and practical users' operational behaviour with phone interfaces.

1.1.3 Individual differences

Individual differences can be categorised according to different aspects. Benyon et al., (2001) refer individual differences to physiological, psychological and sociological aspects and were concerned with the changeability of the differences. Love (2005) indicates that individuals differences with spatial ability, personality, memory, verbal ability, previous experience and age are important characteristics that impact users' usage and attitude with mobile handsets and services.

Regarding the design of a user interface, Shneiderman (1998) mentions the necessity of accommodating human's diversity in physical abilities and physical workplaces, cognitive and perceptual abilities, personality, cultural background and considering users with disabilities and elderly users. Moreover, Hackos and Redish (1998) also point out that cognitive psychology is one of the aspects by which an individual's thinking and learning can be analysed. Integrating researchers' definitions of individual differences, this research focuses on establishing the relationship between users' cognitive styles and their interaction behaviour with phone interfaces.

The importance of recognising and utilising different cognitive styles has been applied to various fields including learning processes and strategies (Riding and Rayner, 1998), learning and teaching styles (Ford and Chen, 2002), interface designs of mobile phones (e.g. Nisbett, Peng, Choi and Norenzayan, 2001; Unsworth, 2005; Lee, 2005; Kim and Lee, 2007), information systems (Mullany, 2001) and categories of searching for information on the internet (Magoulas, Chen and Dimakopoulos 2004). In addition, previous studies have found a correlation between more effective studying programmes which have been matched to an individual's learning style (e.g. Riding and Douglas, 1993; Ford, 1995). Most of these studies highlighted the connection between cognitive styles and a user's preferences for icons and categories of the interfaces through quantitative approaches. This has led to a lack of detailed description of how cognitive style differences affect users' operational behaviour when confronted with human-machine interfaces. This research therefore focuses on establishing the connection between users' cognitive style and their operational behaviour.

Furthermore, user experience is also one of the most important elements of product design and has often been discussed in the human computer interface (HCI) community. The general definition of user experience is beyond the usefulness and usability of a product (Alben, 1996), and it might be affected by the 'user's internal state, the context, and perceptions of the product' (Väänänen-Vainio-Mattila, Roto and Hassenzahl, p.1, 2008). For the purpose of providing necessary elements for interface designers and system developers conducting design; this research also investigates the impact of user experience on the users'

requirements of phone interfaces.

The deep understanding of users not only establishes the linkage between users' individual differences and their operational behaviour; but also presents an alternative angle to improve interface design.

1.2 Research motivation

This research is motivated by those studies that were discussed in the last section. Two key issues were addressed in this research.

First of all, although the differences in cognitive styles were well defined by researchers; the lack of ease in transforming theoretical attributes of cognitive style to practical users' operational behaviour was noted by this research. The linkage can be applied to systems for identifying a user's cognitive style and to provide a suitable interface for the user.

Secondly, according to the design guidelines of the phone industry; most principles focus on graphic design. Although parts of the design guidelines mention the importance of navigating users, giving users the control of the phone, applying metaphors when designing an interface for a mobile phone; an overview of users' requirements of a phone from their interaction with an interface is crucial. This research thus attempts to establish an alternative process of understanding users that integrates quantitative and qualitative methodologies for understanding users more deeply and to contribute alternative design guidelines to improve interface design in mobile handsets.

1.3 Aim and objectives

This PhD thesis suggests that understanding users should take place before conducting design. The aims of this research are to explore the impact of individual differences on users' operational behaviour and users' requirements of mobile phone interface (Figure 1-4). More importantly, to provide an alternative method to categorise phone users in terms of the individual's operational behaviour.

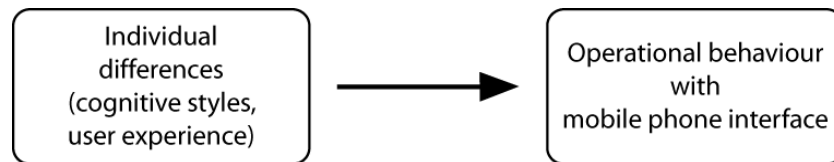


Figure 1-4 Research aim-understanding users' operational behaviour by individual differences.

Previous studies tend to present the relationship between users' cognitive style and their preferences of interfaces by quantitative approaches; it lacks detailed descriptions of the process in which users interact with the interfaces. Therefore, to achieve the aim, transformation of theoretical attributes of cognitive styles to users' practical operational behaviour will provide the information by which designers may understand the user. It is important to understand user experience and their interaction with mobile phones (Jones and Marsden, 2006). Investigating users' requirements of phone interface design will provide alternative aspects to concern design. For the purpose of identifying the effects of individual differences on the users' operational behaviour, this research was conducted using both quantitative and qualitative methodologies. By doing so, qualitative data can be analysed based on the findings of quantitative results, and then provide more effective outcomes.

In order to fulfil the research aims, the following objectives are outlined:

- Objective 1: to integrate quantitative and qualitative methodologies to understand users;
- Objective 2: to understand phone users' operational behaviour with phone interfaces that matches the users' cognitive styles;
- Objective 3: to categorise phone users by their operational behaviour based on cognitive style differences;
- Objective 4: to establish guidelines for identifying phone users in terms of their operational behaviour;

1.4 Research contributions

The major contributions of this research are listed as follows. The connection between users' cognitive styles and operational behaviour was thus developed. In addition, this research also found the relationship between cognitive style

differences and users' problem solving ability whilst responding to a task within different interfaces and the ability of solving problems with hierarchical structures.

1) Understand users by triangulation method

This research applied both quantitative and qualitative approaches to understanding how people use phones. Based on the significance of quantitative data, the qualitative approach of observation was given a clear direction for seeking how individual differences reflect on users' operational behaviour with phone interfaces. The triangulation method integrates strengths from different approaches for a deep and detailed understanding of users.

2) Establishing categories to identify phone users' cognitive style based on their operational behaviour

In terms of the understanding of phone users' interaction with phone interfaces, this research contributes the categories needed to identify phone users' cognitive style based on users' operational behaviour with phone interfaces. The categories transform theoretical attributes of the cognitive styles-holistic and serialistic - to practical descriptions of users' interaction when completing tasks with phone interfaces.

3) Providing alternative concerns of designing phone interfaces in terms of user experience

This research also addresses the importance of understanding users' experience. A novel methodology-Taxonomic of Experience (ToE) was applied for obtaining user experience with mobile phones. The distilled elements provide an alternative concern for designing phone interfaces. ToE not only points out the elements that the users cared about the most, but also provides the solutions to improve the design.

4) Relationship of cognitive style and problem solving ability

This research contributes to understanding the relationship between individuals' cognitive style and problem solving ability whilst observing users' interaction with phone interfaces. The findings demonstrate that holists

were more likely to apply one strategy to complete a task with different phone interfaces than serialists. Furthermore, serialists performed better than holists when solving problems with hierarchical structures.

5) Developing design guidelines based on users' cognitive style differences

According to the findings of this research, design guidelines based on users' cognitive style differences were thus established. This research emphasises that understanding individuals' differences should be a pertinent issue before commencing design. Recognising the link between cognitive style and interface design provides a different angle with which to consider the importance of users in design process.

1.5 Structure of the thesis

Chapter 1: Introduction

This chapter presents an overview of this PhD thesis that includes the background, motivations, objectives and contributions of this research.

Chapter 2: Literature review

In accordance with the aims and objectives of this research, this chapter reviews previous studies and literature that relate to the interface design process, users' interaction process with those interfaces, individual differences and user experience. More specifically, the individual differences in users' cognitive styles were addressed in this chapter.

Chapter 3: Methodology

In order to achieve the aims and objectives, the triangulation method that includes quantitative and qualitative methodologies and approaches was adopted in this research. This chapter provides the details of research methodologies and procedures.

Chapter 4: Understanding mobile phone users' operational behaviour

This chapter presents two stages of understanding individuals' interaction with interfaces of numeric keypad phones. The two-stage studies illustrate how participants used their phone and how they achieve targets with different phone

interfaces. The outcomes were applied as the foundation for investigating touch screen phone users in next chapter.

Chapter 5: Individual differences and users' operational behaviour with touch screen mobile phones

Individual differences of gender, cognitive style and user experience were applied to investigate users' operational behaviour in this chapter. Six touch screen mobile phone interfaces were used to examine the users' performance with conditions. Quantitative approaches were applied to measuring users' task completion time and the numbers of icons clicked to present the impact of individual differences on users' performance. The qualitative approach of observation was therefore adopted for further analysis of users' operational behaviour.

Chapter 6: Taxonomy of Experience (ToE)

In terms of the results of chapter 4 and 5, user experience was found to impact upon the participants' performance with phone interfaces. To further understand what the important elements that influence their usage with a mobile phone where, a novel methodology-Taxnomy of Experience (ToE) was applied in this research. This chapter introduces ToE and its analytic process-SEEing to obtain phone users' requirements of a touch screen mobile phone.

Chapter 7: Cognitive style and problem solving ability

In terms of the findings of chapter 4 and 5, the users' operational behaviour with mobile phone interfaces present the significant relationship between cognitive style and some tasks that require more steps. Due to the cognitive style-holist and serialist that were emphasised in this research, associated with individuals' interaction with hierarchical structure; the psychology test of Tower of Hanoi was thus applied to examine the individuals' cognitive style and problem solving ability. Besides, based on the routes that the individuals applied to achieve the goals in chapter 4 and 5, holists seem to tend to apply the same routes to complete a task across six phone interfaces, whilst serialists were more flexible when applying routes to achieve their goal. The psychology test of Luchins's jar problem was used to examine if holists have a more rigid mental set than serialists.

Chapter 8: Identifying phone users' cognitive style based on their operational behaviour

This chapter evaluates the categories developed in Chapter 5 to identify phone users' cognitive styles when trialing a touch screen mobile phone. This research therefore attempts to identify the participants' operational behaviour based on the categories, and then compares them to the individuals' answer of the SPQ. The outcome shows that the concept of identifying phone users' cognitive style in terms of their operational behaviour has the potential to be applied to designing phone interfaces.

Chapter 9: Conclusion

The applications of this research are discussed in this chapter. In terms of the findings of previous chapters, alternative design elements were established to replenish current design guidelines that are used in the phone industry. Moreover, this chapter summarises the findings and contributions of this PhD thesis, notes the limitations of this research, and provides recommendations for future potential works.

CHAPTER 2 LITERATURE REVIEW

Context

The aim of this PhD research is to establish the link between users' individual differences and their operational behaviour with regard to mobile phone interfaces. More specifically, it seeks to provide an alternative method to categorise phone users in terms of the individual's operational behaviour. The concepts of user centred design and human interaction process with an interface were introduced to aid understanding of the role of users and the importance of placing the user at the core of the design process. This chapter reviews existing literature to determine the scope of the importance of 'users' in the interface design process, and to see how individuals interact with an interface and how individual differences affect their performance with those interfaces. Individual differences of cognitive style and user experience were addressed in this research to enable further understanding of their impact on users' operational behaviour.

Reviewing previous studies establishes a clear framework with regard to the relationship between user individual differences and their performance when interacting with interfaces. In the meantime, some questions arose, more specifically, they focus on how cognitive styles-holist and serialist - reflect on the user's interaction with a mobile phone interface, and how users' experience influences their requirements of a mobile phone.

2.1 Introduction

This chapter discusses the importance to interface design of understanding users, how to place users at the core in design process and how individual differences affect their performance with interfaces. Three differences (gender, cognitive ability and user experience) were applied to explore the effect on users' operational behaviour. The effect of gender on individuals' operational behaviour with the phone interface was rarely investigated. Most previous studies focus on the effects from sociological points of view. When investigating the difference between genders in terms of motor manipulative ability (Halpern, 2000), females seem to be able to perform better than males with mobile handsets. This chapter

discusses relevant studies for further understanding of gender-centric effects on phone users' operational behaviour.

Cognitive style is one of the elements that affects an individual's learning style, learning strategies, the method of seeking information and so forth. Moreover, series of studies have established the connection between cognitive style and users' performance with computers, the web and phone interfaces. This chapter therefore reviews the relevant literature and previous studies to gain a better understanding of the current application of cognitive style to interface design.

The importance of user experience has been addressed by the phone industry in recent decades, and this PhD thesis attempts to provide alternative design elements to phone interface design based on fully understanding users' experience with handsets. This chapter discusses the historical background of user experience and the methods of obtaining information on user experience.

Based on the discussion of interface design, the human-machine interaction process and individual differences, this research integrates the fields of design and psychology. Meanwhile, it seeks to establish a firm foundation for further exploration of the impact of individual differences on users' operational behaviour.

2.2 User-centred design

This section addresses the importance of addressing users' requirements whilst conducting interactive design and reviews the necessary design elements. The term of 'user-centred design' was first used by Norman in 1986, and has become one of the most influential perspectives of interaction design. This perspective states that a good design should make things easy to determine, make the action process visible at any stage, make it easy to evaluate the working state with a system, easy to operate by the users' natural mapping ability, understand the intentions, actions and the consequent outcomes. It is also necessary for designers to be aware of whether the user understands what to do and the current progress of their action (see Figure 2-1) (Norman, 1998).

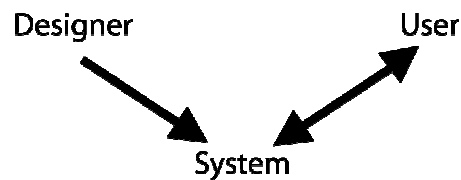


Figure 2-1 User-centered model (adapted from Norman, 1998, p.190)

ISO 13407 (1999) developed the standard process of the user-centred design as a loop activity (Figure 2-2). As such the process not only integrates ergonomic knowledge and techniques and human factors for improving usage and enhancing efficient design; but also avoids negative effects on human health, safety and performance.

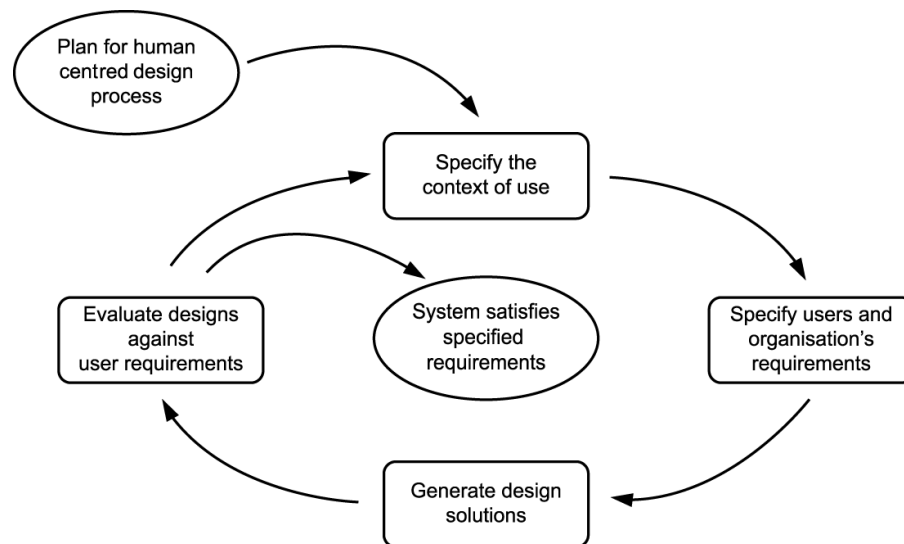


Figure 2-2 ISO 13407 Human-centred design processes for interactive systems (ISO 13407, 1999).

The goal of applying human-centred design to system design is to sustain the users' requirements rather than requiring the users to adopt the system (Wickens, Lee, Liu and Gordon-Becker, 2004, p.35). The concept of human-centred design had been applied to software design; more specifically, four approaches are generally involved in the design process:

- a) early focus on the users and tasks
- b) empirical measurement
- c) iterative design
- d) participatory design

To improve the application of user-centred design to design, Norman (1998, p.188) emphasises seven principles to transform difficult tasks into simple ones:

a) Use both knowledge in the world and knowledge in the head

The knowledge is useful 'only if there is a natural, easily interpreted relationship between the knowledge and the information it is intended to convey about possible actions and outcomes'.

b) Simplify the structure of tasks

Tasks should have the ability to be completed in a simple structure, it is crucial to concern a person's long term, short term memory and active thoughts. In the meantime, to keep the task much the same, mental assistance should be provided, and user control should be maintained through easily visible feedback.

c) Make things visible: bridge the gulfs of execution and evaluation

Visualisation of the process of an action is useful to make sure the user understands the execution process and the effects of their actions.

d) Get the mappings right

To make sure the user can determine the relationships between intentions and possible actions; actions and the effects of the actions on the system; actual system state and what is perceivable by sight, sound, or feel; and the perceived system state and the users' needs, intentions and expectations.

e) Exploit the power of constraints, both natural and artificial

To make the user feels there is only one and right way to complete the task.

f) Design for error

Assume any kind of errors might be made by the users, and formulate a plan for solving the errors.

g) When all else fails, standardise

Standardise the actions, outcomes, layout, and displays when the events can not be designed with a clear mapping.

Furthermore, Shneiderman (1998, p.74) suggests the eight golden rules for improving the design of interactive systems:

- a) strive for consistency,*
- b) enable frequent users to use shortcuts,*
- c) offer informative feedback,*
- d) design dialogues to yield closure,*
- e) offer error prevention and simple error handling,*
- f) permit easy reversal of actions,*
- g) support internal locus of control,*
- h) reduce short-term memory load.*

Overall, user-centred design not only ensures the aspects of ‘ease’ to buy, to set up, to learn, to use, to upgrade; but also ensures engagement, intuition and integration of the users and the design (Vredenburg, Isensee and Righi, 2002, p99).

2.3 Interaction process

This section aims to understand the process by which individuals receive images and identify the meaning of an object; and how individuals interact with an interface, and how to complete a task with an interface. Those steps not only clarify the perception process, but also emphasise the role of cognition during the interaction process.

The common sequence in the visual perception of an object and interpretation of the meaning of the object consists of five stages (Gibson, 2001) (Figure 2-3). When the retina receives the image of an object, the image is then transferred to the brain. The senses integrate and compare the image with memorised images. If the image is not familiar, then it will be categorised by a type, a schema or a concept. The meaning of an object is therefore produced.

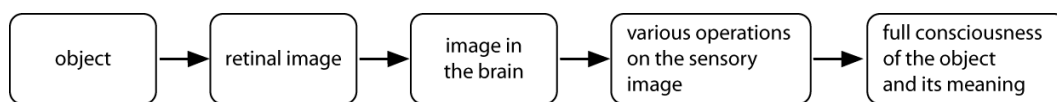


Figure 2-3 Sequence in the visual perceiving of an object (adapted from Gibson, 2001, p.93).

The memory not only provides information to identify the meaning of an object, but also interacts with cognitive and motor processors whilst an individual works with an interface. The next section interprets the process by which individuals interact with an interface using Card's human information processor and Norman's seven stages of action.

2.3.1 Card's human information processor

Card, et al. (1983) illustrate the process of human interaction with a device with a model that includes three subsystems: the perceptual system, the motor system, and the cognitive system (see Figure 2-4). Each system has its processors and memories. As can be seen from Figure 2-4, the information retrieval process lasts from the the perception of information to the execution of the reaction.

When the perceptive processors of sight and hearing receive signals, the first step is to send these signals on to the brain; in which the visual and auditory image are stored individually. While the cognitive processor retrieves information from working memory and long-term memory; working memory conveys signals to the cognitive processor for decisions making and engages the motor processor to execute the actions.

According to Sharp, Rogers and Preece (2007), cognitive ability includes attention, perception and recognition, memory, learning, reading, speaking and listening; problem-solving, planning, reasoning and decision-making. As such, due to the importance of cognition during the interaction process; this research attempts to understand how cognitive style affects individuals' operational behaviour with handsets.

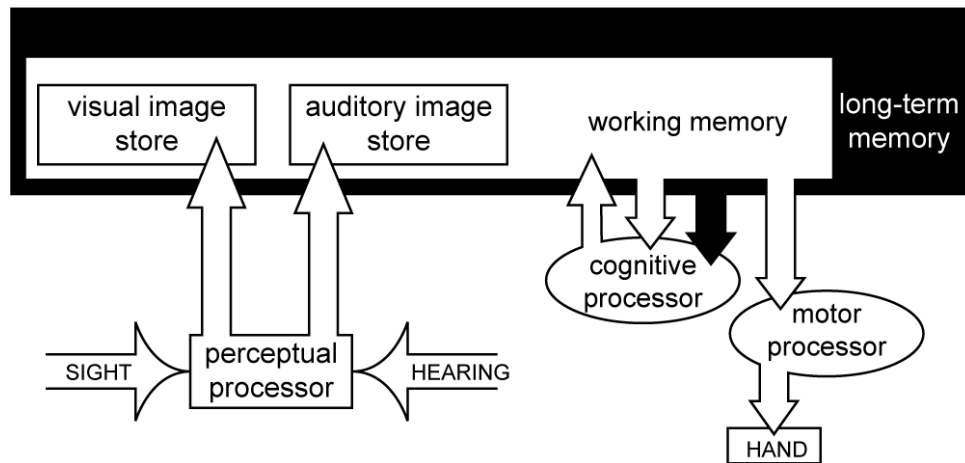


Figure 2-4 The model human information processor (Card, et al., 1983; adapted from Wang, Young and Love, 2011, p.288)

2.3.2 Norman's seven stages

Norman (1998) uses a seven stage cycle to illustrate the process of a person completing a task from beginning, intention to act, execution, perception of feedback, interpretation of results and evaluation of the results (Figure 2-5). Wang, Young and Love (2011) applied Norman's seven stage action cycle to a task on a mobile phone. For example, the goal was to change the ring tone on the mobile phone (Figure 2-6). The intention triggers a series of actions to access the menu, review the ring tones from a list and select one ring tone. Then the user should receive feedback from the system, such as a confirmation by a text box, vibration or other type of notification. According to the users' comprehension of the feedback, they should be aware of whether the task has been completed or not. Nevertheless, the action cycle interprets how an individual completed a task without experiencing the barriers; this research is more concerned with an individual's reaction whilst the task was not able to be completed. It is therefore necessary to address the impact of individual differences on their actions.



Figure 2-5 Norman's seven stage action (Norman, 1998).

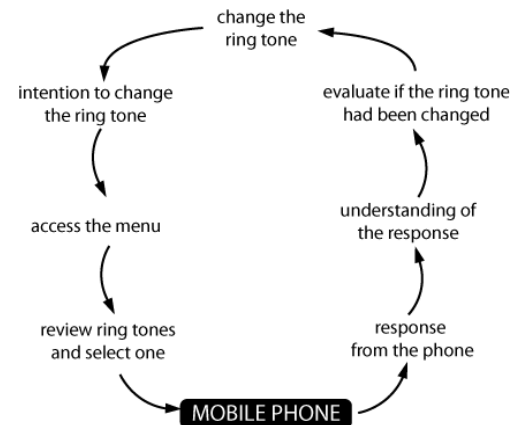


Figure 2-6 Applying a task to Norman's seven stage action (adapted from Wang, Young and Love, 2011, p.289)

2.4 Individual differences of interacting with interfaces

Benyon, Crerar and Wilkinson (2001) categorise individual differences from physiological (includes cerebral hemisphericity, vision, hearing, and mobility/dexterity); psychological (includes intelligence, cognitive style, and personality); and sociological (includes language, culture, and environmental) aspects. More importantly, it is essential to consider the changeability of individual differences. Three types of changeability were drawn in Table 2-1 with individual differences.

Table 2-1 Changeability of individual differences (adapted from Benyon, Crerar, and Wilkinson, 2001, p.30)

	Fixed	Stable		Changeable
Physiological	Gender		Weight	
	Height			Handwriting
	Eye colour		Perceptual Capabilities	Speech
	Cerebral Hemisphericity	Handedness		
Psychological	Intelligence	Cognitive Styles	Strategies	Personal Knowledge
	Personality		Mood	Behaviour
Sociological	Ethnicity	Nationality		
		Language		

The individual differences of gender, cognitive styles and ethnicity were widely applied to users' interaction with interfaces of web and mobile phones. The item of gender has been applied in HCI for decades; most focus on investigating the

users' habits. Relevant studies that discuss users' interactive behaviour with phone interfaces are rare. This research thus includes gender as a variable to understand how gender affects individuals' performance when completing tasks with phone interfaces.

More importantly, cognitive style has been widely applied in education, computer interface design (to develop efficient learning materials) and mobile phone interfaces. As mentioned earlier, the role of cognition in human interaction process with an interface is addressed in this research; cognitive style is therefore one of the elements with which users' performance is examined. However, cognitive styles are variable; the following section will clarify cognitive styles based on Riding and Rayner's (1998) categorisation.

In addition, user experience is one of the most important elements of product design and has been discussed often in the HCI community. The general definition of user experience is beyond the usefulness and usability of a product (Alben, 1996) and it might be affected by the 'user's internal state, the context, and perceptions of the product' (Väänänen-Vainio-Mattila and Hassenzahl, 2008, p.1). One of the difficulties of understanding user experience arises partly because the methods tend to quantify user experience. This research addresses the importance of understanding users from the root. The following section thus reviews the common approaches that were applied to understand user experience. In addition, a new methodology of understanding user experience will be introduced in chapter six to establish necessary design elements for phone interfaces.

2.4.1 Gender

Gender is one of the fixed physiological characteristics that might affect individuals' performance with typing. Numerous previous studies show that females are better at tasks that require fine motor manipulations (Halpern, 2000). Kimura (1993, p.107) defines the motor dexterity as 'quick and effective use of the hands in the manipulation of small objects'. This definition is also supported by Nicholson and Kimura (1996), O'Boyle and Hoff (1987), O'Boyle, Hoff and Gill (1995), and Peters and Campagnaro (1996) as females react faster than males when the task requires a sequence of rapid repetitions of movements or the task

involves mirror-reversed spatial ability. The ability has been used to explain why females are naturally good at typing (Halpern, 2000).

Passig and Levin (2001) investigate the effect of gender differences on children's preference of interfaces, satisfaction with the interfaces, and the ability to solve tasks on time. The outcome shows that different interfaces have different degrees of impact on boys and girls in terms of time spent on the task and their satisfaction with the interfaces. Due to boys being more familiar with computer games, they performed better than girls in terms of time spent on the task and also experienced higher levels of satisfaction with the interfaces of the multimedia interface.

The other study focuses on children's use of mobile phones (Ziefle and Bay, 2008) and shows that boys took more advantage of a specific and successful navigation strategy than girls when operating the mobile phone menu. In addition, boys were more willing to explore and interact with the phone than girls and worried less about adopting a trial and error approach.

2.4.2 Cognitive style

Individual differences of cognitive style was not only considered for educational purpose with regard to individuals' learning process and strategies (Riding and Rayner, 1998), learning/teaching styles (Ford and Chen, 2002); but also related to interface design of mobile phones (Kim and Lee, 2007), information systems (Mullany, 2001), web searching (Magoulas, Chen and Dimakopoulos 2004) and so forth. Some previous studies have found that learners might study more effectively when the instruction is matched to the individual's learning style (e.g. Riding and Douglas, 1993; Ford, 1995).

According to Green (1985, P.3), Messick (1969) define cognitive style as 'stable and relatively enduring consistencies in the manner or form of cognition'. Allinson and Hayes (1996, p.119) quote the definition of cognitive style from Messick (1976, p.5) as being coherent with 'individual differences in preferred ways of organizing and processing information and experience'. Green (1985) indicates that cognitive style is unique for each person when perceiving information, to think, to remember and to solve problems. Furthermore, Jonassen and Grabowski (1993, p.233) mention that cognitive style is the 'general

tendencies to prefer to process information in different ways'. Table 2-2 presents the diverse cognitive styles from previous studies.

Table 2-2 List of cognitive styles (adapted from Wang, Young and Love, 2011, p.290)

Researchers and published year	Cognitive styles
Kretschmer, 1925	Dissociate/integration attention style
Goldstein and Scherer, 1941	Abstractness/concreteness of information
Jung, 1923	Extraversion/introversion
Klein and Schlesinger, 1951	Tolerance for instability/tolerance for unrealistic experience
Bieri, 1955; Messick, 1976	Conceptual articulation: complexity/simplicity
Pettigrew, 1958	Broad/narrow thinkers
Gardner et al., 1959	Equivalence range/breadth of conceptualization/category
	Constricted/flexible control
	Range of scanning
Rokeach, 1960	Open-mindedness/flexible control
Harvey, et al., 1961	Conceptual complexity: abstract/concrete
Kagan et al., 1963	Conceptual differentiation styles (description, relational and inferential)
Messick and Fritzky, 1963	Field articulation: element/form articulation
Hudson, 1966	Convergent/divergent thinkers
Rotter, 1966	Locus of control: external-internal
Kagan, 1966	Reflectivity/impulsivity style
Pask, 1969	Holistic/serialistic
Parlett, 1970	Syllabus-bound/syllabus free style
Paivio, 1971; Richardson, 1977	Visualizer (imager)/verbalizer dimension
Pask, 1972; Pask and Scott, 1972	Holist-serialist
Goldstein and Blackman, 1978	Cognitive complexity/cognitive simplicity

Despite the definition of cognitive style varying between researchers, they all share the idea that an individual's cognitive style is one of the essential determinants of the way in which the individual organises information (Riding and Rayner, 1998; Benyon, Crerar and Wilkinson, 2001).

In spite of the different titles, researchers generally agree that cognitive styles have similar attributes, which Riding and Rayner (1998) divided into two groups: the *wholist-analytic* dimension and the *verbal-imagery* dimension (Table 2-3). The wholist-analytic measures how an individual organises information whilst verbal-imagery measures if an individual represents information by thinking

verbally or with mental pictures. The group of wholist-analytic also comprises field-dependence or field-independence, leveller-sharpener or impulsive-reflective, on vagrant-divergent thinking, and holist-serialist thinking; models in the verbal-imagery dimension include verbalisers-visualisers and verbal-imagery.

Table 2-3 The catalogue of cognitive styles

Wholist-Analytic	Verbal-Imagery
field dependence-field independence	verbalisers-visualisers
leveller-sharpener-impulsive-reflective	verbal-imagery
convergent-divergent thinking	
holistic-serialistic thinking	

2.4.2.1 Wholist and Analytic

The style of wholist-analytic present the way an individual tends to ‘organize, process information into wholes or parts’ (Riding, 1997; Riding and Rayner, 1998). The dimension of measuring an individual’s wholist-analytic style is to understand how the individual organises information. This section discusses the differences between field dependence-field independence and holistic-serialistic thinking which have been applied in HCI often. According to Green (1985), the initial studies concerned with analytic and global styles of thinking were from Santostfano (1969) and Wachtel (1968). The terms of analytical, rule-bound versus flexible, gestalt, global; fixed versus mobile; differentiated versus diffuse were also used to interpret the similar nature of the styles. Not only wholist-analytic styles were often applied in previous studies, but also field-dependence-field-independence (FD-FI) and holistic-serialistic styles. Ford (2002) indicates that the global-analytic dimension was mainly studied by Witkin in the USA and Pask in the UK. They tended to work towards different directions as Witkin’s definition of the dimension of cognitive style tends towards field-dependence and field-independence (Witkin, Moore, Goodenough and Cox, 1977); whilst Pask’s investigation of information processing is more closely related to holistic and serialistic approaches (Pask, 1979; 1988). It should be clarified here that the word ‘wholist’ can not be found in the dictionary and most studies use the alternative spelling of ‘holist’ instead.

2.4.2.2 Field dependence (FD) and Field independence styles (FI)

Historical background

Field dependence (FD)-field independence (FI) is one set of cognitive styles of the wholist-analytic family (Riding and Rayner, 1998, p.14). According to Jonassen and Grabowski (1993), the concept of FD was originally identified by Witkin and Asch (1948a, 1948b) via laboratory experiments. The study focuses on how individuals orient themselves in space. The test of *Using the Body Adjustment Test (BAT)* and the *Rod-and-Frame Test (RFT)* were used to measure whether the individual's perception of the upright will be affected by a surrounding field. The purpose of Witkin and Asch's study is to explore the relationship between 'a person's visual and kinaesthetic cues'. The two tests used tilted equipment and visual cues to adjust the subject's body or the tilted object to make the target upright. Both tests examine the individuals' dependence on internal or external references. Besides, Witkin and his associates (1948) found the significant correlation between Gottschaldt's (1926) test and the RFT. In Gottschaldt's study, participants were required to find a simple figure embedded in a complicated drawing. The comparison of this study and the RFT result from Witkin show that people who tend to FI could identify the embedded figures easily. Therefore, Witkin revised the *Embedded Figures Test* based on Gottschaldt's *Hidden Figures Test*. It provides an easier way to measure the individual's ability to separate or break up the organised visual item from a complex background. Witkin realised the ability, as mentioned before, was the fundamental perceptual style that was related to general analytical ability. Therefore, Witkin and Asch (1948b) extend the definition of FD to describe individual differences in perceptions and cognitive processing, whilst the individual that tends towards FD applies a passive, spectator-like approach to solve problems; FI represents an individual who prefers to adopt active, hypothesis-testing approaches to solve problems.

Witkin also attempted to apply the findings to social and learning fields. The integrated Theory of Psychological Differentiation (Witkin et al., 1962) includes the dimensions of global-articulate, articulation of body concept, sense of identity and defence structures. FD-FI was expanded from the dimension of sense of identity. Individuals who tend towards FD prefer to rely on external referents for psychological functions and are more willing to receive instructions from others

with prior experience. To contrast, individuals who have FI style tend to rely on themselves to be the primary referents (internal referents) and be capable of analysing, disorganised fields of information by imposing their own cognitive structure of the situations. The phenomenon is also associated with how individuals solve problems.

Witkin, Oltman, Raskin and Karp (1971) identify FI-FD as ‘the extent to which the organization of the prevailing field dominates perception of any of its parts’. Jonassen and Grabowski (1993) integrate the characteristic differences of FD/FI as in the following table (Table 2-5).

Table 2-4 Characteristics of FD and FI (adapted from Jonassen and Grabowski, 1993, p.88)

Field dependence (FD)	Field independence (FI)
global	Analytic
accepts structure	generates structure
externally directed	internally directed
attentive to social information	inattentive to social cues
conflict resolvers	philosophical, cognitive
sociable and gregarious	Individualistic
affiliation oriented	distant in social relations
interpersonal	Intrapersonal
needs friendship	reserved, aloof
conventional, traditional	Experimental
influenced by the salient features	generates own hypotheses
factually oriented	conceptually oriented
acquires unrelated facts	acquires information to fit conceptual scheme
accepts ideas as presented	represents concepts through analysis
influenced by format/structure	less affected by format/structure
gets feelings/decisions from others	impersonal orientation
sensitive to others	insensitive to social undercurrents
affected by stress	ignores external stress

Instruments

The instruments of evaluating FD-FI can be traced to Gottschaldt’s *Hidden Figures Test (HFT)* (1926), and Baehr’s *Closure Flexibility Test (Concealed Figures)* (1965). As mentioned in section 2.4.2.2, Witkin et al. (1971) then established the *Embedded figures Test (EFT)*, *Children’s Embedded Figures Test (CEFT)*, and *Group Embedded Figures Test (GEFT)*.

Hidden Figures Test (HFT) (French, Ekstrom and Price, 1963)

This test was developed based on the Gottschaldt's Figures test (1926), well known by researchers as it is one scale from the Kit of Factor-Referenced Cognitive Tests from the Educational Testing Service (Jonassen and Grabowski, 1993). According to Della Sala, Laiacona, Trivelli and Spinnler (1995), HFT is a perceptual attention test to examine the individuals' figure-ground discrimination abilities. The score ranges from 0, being the worst to 35, being the best (Capitani et al., 1988; Gottschaldt, 1926, 1929). It includes 32 items, and requires the individual to decide which of five geometric figures are embedded in a complicated pattern. Based on Witkin's (1948) finding, the result of Gottschaldt's test has high correlation with the Group Embedded Figures Test. Therefore the reliability and validity of HFT has been confirmed.

Closure Flexibility Test (Concealed Figures) (Baehr, 1965)

This test was established based on Gottschaldt's Figures test (Gottschaldt, 1926) by Baehr (1965). Parts of this series of tests measured primary mental abilities of second closure factor (Thurstone, 1944). It includes 49 items. The individual is given a figure that was embedded in a large, and complex diagram to measure the individual's ability to hold a figure in mind in spite of distraction.

Embedded Figures Test (EFT) (Witkin, Oltman, Raskin and Karp, 1971)

This test includes 12 items that divided into two parts. The individual is given limited time and two sets of 8 cards with simple figures and 12 cards with complex figures. Reliability ranges from .61 to .92 and varies with age and gender differences. The concept of FI-FD and the construct validity of the EFT have been verified by numerous studies (Jonassen and Grabowski, 1993).

Group Embedded Figures Test (GEFT) (Witkin, Oltman, Raskin and Karp, 1971)

This test contains 25 items to assess individuals' cognitive style of FD-FI. The form of this test is similar to the EFT. Participants are required to trace one of eight simple figures embedded in complex figures. The reliability of GEFT is highly correlated to the EFT.

2.4.2.3 Holist and Serialist

Historical background

Holistic-serialistic styles are also associated with wholist-analytic family (Riding and Rayner, 1998). Holistic and serialistic strategies were first identified by Pask and Scott in 1972. The instrument of *Clobbits* was applied to the study to distinguish an individual's cognitive strategy. The approach requires no relevant knowledge or experience and aims to observe the complexity of how a student establishes knowledge. Pask and Scott (1972, p.218) therefore indicate that holistic learners tend 'to learn, remember and recapitulate as a whole', based on 'high order relations'. In contrast, serialistic learners prefer to learn, remember and recapitulate a chunk of information in 'string-like cognitive structures' and to find the connection between data through 'low order relations'. In addition, serialists tended to be 'intolerant of irrelevant information' when dealing with lengthy and sequent data unless they had an 'unusually large memory capacity'.

Ford (1985) distinguishes the styles of holist-serialist from global and local approaches as holists tend to concentrate on a global dimension first, to establish broad descriptions for fitting details, serialists prefer a local approach, narrow focus on procedures before illustrating the overall picture. Whilst holists tend to 'focus on several aspects of subject at the same time' (Ford, 1985, p.66), serialists focus on small chunks of information. They also have different ways of interacting with a hierarchical structure. Whilst holists tend to establish relationships with such structures through the use of complex, top-down links, serialists concentrate on the chunks of information that were more clearly defined and sequentially ordered, preferring to use simple links and a step by step approach from the bottom-up. Moreover, holists are likely to use analogies to make the connection between different aspects of the subject; serialists are more likely to emphasise the relationship between previous knowledge and the current subject and to make logical links between them. The contrasting cognitive styles of holists and serialists were therefore chosen for this study to investigate the relationship between individual differences and phone users' operational behaviour.

Jonassen and Grabowski (1993) conclude the characteristic of holist-serialist as in Table 2-5 below.

Table 2-5 Characteristics of holists and serialists (adapted from Jonassen and Grabowski, 1993, p.210)

Holist	Serialist
global approach to learning	local approach to learning
conceptually oriented	detail oriented
low-discrimination skills	high-discrimination skills
simultaneous processor	linear processor
broad description building	narrow procedure building
wide range in hierarchy structure	low in hierarchy structure
top-down processor	bottom-up processor
spans various levels at once	works step-by-step
interconnects theoretical and practical aspects	theoretical-practical aspects learned separately
broad relations	narrow relations
comprehension learning style	operation learning style
forms generalized hypotheses	forms specific hypotheses
relates concepts to prior experience	relates characteristics within concept
personalizes concepts	remains objective
globetrotting-inappropriate connections	improvidence-ignores important connections

Instruments

To evaluate the cognitive style of holistic-serialistic, Pask developed a series of tests such as *Spy Ring History Test* (Pask, 1973), *Clobbits Test* (Pask, 1975), *Caste and Intuition* (Pask, 1976). Moreover, Entwistle (1981) establishes the measurement of *Short Inventory of Approaches to Studying* and Ford (1985) establishes the *Study Preference Questionnaire* (SPQ).

Clobbits Test (Pask, 1975)

As mentioned earlier, Pask and Scott (1972) applied a similar approach to distinguish learners' cognitive strategy as holistic or serialistic style. This method uses cards that present the taxonomic information of Martian animals. Students were asked to identify the principles of classification for two imaginary Martian animals, Gandlemullers and clobbits. Fifty cards present the information about the two animal's characteristics (size, eating habits, and so forth) in rows of 10. Students could turn over any card, in any order, in any row and they were allowed to annotate the cards if necessary. This approach shows the clear hypertext by

parallels. Pask thus analyses the records of which cards were consulted and students' comments on the card to produce the hypertext feedback mechanism.

Spy Ring History Test (Pask, 1973)

Initially, Pask (1973) developed the test of *Spy Ring History Test* to categorise learners' cognitive strategies. It is a method used to estimate the learner's bias toward operational (serialist), comprehension (holist), or versatile (both) thinking. The approach prefers to examine learners with less knowledge of school topics and avoids activities that learners have already knew. The questionnaire assimilates five aspects: versatility (analogy creation), comprehension (description building), operational learning (procedure building), rote recall and a neutral score for calibration. Similar to the *Smuggler's test* developed by Pask, it measures 'connectivity' through complex transactions between the smugglers.

Caste and Intuition (Pask, 1976)

These two tests are based on a computer monitored apparatus to identify one's learning strategy tends to holistic or serialistic.

Short Inventory of Approaches to Studying (Entwistle, 1981)

Based on Pask's work, Entwistle (1979) developed a self-completion inventory that includes 30 items to measure the learner's study attitudes and behaviour by Likert scales. It is a questionnaire format that requires students to rate their agreement with the 30 items on a scale of 0-4. It measures the student's achieving, reproducing, meaning, comprehension learning, operations learning, versatile approach, learning pathologies, and prediction of success. Entwistle then published a shortened version of Short Inventory of Approaches to Studying in 1981. Although this instrument is not capable of measuring the learner's learning strategy in terms of holistic and serialistic biases, it indeed measures the learning styles of comprehension and operation that are associated with the cognitive style of holist and serialist (Chen, 2000).

Study Preference Questionnaire (SPQ) (Ford, 1985)

The 18-item self-report questionnaire was developed by Ford in 1985 to assess the learner's preferences of learning approaches such as 'global description-building predominantly before local procedure-building or vice versa' (Ford, 1985). The 18 items of the questionnaire reflect the way the students read and seek information. Each item shows two statements. Participants were required to rate the degree to which they agreed with either statement or indicate no preference of either statements. If the participant's tendency for holistic statements is higher than serialistic statements, then the participant was identified as having a holistic cognitive style, or vice versa (Ford, 1985).

Instruments that evaluate FD-FI mainly focus on the individual's ability to match the target in a complex pool. Although the reliability and validity have been examined by numerous studies, the purpose seems not to suit the purpose of this research. On the other hand, although the reliability of some instruments that access holistic-serialistic style has not yet been proved, the SPQ has been applied to many studies in education (e.g. Kwok and Jones, 1985; Eills, Ford and Wood, 1993) and information systems (e.g. Clarke, 1993; Magoulas, Chen and Dimakopoulos, 2004; Ghinea and Chen, 2008). More importantly, it associates individuals' interaction with hierarchical structure that is coherent with mobile phone systems.

2.4.2.4 Cognitive style and interface design

Previous studies tend to apply the cognitive styles of holistic-analytic to discuss the relationship between individuals' differences and their preferences of mobile phone interfaces. The series studies apply cultural difference to establish users' performance with phone interfaces. Table 2-6 integrates those studies and refers the results to the categories of holistic and analytic styles.

Table 2-6 Previous studies about the relationship between cognitive styles and the interfaces

Literatures	Holistic	Analytic
Nisbett, Peng, Choi and Norenzayan, 2001 Norenzayan and Nisbett, 2000	East Asian	Westerners
Masuda and Nisbett 2001	explain events by the interaction between the object and the situation	explain events by referencing the character of the object
Unsworth, 2005	categorise objects by the similarity and the relationship between objects	refer objects by similarity
Lee, 2005	performed better with concrete representation of icons	performed better at recognising the abstract icons
Kim, Lee and You, 2007	prefer a thematically grouped menu	a functionally grouped menu

In addition, Kim and Lee's (2007) study involves cognitive style and cultural background to understand users' performance and preference of the mobile phone menu. Based on their series studies, operating the menu on the mobile phone includes three layers-representations, menu structure and interaction flow. Each layer correlates with the cognitive style of FI-FD, taxonomic inferential rule based-relational contextual family resemblance, and planned organised sequential linear-flexible spontaneous random parallel respectively (Table 2-7).

Table 2-7 The connection of interface layers and cognitive styles (adapted from Kim and Lee, 2007, p.380)

Interface layer	Cognitive process	Holistic	Analytic
representations (component and template)	perception	FI, verbal	FD, visual
menu structure	categorisation	taxonomic, inferential, rule-based	relational, contextual, family, resemblance
interaction flow	task handling	planned, organised, sequential, linear	flexible, spontaneous, random, parallel

Although holistic-analytic, FI-FD styles are not completely the same as holistic-serialistic styles, the descriptions in Table 2-6 and 2-7 distinguish holistic style from analytic. Therefore, this research can be concerned with the attributes of holistic style.

2.4.3 User experience

In everyday life, human beings interact with the world for seeking ‘an experience of being alive’ (Campbell, 1988, p.1). Norman describes the importance of experiencing a product as ‘the entire experience, from when I first hear about the product to purchasing it, to opening the box, to getting it running, to getting service, to maintaining it, to upgrading it’ (Anderson, 2000, p.44). The definition of user experience (UX) varies. The general definition from researchers is that the term represents more implications than the usefulness and usability of a product (Alben, 1996) and it might be affected by the ‘user’s internal state, the context, and perceptions of the product’ (Väänänen-Vainio-Mattila, Roto, and Hassenzahl, 2008, p.1). It addresses users’ pragmatic and hedonic level; it is subjective, highly situated and dynamic in nature. According to Hassenzahl and Tractinsky (2006), UX of users’ interactions with technology is composed from the experiential, emotion and affect, and it is beyond the instrumental (Figure 2.7). UX is also ‘a consequence of a user’s internal state (predispositions, expectations, needs, motivation, mood and so forth), the characteristics of the designed system (complexity, purpose, usability, functionality, and so on) and the context (or the environment) within which the interaction occurs’ (Hassenzahl and Tractinsky, 2006, p.95).

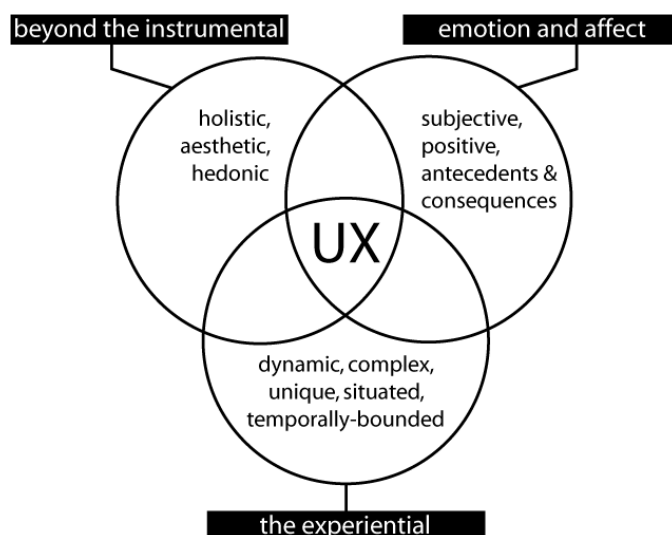


Figure 2-7 UX of user's interaction with technology (Hassenzahl and Tractinsky, 2006)

An understanding of user experience should be able to evaluate the user's experience in a circumstance that is similar to the actual situation in which a product is used so as to avoid the user imagining the experience; the data collection process should record the user's experience when it happens rather than rely on recalling the memory of the experience, and the user's experience should be understood through the user's subjective information about the experience (Isomursu, 2008).

Methodologies for evaluating experience have thus been established based on the user's attitudes and expectations (Isomursu, 2008), emotion (Hole and Williams, 2008), concept of the object (al-Azzawi, Frohlich and Wilson, 2008), judgement of the product (Karapanos and Martens, 2008) and comparing the user's reference to different interfaces (Heimonen, Aula, Hutchinson and Granka, 2008). These studies capture and analyse user experience by experimental pilots (Isomursu, 2008), emotion sampling (Hole and Williams, 2008), multiple card sorting (al-Azzawi, Frohlich and Wilson, 2008), and repertory grids (Karapanos and Martens, 2008). These methodologies attempt to transform UX's qualitative data into quantitative analysis. In addition, diaries (Bolger, Davis and Rafaeli, 2003), focus groups, surveys and competitive analysis are tools that are commonly used for understanding user experience (Kuniavsky, 2003).

Whilst academic research emphasises user experience theories, models and frameworks, industry focuses on practical user experience work in product development, functionality, usability, and novelty (Väänänen-Vainio-Mattila et al., 2008).

The user experience evaluation process at Nokia starts from examining users' needs and behaviours by new concepts, which are drawn from market insights and technological opportunities based on users' reflections. Problems are then identified, as well as any gaps, and then new ideas are generated. It is a cycle of feedback and development. Nokia requires that evaluation results of user experience come out as if on an assembly line, and expect that the results can be applied to different types of products and prototypes, determining pros and cons for each product. Their aim is to use the results to achieve excellent user experience rather than technical quality alone (Roto, et al., 2008). With the smartphone revolution in mind, Kaasinen et al. (2009) revealed that understanding users and their usage of the mobile internet, improving services and how to discover those services, improving the software and hardware of the device, and improving infrastructures are crucial aspects for optimising mobile internet users' experience. This research thus attempts to understand the impact of UX on the phone users' operational behaviour, in addition, to obtain their requirements of a mobile phone interface to replenish current design guidelines.

2.5 Understanding users

A variety of methodologies can be applied to understand users' attitude and behaviour whilst interacting with mobile phone interfaces. Sharp, Rogers and Preece (2007) mention the importance of identifying the users' specific behaviours to gain a deeper understanding of them. Furthermore, they indicate four important issues for collecting data from users: a) setting goals, b) the relationship with participants, c) triangulation, and d) pilot studies. Wang, Young and Love (2011) introduce the pros and cons of the general approaches of understanding users (Table 2-8). The details of applying the approaches to this research will be interpreted in chapter 3.

Table 2-8 Pros and cons of general approaches of understanding users (adapted from Wang, Young and Love, 2011, p.294)

Methods	Results	Pros	Cons
Interviews	Mostly qualitative	Less expensive than ethnographic observation; getting people's experience by their words	Time consuming, interviewer's experience might influence the result
Questionnaire	Quantitative and qualitative	Cheap, easy for analyzing data rapidly, good for specific questions	Not flexible as interviews, questionnaire design is crucial
Observation	Mostly qualitative	Direct in order to get the information about people's natural behaviour	Context might influence the participant's performance
Audio and video data recording	Mostly qualitative	Repeat reviewing the data	Time consuming, might be limited in public place
Diary study	Mostly qualitative	The participant fills the gap when the observer is not around	Might need more time to analyze a large amount of data from participants
Focus group	Mostly qualitative	Allow to raise diverse issues	Time consuming for analyzing the recorded conversation
Field research	Mostly qualitative	Understand people's natural behaviour in their daily life in the context	Time consuming and costly for collecting information; sample size might small
Performance measures	Quantitative and qualitative	Provide both quantitative and qualitative data for analyzing users' interaction behaviour with the system	Principles of calculating times, errors, interrupts and silences are essential
Think aloud protocol	Mostly qualitative	Understanding the participant's thoughts during operating a device	It might difficult for participants to talk out loud and operate the device at the same time; time consuming for transcribing the audio recording
Log file analysis	Quantitative	Collecting data without interrupting the system performance	Ethical considerations may arise due to observation of participants without their perception
Ethnography	Qualitative	Understand details of people's life	Might take weeks even years for collecting data

2.6 Conclusions of literature view

This chapter attempts to understand the human-machine interface from the root of design process, individuals' interaction and how individual differences affect users' performance and preferences. It provides the direction for exploring the relationship between individual differences and the users' operational behaviour.

Firstly, Norman's seven stage action only indicates how to complete a task without making mistakes. This study is more concerned with how an individual interacts with an unfamiliar interface within an uncertain context, how the user selects icons, and chooses paths for achieving the goal. It is thus necessary to establish the model to illustrate the users' operational behaviour and the process of seeking the target.

Secondary, previous studies tend to present the relationship between cognitive styles and the users' preferences of icons (Lee, 2005), categories (Unsworth, 2005), layouts (Kim, Lee and You, 2007). Their performance was examined in terms of completion time (e.g., Kim, Lee and You, 2007; Chen, Magoulas and Dimakopoulos, 2005) of tasks and the selection of items. Parts of the studies only present the results by percentage (e.g., Chen, Magoulas and Dimakopoulos, 2005). In the meantime, the users in those studies were only given two different types of the interfaces to examine the relationship between the differences of cognitive style and their selection. It seems a gap between theoretical cognitive style attributes and individuals' actual behaviour when operating mobile phone interface exists. More importantly, this study assesses if the information is enough to identify a user's cognitive style based on their operational behaviour and then provide a suitable interface to improve the user's sanctification. In terms of mobile phones display functions by hierarchical structure, this research concerns Ford's (1985) point of view that holists-serialists prefer a different method to deal with the hierarchical structure. To achieve the objectives of understanding phone users' operational behaviour in this research, holistic-serialistic styles were therefore chosen. Based on the concerns above, this research therefore focuses on developing the linkage between theoretical descriptions of cognitive styles and the users' operational behaviour whilst interacting with the interfaces of mobile phones.

Key issues derived from the literature:

- a) understanding the gap between users' interaction with mobile phones, their practical behaviour and individual differences, specifically cognitive styles;
- b) the lack of understanding of how individuals deal with problems when operating mobile phone interfaces;
- c) how to identify a user's individual differences by his/her operational behaviour with phone interfaces

Therefore, the aims of this research were confirmed toward exploring how the attributes of individuals' cognitive style-holist/serialist reflect on their operational behaviour whilst interacting with mobile phone interfaces and developing the model of users' interaction with unfamiliar interfaces. To present the validity of this PhD thesis, this research also examined the principles that were established to identify mobile phone users' cognitive style in chapter 8. More importantly, design guidelines based on individual differences of cognitive styles were established; the design elements based on UX were provided for an alternative concern of users' requirements of mobile phones.

CHAPTER 3 METHODOLOGY

Overview

Previous studies tend to present the effects of individual differences on users' performance with interfaces with reference to quantitative interpretations; it seems there exists a lack of detailed descriptions of how the attributes of individual differences reflect on users' behaviour. This research therefore combines both quantitative and qualitative methodologies to interpret individuals' operational behaviour with phone interfaces. This chapter seeks to clarify the differences between methodologies and the selection of approaches that were applied in this research. In terms of research process, the following sections present the aims of this PhD thesis and the discussion of quantitative, qualitative and triangulation methods that are beneficial to this research. More importantly, this chapter presents the methodologies and the aims of this research and links them to further data collection and analysis.

3.1 Introduction

This chapter illustrates the process of conducting research, identifies the character of this research and introduces the methodologies applied. In general, research methods can be categorised as quantitative, qualitative and mixed methods. Strategic inquiry provides the specific direction of procedures when designing a research programme (Creswell, 2008). Quantitative strategies involve complex experiments, many variables and treatments, such as surveys and experimental research. Qualitative strategies can be applied to ethnography, grounded theory, case studies, phenomenological research and narrative research (Creswell, 2008). Due to the limitations and biases of the single method, which might be neutralised or cancelled by the other methods (Creswell, 2008), mixed method strategies combine the strengths of both quantitative and qualitative approaches. The concept of mixed methods was firstly conducted by Campbell and Fiske (1959) for examining the validity of psychological traits.

Quantitative methodology was often applied to previous studies which focus on the relationship between cognitive style and users' interaction with interfaces (e.g. Ford, et al., 2002; Kim, Lee and You, 2007; Chen, Magoulas and Dimakopoulos,

2005). Those studies evaluate users' performance with interfaces by seeking to pinpoint statistical significances between cognitive style and of the time taken to complete tasks, the number of mouse clicks, and preference of icons. They lack detailed descriptions of how an individual's intention influences their ability to reach their goal. This research is concerned with the notion that individuals' operational process of completing tasks might vary in terms of individual differences (Figure 3-1). From those studies above, it seems there is a lack of research on how to transform the process of an individual's selection of items into a practical description of their operational behaviour that is coherent with theoretical attributes of cognitive styles.

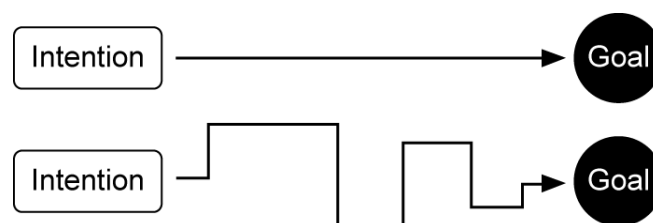


Figure 3-1 Individual differences impacts the process of achieving a goal

To achieve the aim, it is also necessary to observe individuals' interaction processes with the interfaces and to illustrate their operational behaviour with detailed descriptions. Therefore, this research applies triangulation methods that combine both quantitative and qualitative approaches to understand how individual differences affect users' operational behaviour with mobile phone interfaces, more specifically, the difference of cognitive style. Furthermore, based on the results of this research, the impact of cognitive style on the users' problem solving ability was also examined by two psychological tests: *Luchin's jar problems* and *Tower of Hanoi*.

This research thus investigates how to clarify the relationship between individual differences and their operational behaviour with mobile phone interfaces. Chapter 4 aims to understand individuals' operational behaviour when interacting with the interfaces of numeric keypad phones. The routes taken to achieve the goals were observed in addition to the time taken to complete tasks and the numbers of icons the users clicked. In terms of the restrictions of chapter 4, chapter 5 examines the impact of individual differences on users' interaction with touch screen phone

interfaces that are coherent with their cognitive style. Chapter 5 not only analyses the users' performance, but also examines users' satisfaction with the interfaces, observing the process that the users applied to achieve the goals. In the meantime, the categories of identifying phone users' cognitive style based on their operational behaviour were thus developed in this chapter. According to the findings of chapter 5, individuals' performance was linked to the effects of UX. More specifically, the cognitive styles of holist and serialist were therefore linked to individuals' problem solving ability. Chapter 6 then attempts to obtain phone users' requirements of mobile phones. A novel methodology of Taxonomy of Experience (ToE) was conducted to understand the necessary design elements of phones from a UX aspect. The linkage of holistic-serialistic styles and individuals' problem solving ability was examined with two psychological tests in chapter 7. For the purpose of integrating the findings of this research, chapter 8 was conducted to identify phone users' cognitive style based on the categories that were established in chapter 5.

This chapter presents the understanding of the methodological basis and the application of research approaches that are necessary to achieve the aim of this research - to understand users from the root. The specification of approaches in each stage was discussed within the study in the following chapters.

3.2 Research process

The general process of conducting research includes seven steps (Figure 3-2). The process guides the researcher to narrow down the topic by reviewing past studies and literature and to develop a practical strategy for collecting data. A step-by step approach was used for the analysis and interpretation of data in this research. The processes might be affected by the other steps; retrieving the data or re-thinking the procedure (Neuman, 2006). Besides, the details of conducting each step might vary based on the relationship between theory and research (Bryman, 2008). The research in this thesis intends to apply individual differences of gender, cognitive styles and UX to examine users' performance; meanwhile, two types of mobile phones were used in this research. Each study in this research was designed with reference to the results of a previous study. The research process of this PhD

thesis presents a cycle between steps 2 to 6. All outcomes were integrated and evaluated in chapter 8 to develop the application of this research.

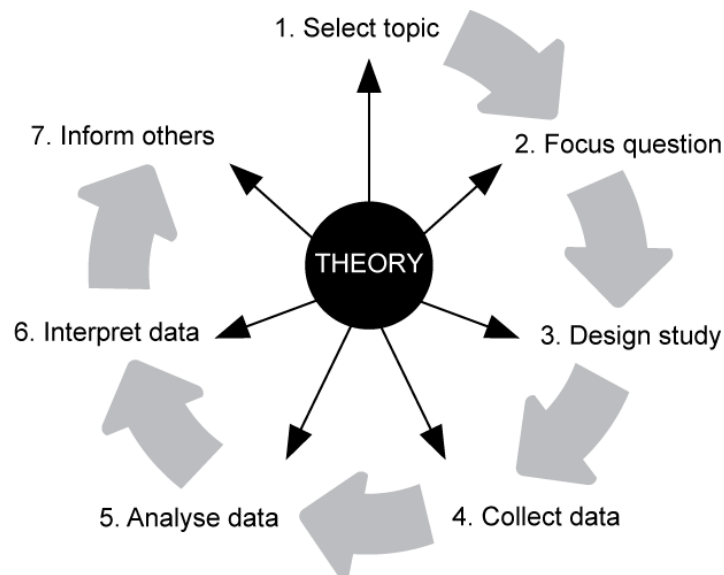


Figure 3-2 Steps of research process (Neuman, 2006)

3.3 Research purposes

The aims of this research are to understand phone users deeply and provide a method by which users can be categorised, and then suggest alternative design guidelines to mobile phone interface design in terms of those individual differences. To achieve those aims, this thesis attempts to understand phone users from the root, to provide detailed descriptions about individuals' operational behaviour with phone interfaces, and then, to develop the categories to identify phone users. Three individual differences: gender, cognitive style and UX were applied in this research. During the research process, partial significance was found between the individuals' cognitive style and their interaction with phone interfaces. Therefore, individuals' performance was focused on the effect of cognitive style. This research thus intends to link individuals' cognitive style differences and the process of their dealing with obstacles when interacting with phone interfaces. Individual differences when operating a phone interface were then illustrated with detailed descriptions of their behaviour. Finally, provide the guidelines to identify a phone users' cognitive style based on the individual's operational behaviour. Besides, to contribute to the understanding of mobile phone users, this research also considers the elements that users care about most

to complement current design guidelines that are applied in the mobile phone industry.

According to Neuman (2006), social research can be categorised into three groups: exploratory, descriptive and explanatory (Table 3-1). In terms of the purposes of this research, to develop detailed descriptions of individuals' operational behaviour with phone interfaces, to provide alternative design guidelines, the character of this research tends towards being descriptive as Neuman's categories.

Table 3-1 Purposes of research (adapted from Neuman, 2006, p.15)

Exploratory	Descriptive	Explanatory
Become familiar with the basic facts, setting, and concerns.	Provide a detailed, highly accurate picture.	Test a theory's predictions or principle.
Create a general mental picture of conditions.	Locate new data that contradict past data.	Elaborate upon and enrich a theory's explanation.
Formulate and focus questions for future research.	Create a set of categories or classify types.	Extend a theory to new issues or topics.
Generate new ideas, conjectures, or hypotheses.	Clarify a sequence of steps or stages.	Support or refute an explanation or prediction.
Determine the feasibility of conducting research.	Document a causal process or mechanism.	Link issues or topics with a general principle.
Develop techniques for measuring and locating future data.	Report on the background or context of a situation.	Determine which of several explanations is best.

3.4 Methodology

As can be seen from Figure 3-3, this research attempts to achieve its aims from observing users' individual differences, operational behaviour and operational experiences. This research intends to understand users more than previous studies that only address users' preferences of items. Thus, both quantitative and qualitative methodologies and approaches were applied in this research. It is necessary to mention that quantitative and qualitative strategies should be viewed as representing different formats of the same outcomes rather than being two opposite methods (Newman and Benz, 1998). This section reviews quantitative and qualitative methodologies, to compare their differences and how the strengths of each method suit the purpose of this research.

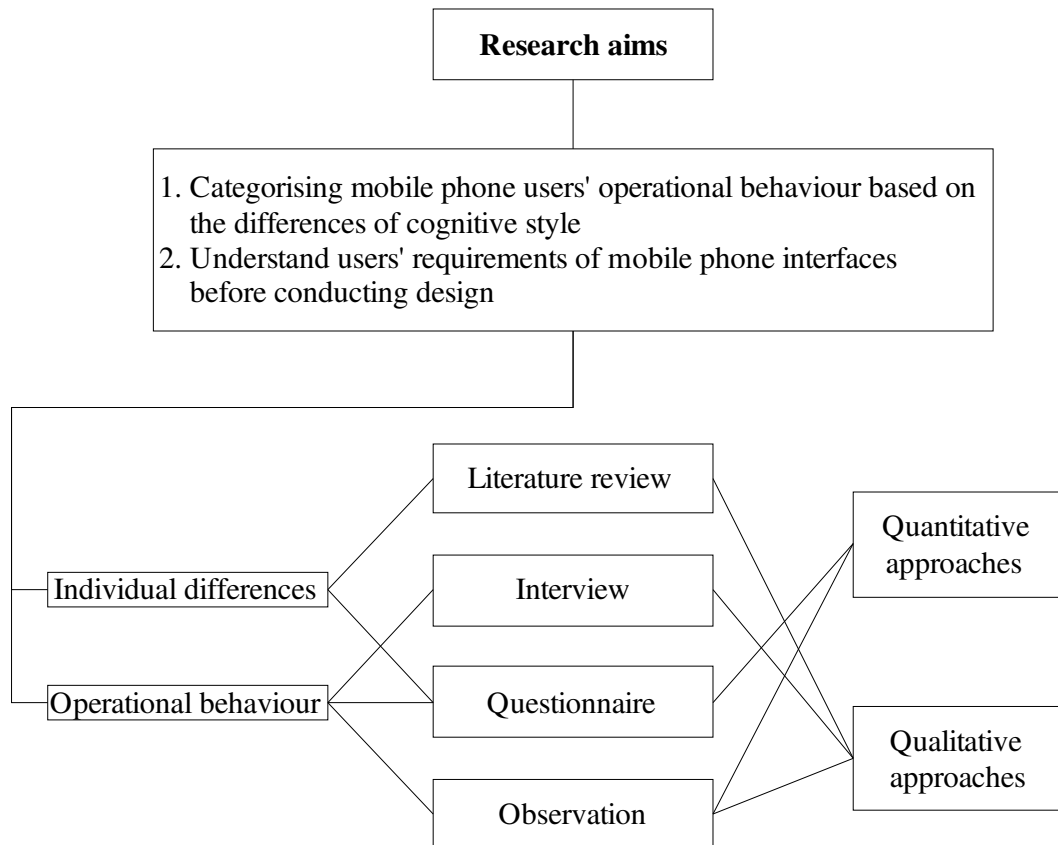


Figure 3-3 Framework of applying methods in this research

3.4.1 Quantitative methodology

Bryman (2008) distinguishes the quantitative research from qualitative research as it collects numerical data, presents the relationship between theory and deductive research; it is interested in a natural science approach. Furthermore, quantitative methodology tends to apply closed-ended questions and to examine the relationship between objective theories by measurable variables. The collected data can be presented numerically and analysed with statistical methods (Creswell, 2008). As mentioned earlier, this research aims to understand the impact of individual differences on users' operational behaviour. Therefore, surveys were applied to identify individuals' differences. Both surveys and experiments are the strategies of quantitative inquiry.

Survey research

The cross-sectional design and longitudinal studies collect data from individuals via self-completion questionnaires, structured interviews or by other methods to establish the connection between more than two variables by numeric descriptions. Then the relationship between the variables is examined (Bryman, 2008; Babbie, 1990).

Experimental research

This type of research aims to explore the impact of a specific treatment on an outcome. More specifically, it seeks to assess different groups by a specific treatment, to find the differences between the groups, and to determine factors that affect the result (Keppel, 1991).

3.4.2 Qualitative methodology

Qualitative research is mainly presented by means of words instead of numbers and adapts open-ended questions such as interview questions. It tends to explore and to understand the meaning of an individual's or groups' social problems (Creswell, 2008). The research design and the data of a qualitative study is not organised before collecting data, instead, it was developed during the empirical working process. In the meantime, qualitative methodology applies multiple strategies and methods to collect data, rather than a single strategy and method as with quantitative research. It places more emphasis on people's natural settings (Punch, 2005). This research addresses the necessity of describing phone users' operational behaviour with detailed illustrations, and the understanding of their requirements of mobile phones. To achieve the objectives, qualitative data from the users provided elaborate information for further analysis with their performance of quantitative data. This section reviews the five aspects of qualitative strategies.

Ethnography

Ethnographic research involves the cultural factors and the population's point of view of life (Punch, 2005). The research process is flexible, sensitive to the natural setting. It is important to describe the issue that happens in the setting and how the individual reacts, the reaction of others, the relationship with the context

(Punch, 2005; Creswell, 2008). It is also important for the researcher to immerse themselves in the setting for a long period of time (Bryman, 2008).

Grounded theory

This strategy attempts to inductively establish theory from the collected data (Punch, 2005). The data could be derived from a general process, action or interaction from the participants (Creswell, 2008). The process involves multiple steps to collect and to distil the data, in addition, to establish the interrelationship between the categorised information (Charmaz, 2006; Strauss and Corbin, 1990, 1998). Therefore, there is no 'up-front' theory and hypotheses are proposed for examination before the research is conducted (Punch, 2005). Creswell (2008, p.13) indicates that the main characteristics of this grounded theory are 'the constant comparison of data with emerging categories and theoretical sampling of different groups to maximise the similarities and the differences of information'.

Case studies

This is the strategy of inquiry that can be applied to explore a topic deeply, such as a program, event, activity and so forth (Stake, 1995). The research has to identify and to describe the boundaries between the cases clearly. A variety of procedures might be applied for collecting data during a period of time (Stake, 1995; Punch, 2005).

Phenomenological research

This strategy aims to establish a phenomenon by identifying the substance of individuals' experiences to the event. Patterns between pieces of information and relationships between results should be developed based on a long term engagement within a small sample size of populations (Nieswiadomy, 1993). In order to understand the individual's behaviour, the phenomenologist should eliminate the preconceptions from his or her view, and try to see things from the participants' point of view (Bogdan and Taylor, 1975).

Narrative research

This is a strategy of inquiry to illustrate the participant's life by collecting stories from more individuals and edit the information into a narrative chronology (Clandinin and Connelly, 2000).

According to the five characters of qualitative methodology, this research was informed by grounded theory and phenomenological research. The category thus provides a foundation for this research and supports the process of achieving aims and objectives in this thesis.

3.4.3 Comparison of quantitative and qualitative methodology

This research attempts to understand phone users by individual differences and their operational behaviour with phone interfaces. It is thus important to clarify the character of data and to analyse the data with proper approaches. The differences between quantitative and qualitative methodology were thus summarised as Table 3-2 (Bryman, 2008).

Table 3-2 Contrasts between quantitative and qualitative research (adapts from Bryman, 2008, p.393)

Quantitative	Qualitative
Numbers	Words
Point of view of researcher	Points of view of participants
Researcher distant	Researcher close
Theory testing	Theory emergent
Static	Process
Structured	Unstructured
Generalisation	Contextual understanding
hard, reliable data	Rich, deep data
Macro	Micro
Behaviour	Meaning
Artificial settings	Natural settings

According to Neuman (2006), quantitative and qualitative approaches can be distinguished by three factors: timing, data itself and the linkage of ideas and data.

Timing

Quantitative researchers- apply variable measurements and to convert it into specific actions before data collection and data analysis.

Qualitative researchers- apply the measurements during the process of data collection.

Data itself

Quantitative researchers- tend to develop techniques to produce quantitative data such as numbers. The specific data collection techniques are helpful to collect precise numerical information to represent researchers' empirical abstract ideas.

Qualitative researchers- sometimes data is in the form of numbers. Most of the time, data includes participants' conversation, behaviour, circumstances, symbols, sounds, physical objects, visual images and so forth. They do not convert the observation results to numbers; instead, they develop many flexible, ongoing processes to measure a phenomenon.

The linkage of ideas and data

Quantitative researchers- contemplate and reflect the aims of concepts before collecting data and establishing the connection between the concepts and data.

Qualitative researchers- reflect on ideas before data collection, and develop the other concepts while collecting data. In addition, the qualitative researcher re-examines and re-evaluates both the data and concepts interactively at the same time.

3.4.4 Mixed methodology

As mentioned earlier, this research seeks to understand phone users from both quantitative and qualitative points of view. Mixed methodology is an approach that combines both quantitative and qualitative forms in a study. It applies quantitative and qualitative approaches to collect and to analyse data. The outcome of a study is therefore broader than with purely quantitative or qualitative research (Creswell and Plano Clark, 2007). Hammersley (1996) mentions that a large proportion of studies adopt both quantitative and qualitative approaches. Five purposes of conducting mixed methods were collated from fifty-seven previous studies by Greene, Caracelli and Graham (1989) as follows.

- a) triangulation: seeking convergence, corroboration, correspondence of results from the different methods;
- b) complementarity: seeking elaboration, enhancement, illustration, clarification of the results and examining a phenomenon by different aspects;
- c) development: applying the outcome from one method to inform the other method to capitalising the strengths from different methods;
- d) initiation: discovering paradoxes and contradictions, comparing new perspectives from one method with questions or outcomes from the other methods;
- e) expansion: extending the breadth and scope to a study by applying different methods for different requirements.

The importance of conducting a triangulation method was also addressed in evaluating users' interaction with interfaces on computer and mobile phones. The mixed method can be applied to obtain both subjective and objective data from users in order to understand the users' attitude and behaviour more deeply (Grinnell and Unrau, 2005; Love, 2005; Hammersley, 1997).

The aim of this research is to understand the impact of individual differences on their operational behaviour with phone interfaces. As mentioned earlier in Figure 3-3, the application of individual differences was identified via reviewing literature; and individual differences of gender, cognitive style, and user experience were identified by questionnaire. Individuals' performance with phone interfaces was analysed via interview, questionnaire and observation. This research thus includes both quantitative and qualitative methodologies to understand phone users deeply. The next section reviews the approaches that were taken when collecting quantitative and qualitative data in this PhD thesis.

3.5 Research methods

As mentioned earlier, to achieve the aim of this research, to understand phone users by their operational behaviour with interfaces, to establish detailed descriptions of their interaction with phone interfaces; it is necessary to collect both quantitative and qualitative data from individuals. This section discusses the

attributes of the quantitative and qualitative approaches which were chosen for collecting data in this research. The details of applying the approaches were discussed within the studies in chapter four to seven.

3.5.1 Quantitative approaches

In terms of the definition of quantitative methodology, the data was general presented as numbers (Bryman, 2008; Creswell, 2008). According to Love (2005), Kim, You and Lee (2007), completion time and the numbers of clicking icons are both quantitative approaches that can be applied to evaluate the users' performance with interfaces. For achieving the objective of understanding phone users' operational behaviour with the interfaces in terms of their performance with regard to time taken to complete tasks, the numbers of clicking icons was observed and examined with individual differences. In this research, individual differences of gender, cognitive style and user experience were identified via questionnaires. This section aims to clarify the types of questionnaires and observation, and to define the character of the approaches in this research.

3.5.1.1 Questionnaire

Questionnaires have been widely applied in academic areas and industries. Because they can be completed by participants themselves, they are deemed to be self-completion questionnaire (Bryman, 2008). It can be conducted to collect demographic data, users' opinions, more specifically; it is also applied to evaluate usability, user satisfaction, error making and attitudes in human factors and design issues. The types of questions were listed as Table 3-3 (Stanton et al., 2005).

Table 3-3 Types of questions of questionnaires (adapted from Stanton et al, 2005, p.32)

Type of Question	When to use	Questionnaire in this research
Multiple choices	When the participant is required to choose a specific response.	The technographic questionnaire (Chapter 4).
Rating scales	When subjective data regarding participant opinions is required.	QUIS (Chapter 5).
Paired associates (Bipolar alternatives)	When two alternatives are available to choose from.	SPQ (Chapter 4, 5, 6, 8).

(Table 3-3 continued)

Ranking	When a numerical rating is required.	QUIS (Chapter 5).
Open-ended questions	When data regarding participants own opinions about a certain subject is required i.e. subjects compose their own answers.	Discussion (Chapter 4, 5, 6).
Closed questions	When the participant is required to choose a specific response.	Select the preferences of interfaces (Chapter 4).
Filter questions	To determine whether participant has specific knowledge or experience. To guide participant past redundant questions.	To understand how participants operate the specific tasks with their mobile phones.

The advantage of using questionnaires for research is that they are cheap and quick to administer, due to an absence of interviewer effects; besides, some questionnaires of evaluating human factors have been established (e.g. QUIS-Questionnaire for User Interaction Satisfaction (HCIL, 1990), SUMI-Software Usability Measurement Inventory (Kirakowski, 2009), SUS-System Usability Scale (Brooke, 1986). Nevertheless, the design process is time-consuming, and, to administer and to analyse the result of a questionnaire also takes time. The reliability and validity of a general questionnaire could be of concern. In addition, researchers cannot probe and ask extended questions, in the meantime, the response rate is low (Bryman, 2008; Stanton et al., 2005).

The aim of this research is to understand phone users from the root, to investigate the impact of individual differences on their interaction with phone interfaces. Taking a cue from Love's (2005) suggestion, technographic data can be used to investigate the individual's performance with an interface. In the pilot study in chapter 4, a technographic questionnaire was applied to understand phone users' background and their usage with their mobile phones. The questionnaire consists of multiple choices, paired associates, ranking, open-ended and closed questions. To identify an individual's cognitive style, this research applied the tool of SPQ that was mentioned in chapter 2. This research attempts to examine users' interaction with a phone interface that was developed based on hierarchical structure. According to Ford (1985), the cognitive style of holist-serialist

associates with individuals' interaction with hierarchical structure. Furthermore, Ford established the Study Preference Questionnaire (SPQ) to identify an individual's tendency as a holistic or serialistic style. This research thus adopts SPQ as the instrument to identify individuals' cognitive styles, combining both paired associates and ranking questions. In terms of the results of chapter 4, participants would appreciate an interface if the tasks can be completed with a few steps; chapter 5 therefore involves users' satisfaction to examine the relationship with the users' performance. The Questionnaire for User Interaction Satisfaction (QUIS) was therefore applied in this research. The QUIS in this research includes 22 questions; participants were given rating scales to evaluate interfaces. The detailed specification of QUIS was introduced in chapter 5. Furthermore, participants were also given open-ended questions to present their opinions, feelings and experiences when interacting with phone interfaces. Overall, this research involved seven types of questions for understanding phone users.

3.5.1.2 Observation

The types of observation are slightly different in social research and interaction design. Whilst social research addresses the structure of observation; the research of interaction design emphasises the impact of circumstance on users' performance and the importance of collecting data in the field. To achieve the objective of this research, to understand how individual differences affect the users' interaction with mobile phones; observation is one of the important approaches in this research. This section discusses the types of observation approach to clarify the character of the approaches, to define the role of observation in this PhD thesis,

The major types of observation in social science are structured observation, unstructured observation, participant observation, non-participant observation and simple observation. In addition, the role of an observer can be covert or overt (Bryman, 2008). A covert observation can involve 'covert participant observation, simple or contrived observation' (Bryman, 2008; p.121). The observer is therefore presented as one of the subjects in a group without noticing the group. On the other hand, the researcher's identity as an observer is open to the group of participants for an overt observation.

Stanton et al. (2005) indicate that observation should include the aspects of tasks (steps and sequence), individuals' performance in the tasks (completion time, error made), the impact of technology and the context whilst the data corresponds to individuals' physical behaviour and verbal commentary of a task or scenario. More specifically, information about the sequence of activities, duration of activities, frequency of activities, proportion of time spent in states and spatial movement of individuals' performance can be obtained from observation (Drury, 1990).

Structured-unstructured observation

The technique of observation can be applied to both quantitative and qualitative approaches (Punch, 2005). With quantitative study, the observation was conducted as highly structured; detailed observation schedules were required before collecting data. Structured observation is also named systematic observation. The researcher establishes rules for the observation and recording of the participants' behaviour. The rules include what behaviour should be recorded and what the observers should look for (Bryman, 2008).

In contrast, unstructured observation is more natural and open-ended in qualitative studies; no categories and classifications were prepared before collecting data (Punch, 2005). The purpose is to collect details of the behaviour from participants and to develop a narrative of the behaviour (Bryman, 2008).

Participant-non-participant observation

Participant observation is more associated with qualitative research; observers were required to engage in a social setting for a prolonged time (Bryman, 2008). It is the main technique for ethnographic data collection (Punch, 2005).

To compare with non-participant observation, the observer does not participate in the social setting while applying the observation. It can be also applied to both structured and unstructured observation (Bryman, 2008).

One of the advantages of applying observation is to obtain data from a 'real life'. In addition, various types of data can be collected via this approach, such as task

sequences, task analysis, completion time, errors made and so forth. It provides objective, detailed information. It is a typical method that was used for human factor studies. The data can be input into the other human factor methods, such as 'human error identification techniques (SHERPA), task analysis (HTA), communications analysis (Comms Usage Diagrams), and charting techniques (operator sequence diagrams)' and so forth (Stanton et al., 2005, p.43). However, conducting observation is time consuming, and might adversely affect the participants' or the tasks' performance. Besides, it tends towards diverse biases, and it becomes difficult to locate the causality in a problem, and to set the experimental control (Stanton et al., 2005; Bryman, 2008)

For the objective of deep understanding of phone users' performance and their interaction with phone interfaces; this research not only involves collecting data from completion time and the numbers of icons clicked, but also the routes they applied for seeking the goals. Moreover, this research attempts to establish the category to identify individuals' cognitive style in terms of their interaction with phone interfaces, detailed descriptions of individuals' operational behaviour are thus important for this research. The process of the users' operation of interfaces was filmed during investigations. Their performance in terms of completion time of tasks, the numbers of icons clicked was transformed into quantitative data first. In terms of the quantitative analysis and the statistical significance, the observation schedules were then established for further analysis. In this case, observation of this research provides both quantitative and qualitative data; it is structured. Meanwhile, the observer was not involved in the event. More importantly, the role of the observer in this study is overt when conducting observations.

3.5.2 Qualitative approaches

Qualitative approaches collect data from interview, observation, ethnography, focus groups, documents and audio-visual materials (Bryman, 2008; Creswell, 2008). More importantly, users' interaction with an interface is important for the research of interaction design. Recording users' behaviour via notes, camera and video is crucial for further analysis (Sharp, 2006; Love, 2005). For a deep understanding of individuals' interaction with phone interfaces, the results of

interviews and observation were applied in this research. This section discusses the types of interviews and the role of observations in qualitative approaches.

3.5.2.1 Interviews

Interview is a process of conducting conversation with a specific purpose (Kahn and Cannell, 1957). The conversation provides the information about the interviewees' behaviour, attitudes, beliefs, values and so forth (Bryman, 2008). It is flexible for obtaining information from individuals. The major types of interviews are structured-unstructured interviews, semi-structured interviews and focus groups (Stanton, 2005; Sharp, 2007; Bryman, 2008).

Structured interviews

An interviewee was given a set of pre-defined questions in a structured interview for the researcher to elicit the specific information for further analysis. The questions are pre-designed, demanded, and specific; interviewees are given a flexible range of answers for the questions. The question types include closed, closed-ended, pre-coded or fixed choice (Bryman, 2008; Stanton, 2005).

Unstructured interviews

This is an exploratory method for interviewers to discover different aspects of the subject. No pre-defined questions were required. The questions are informal in an unstructured interview. The collected data is rich and aids understanding of a topic more deeply; nevertheless, it is time consuming to analyse (Stanton, 2005; Sharp, 2007; Bryman, 2008).

Semi-structured interviews

This type of structure was commonly adopted at interview. It combines both attributes of structured and unstructured interviews. Closed and open questions were applied in semi-structured interviews. The structured questions were prepared, the order of questions is pre-determined; in the meantime, the interviewer is allowed to ask further questions in response to the interviewee's replies (Stanton, 2005; Bryman, 2008).

Based on the aim of understanding users in this research, the interview is an alternative method to obtain more information from users. According to the

structured questions, this research is able to extract the users' opinions of their experiences with the handsets. Furthermore, the unstructured interviews were applied to the studies in this research for further understanding of the user's operational behaviour and their experience whilst completing the tasks. Whilst researchers attempt to transform the UX into quantitative data (e.g. Isomursu, 2008; Hole and Williams, 2008; Azzawi, Frohlich and Wilson, 2008); this research attempts to present the elements of UX that the users care about most where phone interfaces are concerned. A novel methodology-Taxonomy of Experience (ToE) was therefore adopted in this research. To analyse individuals' verbal commentary accordingly, ToE and its analytic process of SEEing distils the elements of the users' experience with an object (Coxon, 2007). Those elements can be also concerned as parts of design guidelines. The background and the application of ToE-SEEing in this research were illustrated in chapter 6.

3.5.2.2 Observation

As mentioned in 3.5.1.2, the approach of observation can be applied to both quantitative and qualitative studies. With the exception of the users' completion time, the numbers of icon-clicking tasks was also referred to quantitative data; the routes by which they seek the goals was observed as qualitative data and was analysed with HTA to see the effects of cognitive style on users' operational behaviour. The details of HTA were introduced in chapter 5. A video camera was adopted in this research. The collected quantitative data was analysed firstly, then the results were applied to set the observation schedules for seeking the users' difference of operational behaviour from qualitative data.

3.6 Sampling and sample size

This research attempts to establish detailed descriptions of phone users' operational behaviour that are consistent with theoretical attributes of cognitive style. As mentioned in chapter 3.3, this research is then referred to as descriptive research. To achieve the aim of understanding phone users deeply, questionnaires, interviews and observation were used to obtain information about their operational behaviour. Therefore, this research tends to be qualitative. According to Neuman (2006), qualitative researchers focus on the relationships between sampling and social life rather than drawing a probability sample by detailed

techniques and analysing its representativeness. Meanwhile, qualitative researchers select samples gradually in accordance with the specific purposes instead of determining the sample size in advance.

Non-probability and non-random samples were general applied to qualitative studies (Neuman, 2006) (Table 3-4). According to the analyst firm iSuppli, nearly 3 out of every 4 people owned mobile phones worldwide by the end of September, 2010 (Intomobile, 2010). Based on the fact that the aim of this research is to understand individual differences of user interaction with phone interfaces, the haphazard sample can be applied for collecting data. For the convenience of recruiting participants, students in a British University were invited to take part of the investigations of this research. In terms of users' experience with different models of mobile phones, participants were invited based on their technographic background.

Table 3-4 Types of non-probability samples (adapted from Neuman, 2006, p.141)

Type of sample	Principle
Haphazard	Obtain any cases in any manner that is convenient.
Quota	Obtain a preset number of cases in each of several predetermined categories that will reflect the diversity of the population, using haphazard methods.
Purposive	Obtain all possible cases that fit particular criteria, using various methods.
Snowball	Obtain cases using referrals from one or a few cases, and then referrals from those cases, and so forth.
Deviant Case	Obtain cases that substantially differ from the dominant pattern (a special type of purposive sample).
Sequential	Obtain cases until there is no additional information or new characteristics (often used with other sampling methods).

Regard should be given to the sample size of conducting research with Human-Computer Interface (HCI), Love (2005) compares sampling size from literatures as researchers suggest different number of participants for HCI studies. Neilson (1993) states that the main phenomena or problems can be found within a usability evaluation exercise by five to ten participants. Whilst Coolican (2000) argues that thirty is the proper number of participants for investigating the effects of experimental independent variables. As mentioned in chapter 3.4.2, this thesis was informed by grounded theory strategy and phenomenological research, followed by the guidelines; the sample size should range from 15 to 20 participants (Creswell, 2002) to 20-30 participants (Creswell, 1998). More importantly, this PhD research attempts to understand and to analyse phone users' operational behaviour based on qualitative data, such as the paths that the users applied to complete tasks, users' verbal commentary and interviews. The comprehensive observation provides a large amount of information for further analysis. Therefore, this research attempts to examine the effects of individual differences to phone users' operational behaviour by the sample size between 10-20 for the pilot study, 20-40 for further data collection and analysis.

3.7 Reliability and validity

Based on the discussion of previous sections in this chapter, the character of this research tends to be qualitative. In general, reliability addresses the consistency of the measurements of the research and the application of particular research instruments (Gomm, 2008). Validity tends to find 'the match' between a construct, and how well a concept of reality fits with actual reality (Neuman, 2006). In addition, reliability of research can be interpreted as 'whether the results of a study would be the same if the study were repeated' whilst validity is concerned with 'the integrity of the conclusions generated by a piece of research' (Bryman and Teevan, 2005, p.25).

Quantitative research tends to improve its reliability of measures by clarifying and conceptualising constructs, using a precise level of measurement, using multiple indicators and pilot tests. However, qualitative researchers argue that the standard, fixed measures might limit the advantages from researchers and the application of diverse approaches. Qualitative researchers emphasise the consistency of

observations with regard to reliability more. In the meantime, the relationships between researchers and participants are growing, evolving processes (Neuman, 2006). Whilst quantitative researchers emphasise validity of measurements in the studies; researchers suggest evaluating qualitative research from trustworthiness and authenticity. The trustworthiness consists of credibility, transferability, dependability, confirmability (Lincoln and Guba, 1985).

- **Credibility:** to ensure the research was conducted in terms of well defined scientific practice and the findings of previous studies to confirm the research fully understood the issue in the context of the social world.
- **Transferability:** detailed description is necessary as a database to interpret the context in which research is conducted.
- **Dependability:** auditing is an approach to improve dependability. It is necessary to make sure the collected data is consistent within problem formulation, selection of research participants, fieldwork notes, interview transcripts, data analysis decisions, and so on in the research.
- **Confirmability:** ensuring personal values or theoretical attributes were not impacted by the research findings.

In terms of the criteria of ensuring the reliability and validity, the chosen triangulation method is necessary. Furthermore, to establish the linkage of literature and findings, provide detailed description of individuals' operational behaviour, keep the consistency of research process and ensure the research findings are independent are crucial to improve the reliability and validity of this research.

3.8 Research procedure

As mentioned in chapter 3.2, the research process of steps two to six were conducted repeatedly in this research. All research approaches and purposes were presented in Figure 3-4. Chapter 4, 5 and 6 present the process of achieving the aim of this research. Chapter 4 consists of two stages of understanding users' operational behaviour with phone interfaces. The results provide a clearer concept for further exploration of the relationship between individual differences and phone users' interaction with phone interfaces. Chapter 5 investigates the impact

of individual differences on their performance with phone interfaces; more specifically, to examine the users' operational behaviour with the interfaces that are consistent with their cognitive style. In terms of the outcomes of chapter 5, the categories for identifying phone users' cognitive style in terms of their interaction with phone interfaces was established. More importantly, it provides alternative design guidelines for improving designing phone interfaces based on individual differences aspects. Moreover, based on the findings of chapter 5, individuals' differences of cognitive styles were linked to UX and problem solving ability in chapter 6 and 7, respectively. Chapter 8 integrates the results and findings of this research, then applying the outcomes to identify an individual's cognitive style in terms of his/her interaction with a mobile phone interface.

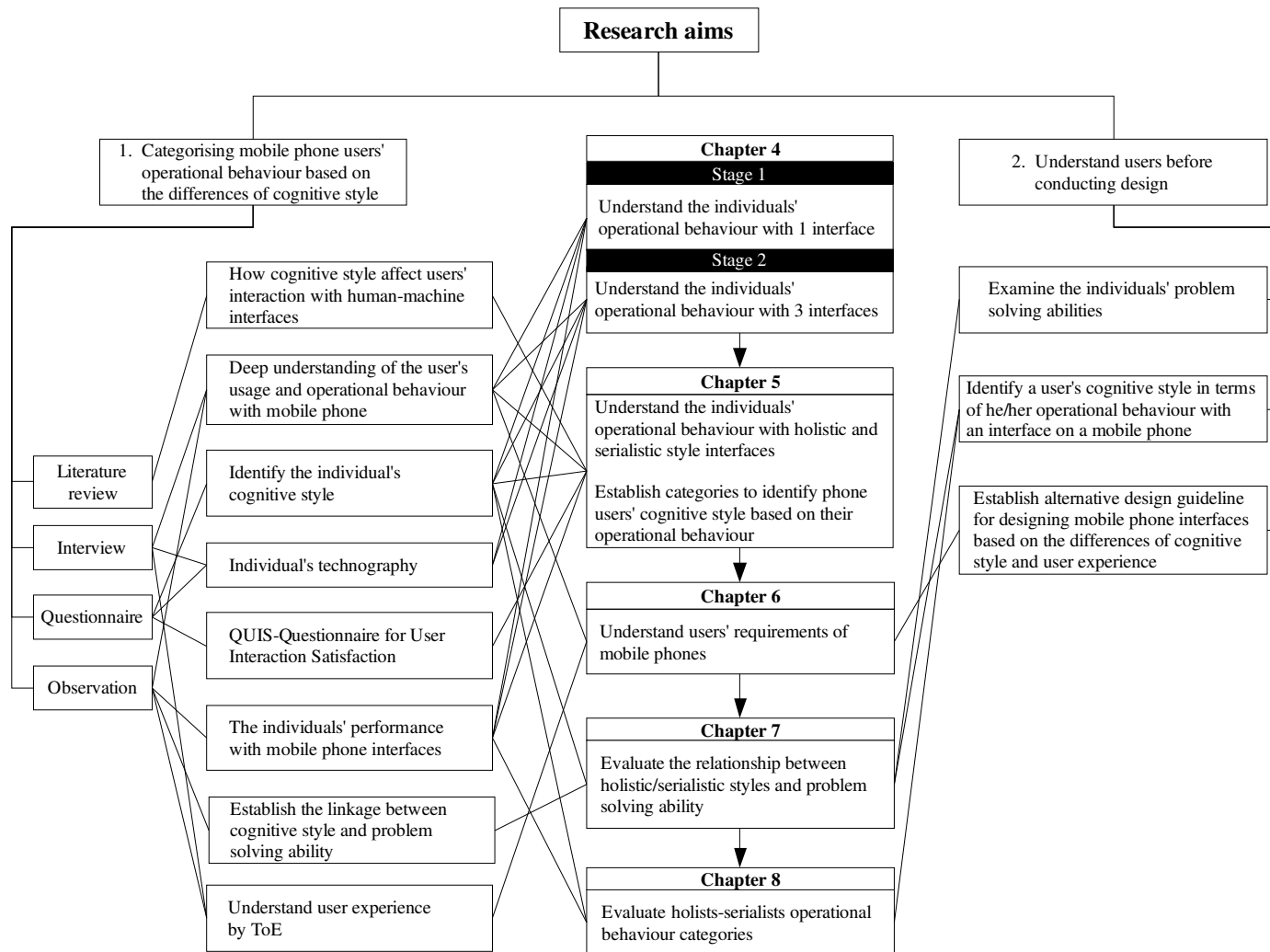


Figure 3-4 Methodology map of this research

3.9 Conclusion

This chapter identified the character of this research, as its purpose tends to be descriptive. To achieve the aim of understanding users deeply, to describe the impact of individual differences on users' operational behaviour, both quantitative and qualitative data were necessary for further analysis. For the understanding of individual differences, a technographic questionnaire was applied to obtain information about an individual's gender, educational background, user habits and experience; SPQ was applied to identify an individual's cognitive style. Besides, a brief discussion was conducted after the investigations for obtaining more information about the users' opinions, feelings and using experiences with the instruments and the tasks. This research includes seven types of questionnaires (see Table 3-3); the aim of this PhD thesis thus can be achieved via different methods. To examine individuals' interaction with phone interfaces, observation is the main approach that was applied in this research. The process of participants' interaction with phone interfaces was filmed. According to the character of the data set; users' completion time and the numbers of icons clicked during tasks were analysed with a statistical approach; the routes of seeking the goals, their body language and verbal commentary were transformed into qualitative data. In terms of the results of quantitative analysis, the observation schedules were set for further analysis of the differences of users' operational behaviour. Overall, this research has a tendency towards being qualitative.

CHAPTER 4 UNDERSTANDING MOBILE PHONE USERS

Overview

According to the aim and objectives of gaining a deeper understanding of individuals' interaction with phone interfaces and establishing detailed descriptions of their operational behaviour; two studies were designed to understand phone users more in this chapter. Three aspects of individuals' differences-gender, cognitive style and user experience were applied to analyse phone users' operational behaviour. Two stages of studies examined individuals with one phone interface and three phone interfaces, respectively. The results show that the users' operational behaviour was affected by cognitive styles and UX. The purpose of conducting two stages investigation in this study was to understand the users' interaction with the phone interface, moreover, to examine the consistency of their operation across different interfaces, and to establish the research process for further exploration in this research.

4.1 Focus questions

Studies in this chapter were thus conducted to seek the impact of individuals' gender, cognitive style and user experience differences on operational behaviour with phone interfaces.

According to the literature (Kimura, 1993; Nicholson and Kimura, 1996; O'Boyle and Hoff, 1987; O'Boyle, Hoff and Gill, 1995; Peters and Campagnaro, 1996), females are better at typing than males due to the fact that their motor dexterity is demonstrated by 'quick and effective use of the hands in the manipulation of small objects' (Kimura, 1993, p.107). Meanwhile, the investigation of children's operation with mobile phones shows that boys performed better than girls due to having a specific and successful navigation strategy. Moreover, boys were more willing to explore and interact with the phones without worrying about making an error (Ziefle and Bay, 2008). This research thus assumes that females might think before operating tasks with phone interfaces. The hypothesis of the relationship between gender differences and individuals' interaction with phone interface was summarised as:

- a) females complete tasks faster than males;
- b) females click fewer number of icons to achieve the goals.

In additional, due to the attributes of the cognitive style-holist and serialist being related to individuals' interaction with a hierarchical structure (Ford, 1985), holist-serialist were chosen to examine phone users in this research. In this chapter, the methods by which the users seek items and the routes they took in order to complete tasks were observed. Serialists prefer to concentrate on the chunks of information that are well defined, sequentially ordered, and tend to use simple links in hierarchical structure; whilst holists have the tendency to focus on several subjects at the same time and establish complex links within hierarchical structure (Ford, 1985); this research assumes that:

- a) serialistic users complete tasks quicker than holistic users;
- b) serialistic users click fewer icons to complete tasks than holistic users.

With regard to user experience (UX) when interacting with technology, Hassenzahl and Tractinsky (2006) indicate the UX consists of three facets: beyond the instrumental, emotion and affect, and the experiential. Besides, user experience has been applied in human-computer interface widely in recent decades (as discussed in chapter 2.4.3). This chapter thus also includes the effect of UX to examine the differences of users' operational behaviour with phone interfaces to explore the possibility of categorising phone users' operational behaviour by their UX differences. Because phone interfaces may be similar between handsets from the same manufacturer, this research assumes that:

- a) users who have the experience of using similar phone interfaces complete tasks quicker;
- b) users who have experience of using similar phone interfaces complete tasks with fewer icons being clicked.

These hypotheses are the core of this chapter to understand users. Two stages of studies were conducted to understand individuals' interaction with phone interfaces. Individuals were given one interface at stage one for obtaining basic understanding of users' operational behaviour. The second stage examines users

with three phone interfaces for further analysis of whether individuals' performance is consistent between different interfaces or not.

4.2 Stage one-pilot study

This pilot study attempts to investigate the impact of individual differences on users' operational behaviour with one phone interface. Three differences of gender, cognitive style and user experience were applied to examine, to observe the participants' interaction with the mobile phone interfaces. Therefore, the three differences were identified by questionnaires; individuals' interaction with phone interface was analysed by completion time of tasks, the number of icons clicked to achieve the goals and the routes of seeking the goals.

4.2.1 Method

As mentioned in chapter 3, this research adopts mixed methods to understand phone users. The concept of triangulation is important for seeking convergence, corroboration, correspondence of results from the different methods (Greene, Caracelli and Graham, 1989). Three facets of individual differences were identified as quantitative data. The users' completion time of tasks and the numbers of icons clicked to achieve the goals were examined with the three differences using a statistic approach. The routes that the users applied to seek the goal were analysed with three differences using a qualitative approach. Besides, a brief post-interview was conducted for further understanding with regard to the problems that occurred when completing the tasks.

4.2.1.1 Design of the investigation

This investigation was a 2*2*2*3 (Gender*Cognitive styles*Using experience *Trial) mixed factorial design, where gender, cognitive styles and user experience were between-subjects factors and the trial was a within-subjects factor. The dependent variable of the users' performance with three tasks with one mobile phone interface was evaluated. All participants were invited from a British university. They were given two questionnaires in order to understand their technographic background; to identify their cognitive styles, respectively; and three tasks with one mobile phone. Participants' performance with regard to completion time and the number of icons clicked to achieve the goals were recorded and tested by SPSS (SPSS package 15.0 for Windows). Furthermore, the

routes that the individuals applied to complete the tasks were also transformed as qualitative data for further analysis.

According to Shneiderman and Plaisant (2005), user's basic background, experience with computers, job responsibilities, personality style, reasons for not using an interface, familiarity with features and feelings after using an interface are helpful to understand users' preference of an interface. In addition, to conduct user research for mobile applications, the model of devices, purchasing behaviour, social purposes and personalised behaviour on the mobile phones are common questions for comprehending users (Ballard, 2007). Therefore, the questionnaire of this study includes three aspects (Appendix A). The first part is to understand participants' basic background and their experience of using mobile phones. The second part is to investigate the history of the mobile phones that participants used to own and the main factor that influences their purchase decision. The third part investigates the participants' most frequently used functions and services on the mobile phones.

4.2.1.2 Task design

According to Parks Associates (2005), the most important functions on the mobile phones were voice communication, followed by the address book, text/instant messaging, calendar, e-mail, the camera and photo viewer, the internet browser and the PC synchroniser. This study thus adopts three frequently used functions a) to make a phone call, b) to establish a new contact, c) to send a text message; and one infrequently used function, turning on the Bluetooth, to examine the impact of individual differences on their interaction with the phone.

4.2.1.3 Instruments

The mobile phone brand of Nokia sold 115.2 million mobile phones worldwide and occupied a significant share of the mobile phone market in 1Q 2008 (Gartner, 2008) (Winter 2008, whilst this study was being processed). The Nokia 6120 handset was therefore chosen for examining participants' performance in this study. This phone comes along with numeric keypad, and another 10 keys for further functions. Figure 4-1 shows the terminological title of the keys on the phone. The desktop of Nokia 6120 presents the shortcuts for accessing the functions of messaging, contact list, instant message software of Yahoo, Skype,

MSN, and connecting to the auction web site eBay. Because main menu functions were only represented by graphics on the physical handset, the examination of how users choose keys to reach menu items can be assessed.

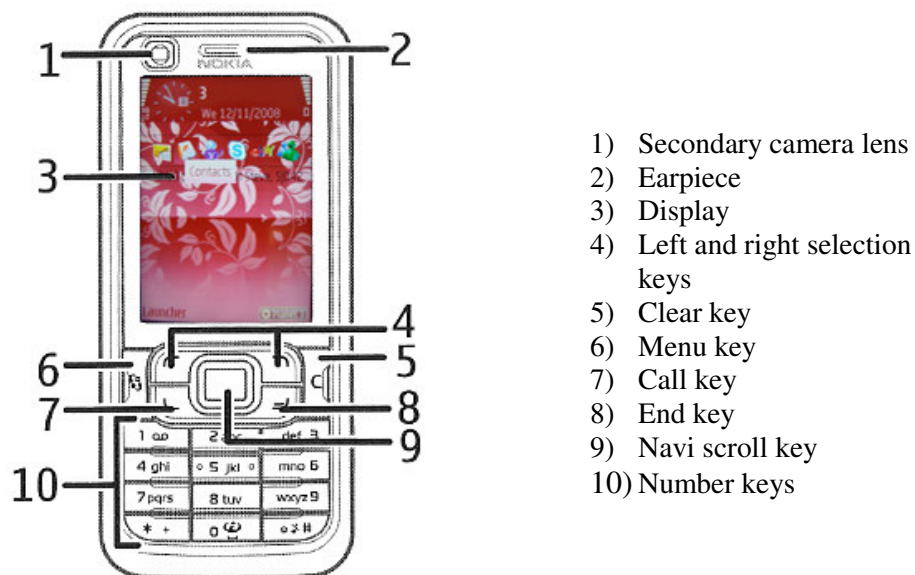


Figure 4-1 Functions of the keypad on Nokia 6120 (manual of Nokia)

4.2.2 Data collection

4.2.2.1 Quantitative approaches

Two questionnaires were applied in this pilot study. The technographic questionnaire (Appendix A) aims to understand the users' background and the usage with their mobile phones. The SPQ was applied to identify the individual's cognitive style (see chapter 2.4.2.3 and Appendix B). It has been applied to many studies in education (e.g. Kwok and Jones, 1985; Eills, Ford and Wood, 1993) and information systems (e.g. Clarke, 1993; Magoulas, Chen and Dimakopoulos, 2004; Ghinea and Chen, 2008). Besides, SPQ was developed by Ford (1985) and also emphasises the linkage between holist-serialist and interaction differences with hierarchical structure. Moreover, participants' completion time of tasks and the number of icons clicked were also recorded for further analysis.

4.2.2.2 Qualitative approach

The routes that the users took to seek the goals were also observed in this investigation. It is necessary to establish the observation schedule before

conducting this approach. Based on the research question in this chapter, the observation schedule was thus established as follows:

- a) if an individual prefers to complete the tasks via shortcuts or the main menu;
- b) how an individual seeks the right category to complete the tasks;
- c) what the participant's reaction when he/she struggling of completing the tasks is.

In the meantime, participants were also required to conduct 'think aloud' whilst interacting with the mobile phone. It is an approach that requires the participants to talk out loud about what they are thinking of when completing the tasks (Love, 2005). It is helpful for the observer to understand the user's thinking deeply.

4.2.2.3 Study procedure

This study was conducted in a laboratory. Participants were firstly required to answer the technographic questionnaire (Appendix A) and the SPQ (Appendix B). The technographic questionnaire consists of twelve questions to investigate the individual's background and the usage with mobile phones. The SPQ includes eighteen items to enable the individual to self-determine, using a Likert 5 scale, in terms of the measurement that was established by Ford (1985) (see chapter 2.4.2.3), the individual was then identified as holist or serialist. And then, the individuals were given the mobile phone Nokia 6120 and were asked to adopt a comfortable position to operate the phone. Three frequently used functions (a) to make a phone call, b) to establish a new contact, c) to send a text message); and one infrequently used function (turning on the Bluetooth) were given to the participant to complete with Nokia 6120. A camera was set to record the movements of individuals' fingers and the paths they took to complete each task. More importantly, the experimenter was not allowed to intervene in the participants' operation. After they completed the tasks, a post-task interview discussed the difficulties of completing the tasks with the Nokia 6120 with the individual.

4.2.2.4 Participants

All eleven participants, recruited from a British university, currently use phone handsets with numeric keypads. Five were male (45.5%), and six female (54.5%).

Meanwhile, according to the SPQ, eight participants (72.7%) were identified as holists; three (27.3%) are serialists. Participants' age ranged from 18 to 30, with a mean value of 25 ($SD = 3.4$). In addition, for the purpose of examining the users' experience with phone interfaces, five participants currently use Nokia mobile phones (Group A), the other six current use other brands of mobile phones (Group B), such as Sony Ericsson and Samsung.

4.2.3 Analyse data-quantitative data

All collected quantitative data was analysed by the software package SPSS (SPSS 15.0 for Windows). All effects will be reported at a .05 level of significance.

4.2.3.1 Participants' technographic background

To analyse the participants' technographic background with mobile phone usage, all of them have more than four year's experiences of using mobile phones. On average, nine participants send less than ten messages per day, the others send more. Regarding the function of calling, most participants used the phone to make less than ten calls every day and to complete each call within 2-5 minutes. The main reason of making calls is to contact friends rather than contacting family. Around half of the participants only have experience of two different brands of mobile phone. More than half of users emphasised the importance of having a friendly interface on the mobile phone. Price and ease of use are the crucial factors that affect the participants' purchasing behaviour. Participants trialled the mobile phone by taking a photo, setting the ring tone, and sending a text message. The frequently used functions in daily life are making calls, sending messages, and setting alarms.

4.2.3.2 Gender differences and performance with tasks

As mentioned in the introduction, the hypotheses in this chapter regarding gender differences and their performance with phone interfaces are as follows:

- a) females complete tasks faster than males;
- b) females click fewer icons to achieve the goals.

Gender and completion time

Concerning the participants' gender and the time they took to complete three frequently used functions, females seemed to perform better at Task A ($M = 34.6$, $SE = 13.18$), Task B ($M = 35.6$, $SE = 4.76$), and Task c ($M = 52.2$, $SE = 13.12$) than

males ($M = 36.3, SE = 8.23$; $M = 51.5, SE = 10.13$; $M = 82.3, SE = 20.94$). However, males ($M = 66.3, SE = 27.01$) spent less time than females ($M = 69.4, SE = 18.08$) when switching on the Bluetooth. Although no significant correlation was found between the participants' gender and their task-completion time using independent-samples of t-test; the descriptive mean shows that females performed quicker than males with familiar tasks, males performed better than females with unfamiliar tasks. The results were partially consistent with the hypotheses in this chapter.

Gender and the number of clicking icons

Participants completed three frequently used tasks using similar paths, respectively; the difference between the individuals was how easily they found the button to access the main menu. Figure 4-2 and Figure 4-3 present the order of clicking buttons to access the main menu based on gender differences. It shows that 60% ($N=5$) male users and 66.67% female ($N=6$) found the button within two presses. Participants preferred to press the largest key in the middle of the Navi scroll key at the initial time. It seemed that they assumed the key can be used for accessing the main menu whilst the instruction was unclear.

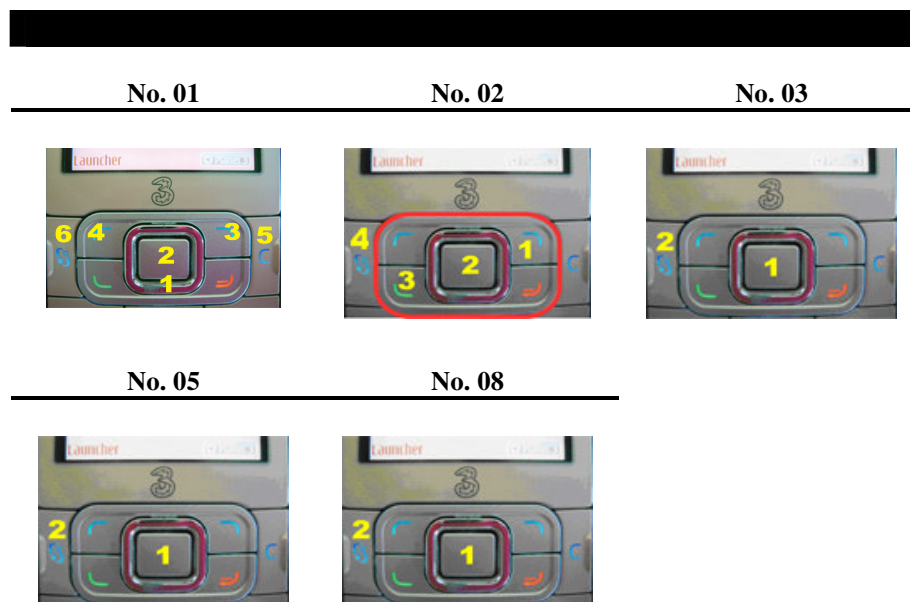


Figure 4-2 Buttons that were clicked for accessing 'Menu key' on Nokia 6120 based on gender differences.

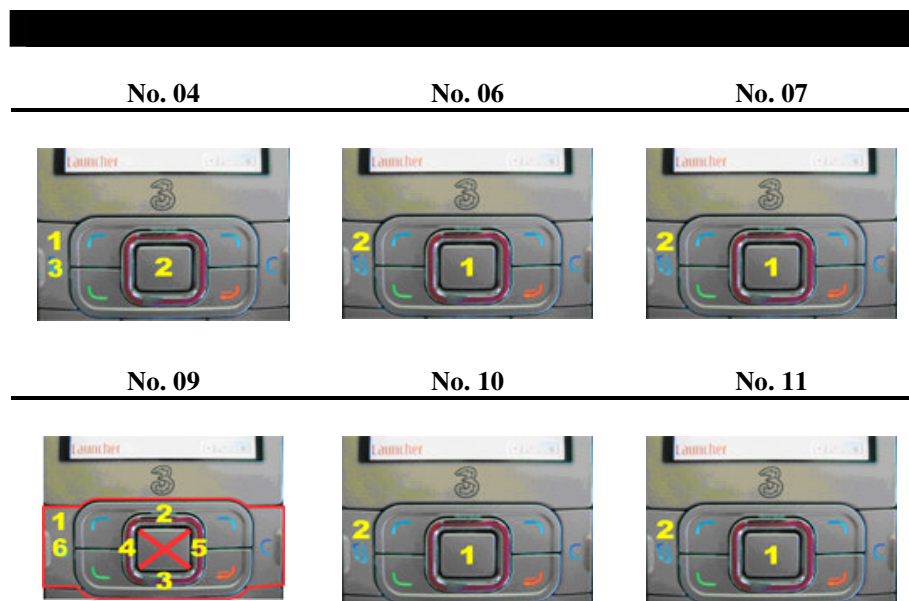


Figure 4-3 Buttons that were clicked for accessing 'Menu key' on Nokia 6120 based on gender differences.

To compare males and females' performance of switching on the Bluetooth, males reviewed ($M = 18.17$, $SE = 8.06$) and accessed ($M = 3.17$, $SE = 1.42$) more icons than females ($M = 10.40$, $SE = 5.77$; $M = 2.40$, $SE = .98$). To compare the users' completion time of the infrequently used function-switching on the Bluetooth, males spent less time than females; however, they reviewed and accessed more icons than females. The phenomena matched the hypotheses in this chapter.

4.2.3.3 Cognitive style differences and performance with tasks

In terms of the attributes of holist-serialist, the hypotheses of the relationship between cognitive style differences and users' performance with tasks were set as

- a) serialistic users complete tasks quicker than holistic users;
- b) serialistic users click fewer icons to complete tasks than holistic users.

Cognitive style and completion time

This investigation also examines the relationship between participants' cognitive style and the completion time of each task. It seems that holistic participants ($M = 31.38$, $SE = 8.09$) only performed better than serialistic participants ($M = 46.67$, $SE = 14.92$) with Task A - making a phone call. Serialistic participants ($M = 27.67$, $SE = 4.41$) spent significantly less time than holistic participants ($M = 50.5$, $SE = 7.28$) when establishing a new contact (Task B), $t = 2.68$, $p < .05$, $d = 1.6$. Besides,

serialistic participants ($M = 32, SE = 7.55$) spent significantly less time to send a text message (Task C) than holistic participants ($M = 82.38, SE = 15.35$), $t = 2.94, p < .05, d = 1.8$. The effect size estimate indicates that the difference of the individuals' cognitive style with the time to complete tasks represents a large, and therefore substantive, effect. Furthermore, serialistic participants ($M = 46, SE = 21$) also performed better than holistic participants ($M = 75.9, SE = 20.64$) when initiating the infrequently used function of switching on the Bluetooth, and no significance was found between conditions.

Cognitive style and the number of clicking icons

Figure 4-4 shows the buttons in the order in which they were clicked before the main menu was accessed, based on cognitive style differences. All serialists accessed the main menu with two clicks; 50% holists clicked more times of the keypad before accessing the main menu. However, the sample size of this investigation was small, thus the outcome can only present the trend that serialists might perform better than holists at looking for the item in an unfamiliar context.

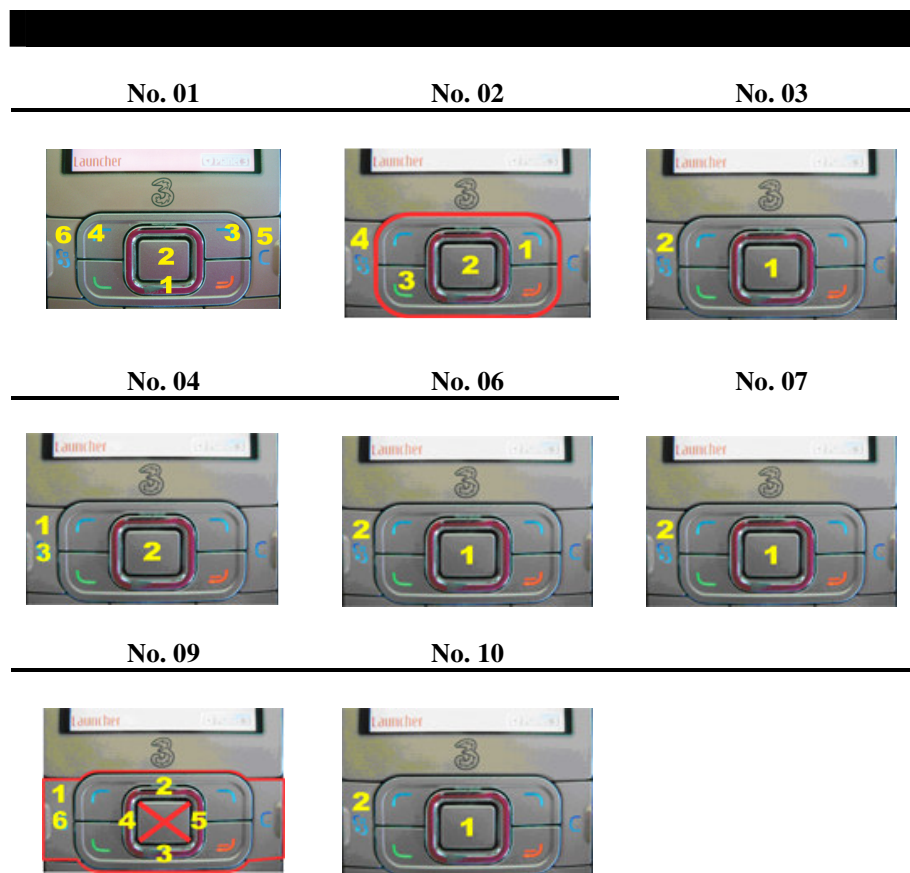


Figure 4-4 Buttons that were clicked for accessing 'Menu key' on Nokia 6120 based on cognitive style differences.

(Figure 4-4 Continued)



On average, holistic participants ($M = 14.13$, $SE = 6.42$) passed through fewer icons before accessing the correct category to switch on the Bluetooth than serialistic participants ($M = 16$, $SE = 8.74$). It is interesting to note that during the search process, holistic participants accessed more categories when looking for the function of switching on the Bluetooth ($M = 2.88$, $SE = 1.08$) than serialistic participants ($M = 2.67$, $SE = 1.67$).

4.2.3.4 User experience differences and performance with tasks

Since interfaces of different mobile phone models manufactured by the same company might be highly similar, the hypotheses of the relationship between UX and the users' performance with tasks are as follows:

- a) users who have experience of using similar phone interfaces complete tasks quicker;
- b) users who have experience of using similar phone interfaces complete tasks by clicking fewer icons.

Previous user experience and completion time

This section compares participants' previous experience of using Nokia mobile phones and their performance when completing four tasks. The descriptive statistics show that Nokia mobile phone users (Group A) performed better with Task B) to establish a new contact ($M = 33.4$, $SE = 5.71$) and Task C) to send a text message ($M = 41.4$, $SE = 7.38$) than the other participants (Group B) ($M = 53.3$, $SE = 9.1$; $M = 91.3$, $SE = 19.31$). However, Group A were not taking advantage of Task A, making a phone call ($M = 38.4$, $SE = 9.88$) and the infrequently used function of switching on Bluetooth ($M = 69.4$, $SE = 32.43$), whilst Group B spent less time to achieve the goals ($M = 33.17$, $SE = 10.78$; $M = 66.33$, $SE = 15.69$).

Previous user experience and the number of clicking icons

Figure 4-5 shows the order in which the individuals clicked the buttons to access the main menu based on whether they had experiences of using Nokia mobile phones or not. Participants of Group A are current Nokia mobile phone users, and all of them found the 'Menu key' in two presses. However, only 33.3% participants ($N=6$) of Group B found the 'Menu key' in 2 presses (Figure 4-6).

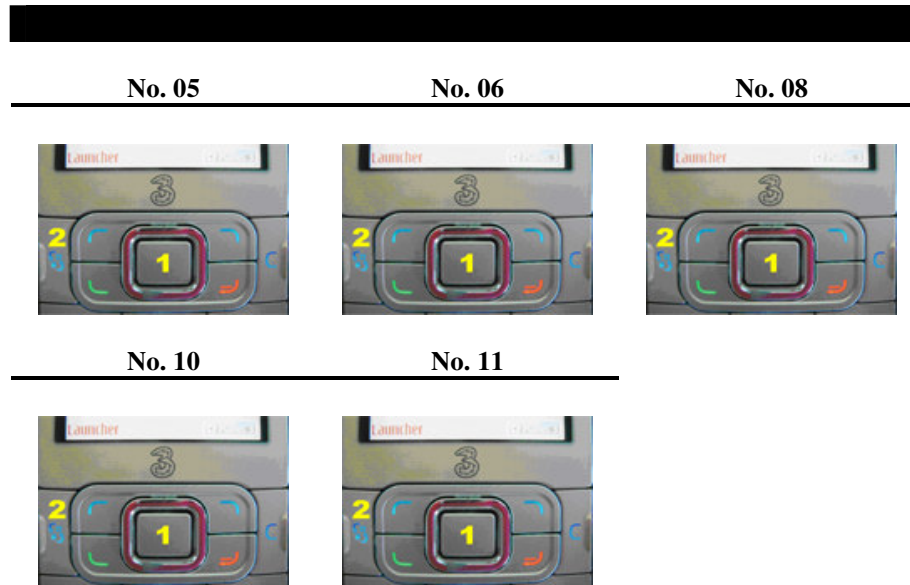


Figure 4-5 The order of clicking buttons before accessing menu on Nokia 6120 by previous experiences with using Nokia mobile phones.

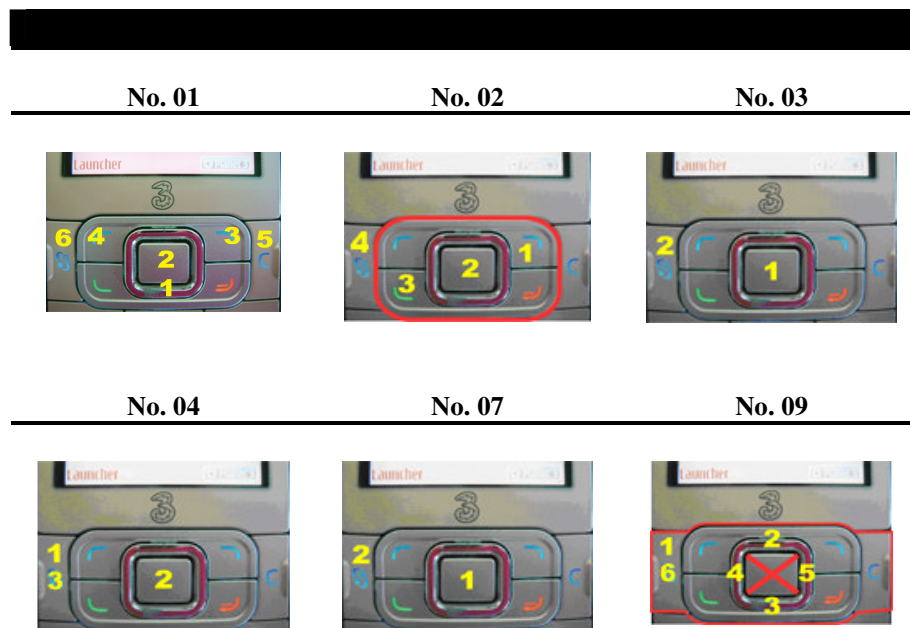


Figure 4-6 The order of clicking buttons before accessing menu on Nokia 6120 by previous experiences with using other mobile phones.

To compare the paths that the participants passed through to complete the function of switching on the Bluetooth, Group A reviewed more icons ($M = 21.20$, $SE = 10.29$) than Group B ($M = 9.17$, $SE = 2.96$). In addition, Group A ($M = 3.80$, $SE = 1.83$) accessed more sub-menus when seeking the function of switching on the Bluetooth than Group B ($M = 2.0$, $SE = .48$).

Most of the quantitative data was not found to be of significance with an independent t-test. However, the routes that the participants reviewed and the icons they passed through seem to imply the impact of individual differences on their interaction with the interface of the instrument in this investigation. Therefore, the next section focuses on analysing participants' operational behaviour with qualitative approach.

4.2.4 Analyse data-qualitative data

The qualitative approach of observation was conducted in this study. In the mean time, participants were required to apply 'think aloud' protocol to deliver their thoughts regarding their trial experience with the Nokia 6120.

As discussed earlier, participants' operational behaviour when using the three most frequently used functions are similar because they preferred to operate those functions via the main menu. Participants only used the shortcut when they could not find the button to access the main menu. Some of the participants were confused by the graphic symbol on the button of accessing 'Menu key' at the outset.

The figure 4-7 highlights the buttons that each participant pressed before accessing the main menu by the order in which they pressed the buttons. The 'Menu key' was located at the left side of the functional keypad. Participants who could not find the 'Menu key' also complained that the instructions were not clear. Participant No. 01 panicked, and complained repeatedly that:

'No.01: I don't know how to get the menu. Where is the button?'

When Participant No. 09 was looking for the key to access the menu, he kept pressing function keys and said:

'No.09: I don't know how to use this phone, it's difficult. Where is the menu?'

Except for participant No. 09, all participants clicked the key in the middle of the function keys the initial time. They assumed the key is the 'Menu key' as it has the largest size and in the middle of function keys. Furthermore, the graphic symbol on the 'Menu key' is not clear; participants were confused as to its meaning. (see the first graphic icon of Figure 4-7).

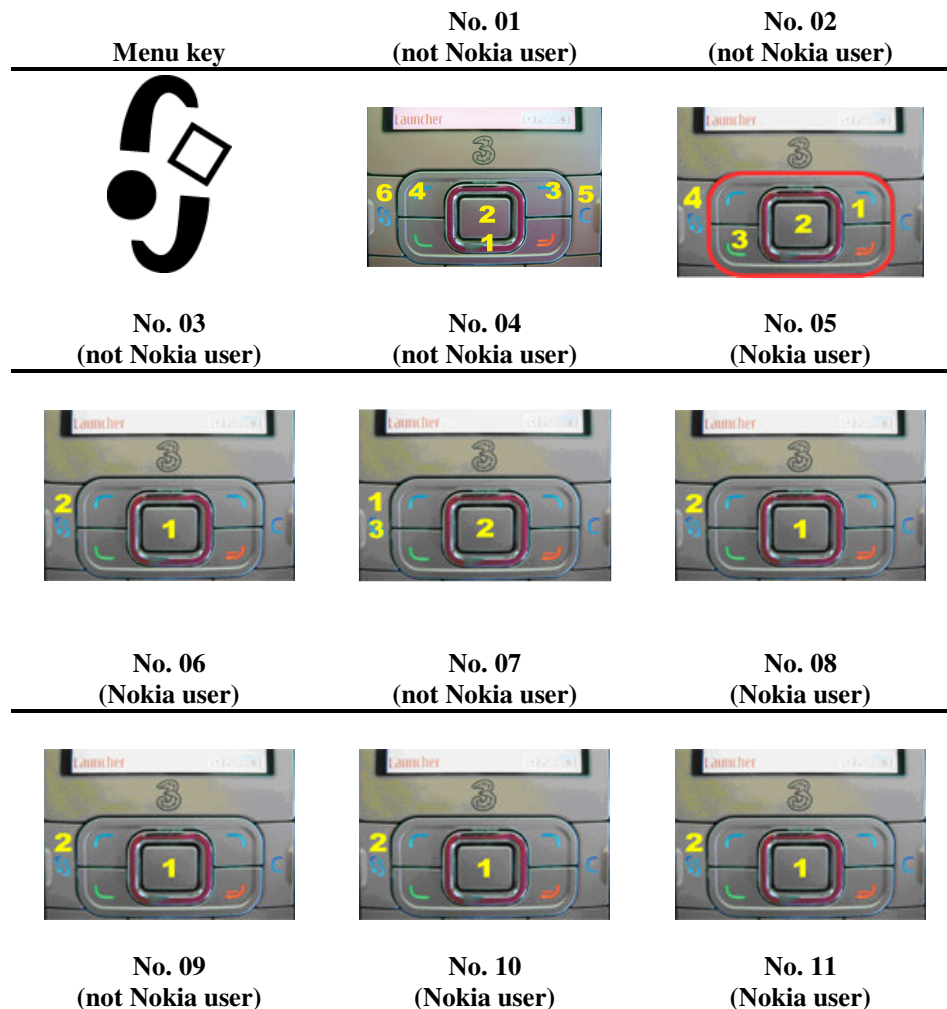




Figure 4-7 The keys that each participant press for looking for the menu key

Observing how participants switch on the Bluetooth; Figure 4-8 presents the routes that each participant took when seeking the function of Bluetooth. The yellow lines represent the 1st route they passed through; white lines represent the second trial, followed by blue and red lines. The red squares highlight the icons that the participant accessed to its sub-level of the menu. Participants used the ‘Navi scroll key’ to seek the target. When the user pressed the ‘Navi scroll key’ to check the last icon on the row or line, one more press led the navigation to the first icon on the row or line.

The routes of the participants No.06 and No.08’s operation of switching on the Bluetooth show a more complicated pattern than other participants. They were panicked and retrieved functions and menus randomly.

‘No. 06: I cannot find the icon of the Bluetooth. I do not know where the icon is. It should be easy. I have not used Bluetooth on my phone before. I just cannot find it.’

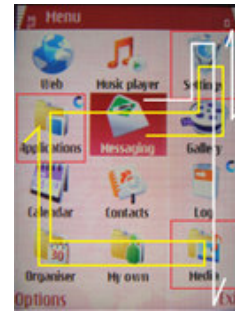
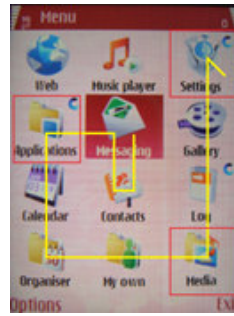
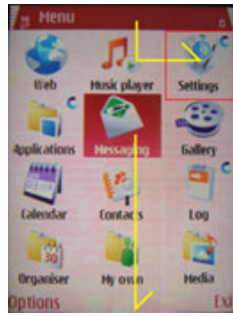
‘No. 08: I used the Bluetooth on my phone once. I do not remember how to find the icon. It is annoying. Why can I not see the icon?’

No. 01

No. 02

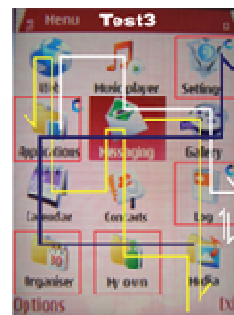
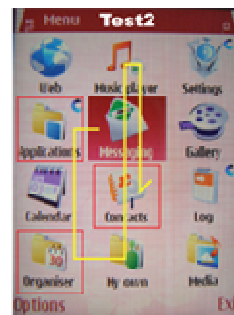
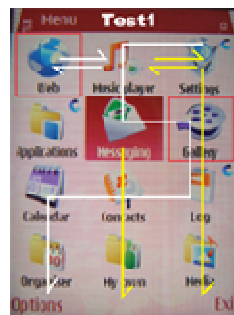
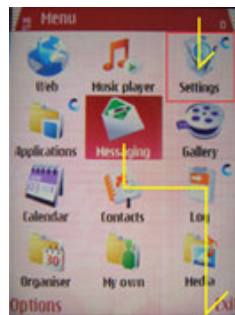
No. 03

No. 04



No. 05

No. 06

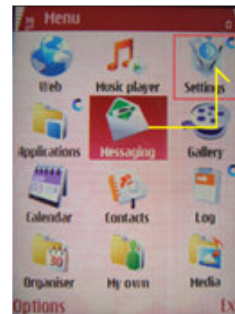
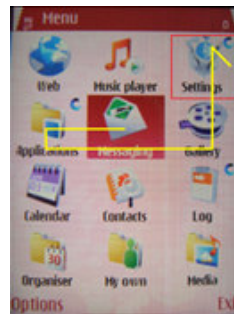


No. 07

No. 08

No. 09

No. 10



No. 11

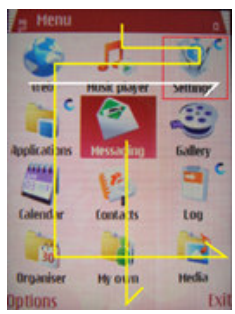


Figure 4-8 The keys that each participant presses for switching on the Bluetooth.

4.2.5 Discussion

This pilot study presents the impact of users' individual differences of gender, cognitive style and previous experience on their performance with Nokia 6120 mobile phone. The significant results were only found between cognitive style difference when participants completed Task b) to establish a new contact and c) to send a text message (Table 4-1, 2 and 3). According to Ford (1985), the attributes of holistic-serialistic style are also associated with individuals' interaction with hierarchical structure, to impact upon the individuals seeking information. This pilot study thus assumes that Task b) and c) are the proper tasks by which to examine the effects of cognitive style on individuals' performance with phone interfaces because they require more steps to complete. Meanwhile, the infrequently used function -turning on Bluetooth -seemed too difficult for the users in this pilot study.

Table 4-1 Significances between gender differences and completion time

Gender differences and completion time				
Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Task A	Male	36.33	8.23	$p = .91$
	Female	34.60	13.18	
Task B	Male	51.50	10.13	$p = .20$
	Female	35.60	4.76	
Task C	Male	82.33	20.94	$p = .28$
	Female	52.20	13.12	
Switch on Bluetooth	Male	66.33	27.01	$p = .93$
	Female	69.40	18.08	

Table 4-2 Significances between cognitive style differences and completion time

Cognitive style differences and completion time				
Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Task A	Holists	31.38	8.09	$p = .36$
	Serialists	46.67	14.92	
Task B	Holists	50.50	7.28	$t = 2.68, df = 8.90,$ $p < .05, r = .67$
	Serialists	27.67	4.41	
Task C	Holists	82.38	15.35	$t = 2.94, df = 8.96,$ $p < .05, r = .70$
	Serialists	32.00	7.55	
Switch on Bluetooth	Holists	75.88	20.64	$p = .44$
	Serialists	46.00	21.00	

Table 4-3 Significances between UX differences and completion time

Cognitive style differences and completion time				
Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Task A	Group A	38.4	9.88	<i>p</i> =.73
	Group B	33.17	10.78	
Task B	Group A	33.4	5.71	<i>p</i> =.11
	Group B	53.33	9.1	
Task C	Group A	41.4	7.38	<i>p</i> =.05
	Group B	91.33	19.31	
Switch on Bluetooth	Group A	69.40	32.43	<i>p</i> =.93
	Group B	66.33	15.69	

Besides, this pilot study also applies a quantitative approach to analyse the routes that the users took to achieve the goals. It provides more information with regard to how individuals interacted with the phone interface. According to the ‘think aloud’ protocol, this pilot study was not only obtaining the users’ operational behaviour with the interface, but also their complaints about the phone. Parts of the participants illustrated the difficulties of turning on Bluetooth with the instrument by saying they expected to see the icon on the first level of the menu and became confused about the category of the function. It is important to notice that, whilst the significant differences between variables were not found by statistical analysis as quantitative data, the qualitative analysis of the users’ operational behaviour might show different phenomena; for instance, individual differences of switching on Bluetooth (Figure 4-8).

4.2.6 Summary and Conclusions

Hypothesis	Results
1) females complete tasks faster than males;	No significant results
2) females click fewer number of icons to achieve the goals;	No obvious phenomenon was observed
3) serialistic users complete tasks quicker than holistic users;	Task B and C; serialists performed better than holists
4) serialistic users click fewer icons to complete tasks than holistic users	According to the observation, holists seemed to click the keypad more times to access main menu
5) users who have the experience of using similar phone interface complete tasks quicker;	No significant results
6) users who have the experience of using similar phone interface complete tasks with fewer number of clicking icons.	According to the observation, UX affected participants to find the button to access the main menu

4.3 Stage two-individual differences between phone interfaces

According to the significant outcomes of the pilot study in stage one of this chapter, individual differences might be the factors which affect the users' operational behaviour with phone interfaces. More specifically, significant differences were found between cognitive style differences and the users' performance. The pilot study intends to explore and to observe how individuals interact with a phone interface. Then in terms of the results and phenomena, to conduct more investigations to understand more details of individuals' operational behaviour with phone interfaces. However, the sample size of the pilot study in stage one was small. Although the process of individuals' interaction with interfaces was illustrated by Card's human information processor (1983) and Norman's seven stages (1998); the interfaces and keypads of mobile phones are not all the same. This research was therefore interested in whether individuals apply the same strategy to complete a task across different interfaces. Except for the hypotheses of this chapter that were mentioned in chapter 4.1 as a)-f) as follows, more research questions arose in terms of the findings of stage one as g) and h):

- a) females complete tasks faster than males;
- b) females click fewer number of icons to achieve the goals than males;
- c) serialistic users complete tasks quicker than holistic users;
- d) serialistic users click fewer icons to complete tasks than holistic users;
- e) users who have experience of using similar phone interface complete tasks quicker;
- f) users who have experience of using similar phone interface complete tasks by clicking fewer icons.
- g) whether the differences of cognitive styles also affect whether the individual completes tasks by following the same route with three different mobile phone interfaces;
- h) if the differences in cognitive styles affect the individual's preference of the mobile phone interfaces.

Moreover, previous studies examined phone users with different interfaces to establish the linkage between cognitive style and the users' preferences of phone

interfaces (e.g. Masuda and Nisbett, 2001; Unsworth, 2005; Kim, Lee and You, 2007). This stage thus also investigates the users' preference of phone interfaces based on their cognitive style-holist and serialist as quantitative data.

For deep understanding of the consistency of individuals' operational behaviour with phone interfaces, the qualitative tool of concept maps was applied to present the routes that the users used to initiate common functions. The approach of concept maps was introduced in chapter 4.3.1.2.

In addition, this research aims to understand phone users deeply. The concept of UX was involved in HCI in recent decades; this stage also attempts to understand individuals' requirements of mobile phones from UX. It includes two aspects: past UX and the UX with the instruments in this investigation.

More importantly, for improving the trustworthiness of this research; keeping the design of this study consistent with the pilot study is essential (Lincoln and Guba, 1985). Individuals' differences of gender, cognitive style and user experience were applied to this stage for understanding individuals' interaction with phone interfaces as well. For further exploration of whether individuals' performance is consistent with different phone interfaces, three phone interfaces were selected for this investigation. The users' performance was analysed by completion time of tasks, the number of icons clicked to achieve the goals and the routes of seeking the goals.

4.3.1 Method

As mentioned in chapter 4.2.1.1, this stage also adopts mixed methods to examine the impact of individual differences on phone users' operational behaviour. Quantitative methodologies includes statistical analysis for determining the significance between individual differences and the users' task completion time performance, and the number of icons clicked to achieve the goal with three mobile phones. In addition, the users' preference of phone interfaces was also examined in accordance with their cognitive style. Qualitative data of the routes that the users applied to achieve the goal was compared with their usage of their own mobile phones.

The participants' UX was investigated after completing all tasks. According to their past UX with mobile phones, they were asked to define 'easy to use' with regard to mobile phones. In addition, their UX with the three instruments was also discussed in the post-interview.

4.3.1.1 Design of the investigation

This investigation was a 2*2*3*2 (Gender*Cognitive styles*Using experience*Trial) mixed factorial design, where gender, cognitive styles, user experience were between-subjects factors and the trial was a within-subjects factor. The dependent variable of the users' performance with two tasks with three mobile phone interface was evaluated. All participants were recruited from a British university. They were required to complete the SPQ to identify their cognitive styles. Participants' performance with regards to completion time and the number of icons clicked to achieve the goals were recorded and tested by SPSS (SPSS package 15.0 for Windows). Furthermore, the routes that the individuals applied to achieve the goals were illustrated with concept maps for further analysis.

Concept maps are a tool to organise and to represent the knowledge by graphic means (Novak and Cañas, 2006). It presents concepts and the relationship between two concepts by a line and words or phrases to delineate their relationships. Novak and Cañas (2006) define that the concept is 'a perceived regularity in events or objects, or records of events or objects, designated by a label' and suggest that the concept maps are 'statements about some object or event in the universe, either naturally occurring or constructed'. The presentation of concept maps is a hierarchical style with the most inclusive ideas. It presents the general concepts at the top and places those more specific and less general concepts below the structure. It is essential to set a focus question with reference to the answer that the researcher expects to seek for constructing the concept maps; therefore, the concept maps presents the answer by organised knowledge. The other important attribute of concept maps is the cross-links that help to show the relationship or links between different segments or domains. To sum up, the important feature of concept maps in creative thinking is to represent the relationships between the questions and the answers by a hierarchical structure map for searching and characterising new cross-links (Novak and Cañas, 2006).

Because of the flexibility of the concept map, it is a suitable tool to represent how an individual operates with the hierarchical structure of mobile phone interfaces. Besides, it is easy to present the ideas of linking different functions. This study thus adopts concept maps as an instrument to illustrate how an individual operates the most often used functions on their own mobile phones and how they achieve a goal by crossing different functions if it is necessary.

4.3.1.2 Task design

The outcomes of stage one indicate that participants might perform differently when the task requires more steps to complete. This study therefore chose one simple and one complicated task to evaluate participants' operational behaviour. The two tasks are frequently used functions: a) making a call to a specific person who was on the contact list; b) sending a message to a specific person who was on the contact list.

4.3.1.3 Instruments

According to the report from ABI Research (Snol, 2009), Nokia occupied the largest share of the mobile handset market in 2008; followed by Samsung, LG, Motorola and Sony Ericsson. However, the telecom companies in the UK such as O2, Vodafone, Orange, T-mobile and 3 sell less LG and Motorola models than Nokia, Samsung and Sony Ericsson. Furthermore, latest models from LG tend to use touch screens instead of a keypad. Thus, mobile phones from Nokia, Samsung and Sony Ericsson were chosen as the instruments for this investigation. Due to the aim of this research being to understand phone users' operational behaviour from the root, basic models of mobile phones were therefore selected in this stage rather than QWERTY and touch screen mobile phones.

To examine participants' interaction with different mobile phone interfaces and different keypads, Nokia 6120, Samsung M150, Sony Ericsson C510 models were selected. Different styles of interfaces were shown on their desktop (Figure 4-9), main menu (Figure 4-10), and sub-menu (Figure 4-11). More specifically, mobile phones from Nokia and Sony Ericsson emphasise visual effects on the sub-menu whereas Samsung tends to display the items by text on the sub-menu.



Nokia 6120 classic

Samsung M150

Sony Ericsson C510

Figure 4-9 The desktop of the three instruments that were used in this stage



Nokia 6120 classic

Samsung M150

Sony Ericsson C510

Figure 4-10 The main menu of the three instruments that were used in this stage



Figure 4-11 The sub-menu of the three instruments that were used in this stage

4.3.2 Data collection

4.3.2.1 Quantitative approaches

The questionnaire of SPQ (Appendix B) was also applied in this study to identify the individual's cognitive style. In the meantime, participants' completion time with tasks and the number of icons clicked to achieve the goals were recorded. Then participants' individual differences of gender, cognitive style and UX were examined by SPSS for the purpose of seeking the effects between conditions. Besides, the users' preferences of phone interfaces were also presented as quantitative data.

4.3.2.2 Qualitative approaches

This study attempts to understand if the users' operational behaviour is consistent across different mobile phone interfaces. The tool of concept maps was applied to illustrate participants' operational interactions with their own phones.

In the meantime, observation was also conducted in this study. As mentioned in chapter 3.5.1.2, it is essential to set the observation schedule for a struttred observation. The observation schedule was therefore set as follows:

- a) the routes that the users applied to complete the tasks;
- b) compare the routes that the users applied to complete the tasks and their operational behaviour with their own mobile phones.

A semi-structured post-interview was conducted with each user with regard to the factors that affect their definition of ‘easy to use’ with a mobile phone and their trial experiences with the three mobile phones that were used in this study. The aim of this interview is to understand users deeply, to determine the criteria that the users care about.

4.3.2.3 Study procedure

Participants were firstly required to answer the SPQ, which includes 18 items of self rating by Likert 5 scale to identify whether the individual demonstrates holistic or serialistic style (see the measurement in chapter 2.4.2.3). This research then discussed the five functions that each participant used most often with their phone in general. The discussion was thus applied for developing a concept map. Before completing tasks with the mobile phones, the individuals were given one of the mobile phones (Nokia, Samsung and Sony Ericsson) and were asked to adopt a comfortable position to operate the phone. Then, participants were given two tasks to complete with three numeric keypad mobile phones: a) making a call to a specific person who was on the contact list; b) sending a message to a specific person who was on the contact list. A camera was set up to record the movements of individuals’ fingers and the paths they took to complete each tasks. More importantly, the experimenter was not allowed to intervene in the participants’ operation process. Finally, the post-interview was conducted to understand how UX affects the users’ judgements of mobile phones. The semi-structured interview consists of two parts: 1) according to the past UX, define ‘easy to use’ with mobile phones; 2) the users’ trial experience with the three instruments in this study. Participants were then given further questions in terms of their response to the two questions.

4.3.2.4 Participants

Twenty-two participants were recruited from a British university, of which nine were male (40.9%), thirteen were female (59.1%); sixteen have holistic style (72.7%), another six have serialistic style (27.3%). Participants’ age ranged from 18 to 30, with a mean value of 24 ($SD = 3.9$) (Table 4-4). All participants were currently use mobile phones with a numeric keypad. Six of them were Nokia mobile phone users, four were Samsung mobile phone users, and the other twelve were current users of Sony Ericsson phones.

4.3.3 Analyse data-quantitative data

All collected quantitative data was analysed by the software package SPSS (SPSS 15.0 for Windows). All effects will be reported at a .05 level of significance. This section includes the examination of individual differences and the participants' performance with tasks; and their preferences of phone interfaces.

4.3.3.1 Gender differences and performance with tasks

The hypotheses that seek to establish a relationship between gender and individuals' performance were set as the core questions of this chapter:

- a) females complete tasks faster than males;
- b) females click fewer number of icons to achieve the goals.

The pilot study of stage one in this chapter shows that females performed better than males with three frequently used functions with the Nokia 6120 mobile phone. In this investigation, although women ($M = 17.9$, $SE = 2.61$) only performed better than men ($M = 22.6$, $SE = 4.37$) of Task A on Sony Ericsson C510; Task B on both Nokia 6120 ($M = 62.7$, $SE = 11.68$; $M = 65.6$, $SE = 12.81$) and Sony Ericsson C510 ($M = 61.5$, $SE = 10.75$; $M = 69.2$, $SE = 13.46$); females ($M = 255.7$, $SE = 23.87$) took less time in total than males ($M = 259.4$, $SE = 21.42$) to complete two tasks on three mobile phones.

To compare the number of icons clicked by gender whilst they completed the tasks, overall, females clicked fewer buttons than males to achieve the goals. Males completed Task A faster than females with Nokia ($M = 9.89$, $SE = 1.95$; $M = 10.62$, $SE = 1.016$), Samsung ($M = 7.56$, $SE = .88$; $M = 9.46$, $SE = 1.66$); and Task B on Samsung ($M = 20.78$, $SE = 2.9$; $M = 23.62$, $SE = 3.28$).

To integrate the results, generally females seemed to click fewer icons to complete the tasks. The outcomes might imply that women tend to spend time thinking before executing tasks.

4.3.3.2 Cognitive style differences and performance with tasks

In terms of the findings of the pilot study, this study not only examines the impact of cognitive style differences on the users' performance. The hypotheses of this chapter can be expressed as:

- a) serialistic users complete tasks quicker than holistic users;

- b) serialistic users click fewer icons to complete tasks than holistic users.

Cognitive style and completion time

To explore the relationship between participants' cognitive style and their performance with two tasks on different mobile phone interfaces, serialists performed better than holists with most of tasks. It was found that serialists ($M = 16.67$, $SE = 2.45$) took less time than holists ($M = 21$, $SE = 3.09$) to complete Task A with Sony Ericsson C510; $t = 2.22$, $p < .05$, $d = 0.47$. The Cohen's effect size was medium. In the meantime, holistic participants ($M = 21.44$, $SE = 2.54$) only spent less time than serialistic participants ($M = 21.67$, $SE = 5.6$) of Task A when making a call with a Samsung M150.

To compare with the results of stage one, both of the outcomes show similar a trend: that serialists completed tasks quicker than holists with mobile phones.

Cognitive style and the number of clicking icons

With regard to the relationship between cognitive style differences and the number of icons clicked to complete the tasks; serialists performed better than holists with all tasks. The significance was also found with Task B of Sony Ericsson C510 as serialists ($M = 17.33$, $SE = 1.93$) clicked fewer icons than holists to achieve the goals ($M = 28.75$, $SE = 3.05$), $t = 3.16$, $p < .05$, $d = 1.35$. The Cohen's effect size indicates that the difference between the number of times the participants pressed the keypad to complete the tasks represents a large, and therefore substantive, effect.

4.3.3.3 User experience differences and performance with tasks

According to the pilot study of stage one in this chapter, users completed tasks faster if they were familiar with the interface. This stage involves more interfaces to evaluate if participants' performance was consistent across different phone interfaces. The hypotheses were followed by the core questions of this chapter:

- a) users who have the experience of using similar phone interface complete tasks quicker;
- b) users who have the experience of using similar phone interface complete tasks with fewer number of icons being clicked.

Previous user experience and completion time

This section examines the impact of the users' previous experience with Nokia, Samsung and Sony Ericsson mobile phones on their performance with three tasks. The Mauchly's test of one-way within-subjects ANOVA indicates that the assumption of sphericity had been violated, $X^2(27) = 295.43$, $p < .001$, thus degrees of freedom were corrected by Huynh-Feldt estimates of sphericity ($\epsilon = .32$). The results show that the individual's completion time of the tasks was significantly affected by the brand of the mobile phone that the individual currently used. Participants completed tasks quicker if the phone being tested was the same brand as the one they currently use, even if the handset and the interface are slightly different, $F(2.49, 52.27) = 142.44$, $p < .001$.

Previous user experience and the number of clicking icons

In addition, the relationship between the participants' previous experience with Nokia, Samsung, Sony Ericsson and the number of icons clicked to complete the tasks was also examined. The outcome shows that the frequency with which an icon was clicked was affected by their familiarity with the mobile phone interface, $F(7, 147) = 205.35$, $p < .001$. Participants clicked the icons fewer times to complete the tasks if they currently use the same brand of mobile phone as the instrument in question.

4.3.3.4 Correlation between completion time and the number of clicking icons

The correlation between the participants' completion time of the tasks and the number of icons they clicked to achieve the goals was also examined at this stage. There were significant positive correlations between the two elements: when the participants spent less time to complete the tasks, they also clicked fewer icons; except Task B on Samsung mobile phone.

4.3.3.5 Users' preferences of interfaces

This section attempts to develop the linkage between the participants' cognitive styles and their preference of the interfaces. According to previous studies that examined the relationship between cognitive style and the users' interaction with interfaces, cognitive style is one of the factors to affect the individuals' selections of items and categories (e.g. Masuda and Nisbett 2001; Lee, 2005). This stage therefore also investigates the individuals' preferences of numeric keypad mobile phones based on

cognitive style differences. The research question is: whether the differences of cognitive styles affect the individuals' preferences of mobile phone interfaces. This investigation collects different formats of the interfaces from the mobile phones of Nokia, Samsung, and Sony Ericsson. To clarify the layout of the interfaces, this study also shows the black and white layouts given to participants for understanding the differences between samples.

Figure 4-12 and 4-13 present the layouts of the main menu and sub-menu of mobile phones and its sketch, respectively. Participants were required to choose the interfaces that they prefer in each group.

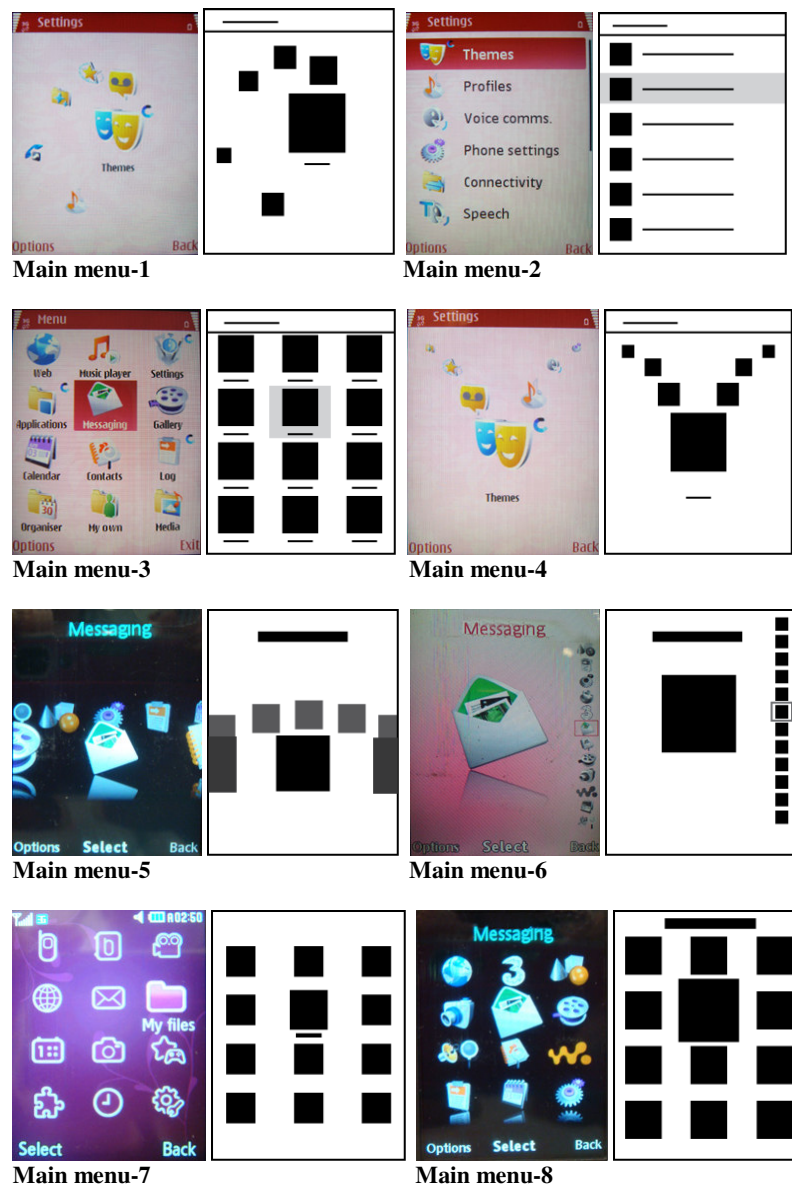


Figure 4-12 Interface styles of the main menu



Figure 4-13 Interface styles of the sub-menu

In general, as can be seen from Figure 4-14 and 4-15, 73% and 23% participants preferred the main menu 3 and sub-menu 3 respectively. To compare the cognitive style differences between users' preferences of the interfaces, it shows that users' preferences of the main menu's style were not affected by cognitive style differences (see Table 4-5). The main menu of No.3 was selected by 68.8% holists ($N=16$) and 85.7% serialists ($N=6$) as their preferred styles. However, the participants' preferences of sub-menu vary by cognitive style differences as holists preferred No.3 (25%, $N=16$), serialists had the tendency of No.1 (33.3%, $N=6$) (see Table 4-6).

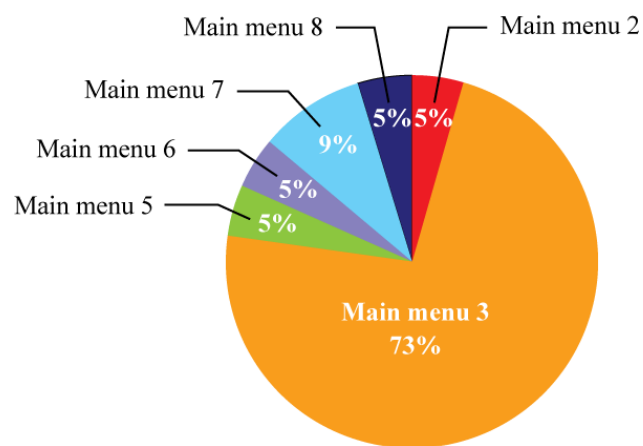


Figure 4-14 Participants' preference of the main menu

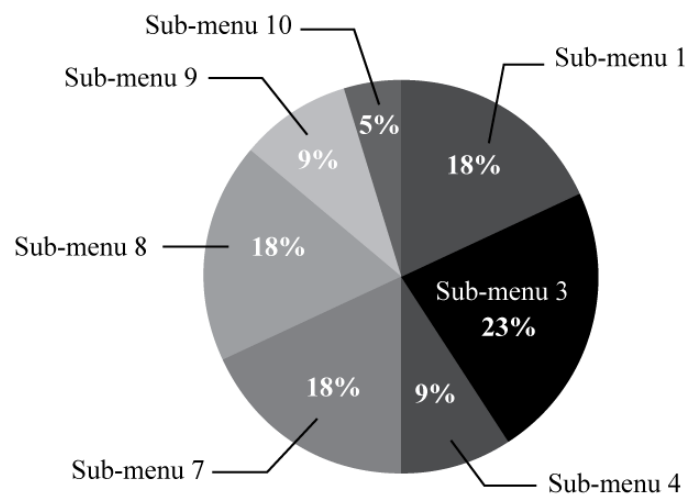


Figure 4-15 Participants' preference of the sub-menu

Table 4-4 Participants' preference of main menu style on the mobile phone by cognitive style difference

	Main menu							
	No. 1	No. 2	No. 3	No.4	No. 5	No. 6	No. 7	No. 8
Holists (N-16)	0	6%	68.8 %	0	0	6%	12.5%	6%
Serialists (N=6)	0	0	85.7%	0	14.3%	0	0	0

Table 4-5 Participants' preference of sub-menu style on the mobile phone by cognitive style differences

	Sub-menu					
	No. 1	No. 2	No. 3	No.4	No. 5	
Holists (N-16)	12.5%	0	25%	12.5%	0	
Serialists (N=6)	33.3%	0	16.7%	0	0	

	Sub-menu					
	No. 6	No. 7	No. 8	No.9	No. 10	No. 11
Holists (N-16)	0	18.8%	18.8%	6.3%	6.3%	0
Serialists (N=6)	0	16.7%	16.7%	16.7%	0	0

4.3.4 Analyse data-qualitative data

This section presents the analysis of the users' usage with their own mobile phones, the comparison of the routes that the users applied to complete tasks with their phone and the instruments; and their UX with mobile phones.

4.3.4.1 Understand users with concept maps

This study investigates the most frequently used mobile phone functions from the participants' daily life. Moreover, to compare the routes they took when making calls and sending a message with their own mobile phones, and their performance in this study. As can be seen from Table 4-6, participants most often used the function of sending message and calling; except one participant who rarely made calls. Surprisingly, fourteen participants (64%) use the alarm function more often than using the camera (45%). In general, asking participants to point out five functions that they used often was excessive since they only normally used two to three functions daily. Participants' usages of their mobile phone were variable; only two pairs of participants often use the same five functions. Next section, three functions that were used often by participants-calling, messaging and using camera were discussed with regard to their performance in this investigation. The tool of concept map was thus applied for presenting the outcomes.

Table 4-6 Five functions that participants use often on their mobile phones

Functions	Usage	Functions	Usage
msg	100%	calculator	9%
calling	95%	radio	9%
alarm	64%	redio/mp3	9%
camera	45%	balance	5%
calendar	36%	Contact list	5%
Internet	27%	Light	5%
games	22%	Transfer files	5%
mp3 player	22%	time and date	5%
clock	14%	video	5%
notes	14%	video call	5%

As mentioned earlier in chapter 4.3.1, in terms of the findings of stage one, this stage also addresses the effects of cognitive style on the routes that the individuals apply to interact with different interfaces. The research question: ‘if the differences of cognitive styles also affect the individual’s ability to complete tasks by following the same route with three mobile phone interfaces’ was discussed with the participants by concept maps. Moreover, comparisons were made with the individuals’ performance in this investigation.

Figure 4-16 presents how the individuals made calls with their own mobile phones. One of the participants rarely made calls. It shows that only six participants follow one route to make calls; most participants applied different routes to make calls depending on if the person was contacted recently. And then the participants prefer to make a call via the functions of ‘recent calls’ or ‘speed dial’. Due to the fact that the participants were not only following one route to make calls with their mobile phones, it is difficult to compare the differences of their cognitive style and operational behaviour of applying routes to achieve a goal.

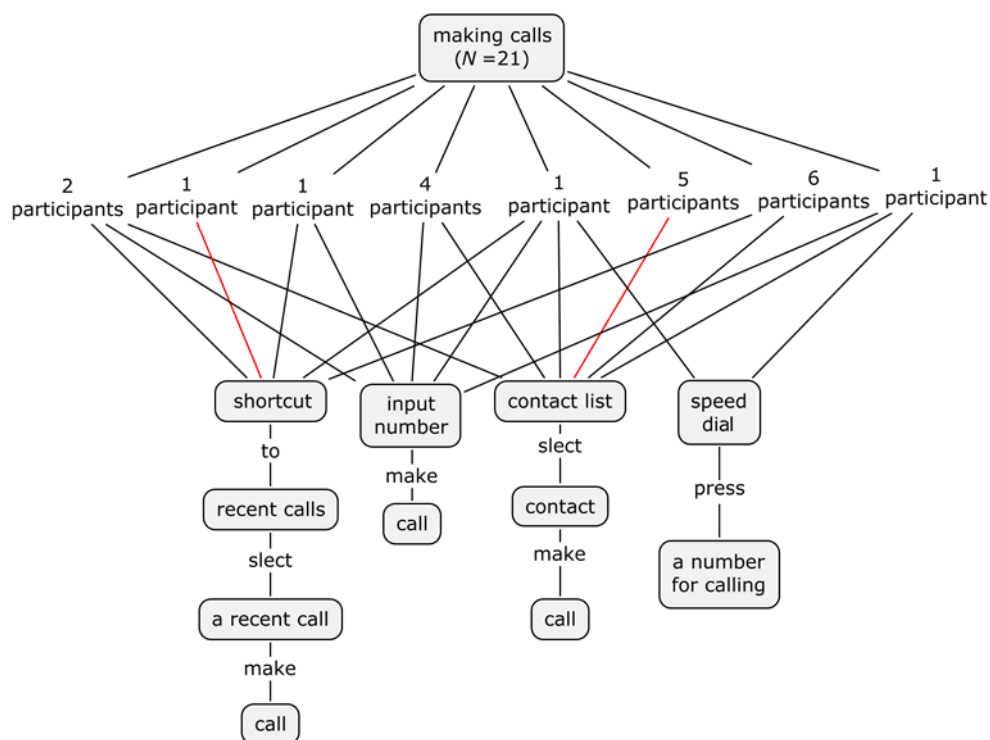


Figure 4-16 Concept map of making calls

As can be seen from Figure 4-17, 91% ($N=22$) participants only follow one route of sending text messages with their own mobile phones. Although most mobile phones provide the shortcuts to edit messages, only 13.6% ($N=22$) participants sent a message via this route. It seemed that users still prefer to execute the functions by accessing the main menu, rather than using shortcuts on the desktop. According to the observation schedule as mentioned earlier, the users' operational behaviour of completing Task B (sending a message) across three interfaces, on average, 33% ($N=9$) of males and 56% ($N=13$) of females applied the same route to achieve the goal. In addition, 75% ($N=16$) holistic participants sent a message by accessing the main menu whilst 66.7% ($N=6$) serialists also applied the shortcut to send the message with Nokia 6120.

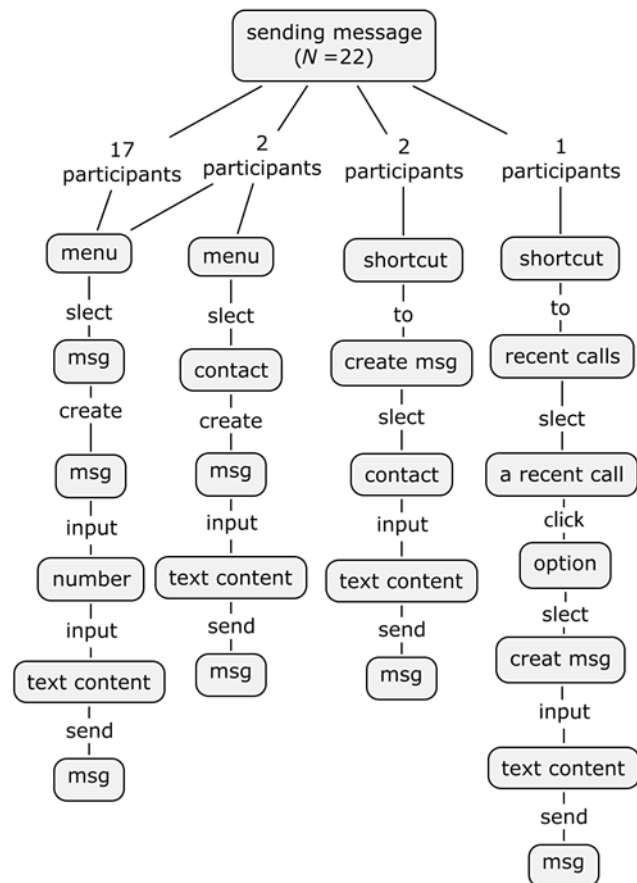


Figure 4-17 Concept map of sending messages

Figure 4-18 shows how the participants use the camera with their mobile phones. All participants used the menu to activate the camera. Participants prefer to transfer the photos to the computer before sending to friends by email, or transferring the photos to the other mobile phones via the Bluetooth. Although most mobile phones are capable of sending photos to recipients with messages, only 20% ($N=10$) participants used this function. The main concern was the service charges for extra expense. In general, the way to operate the camera and share photos is simplex.

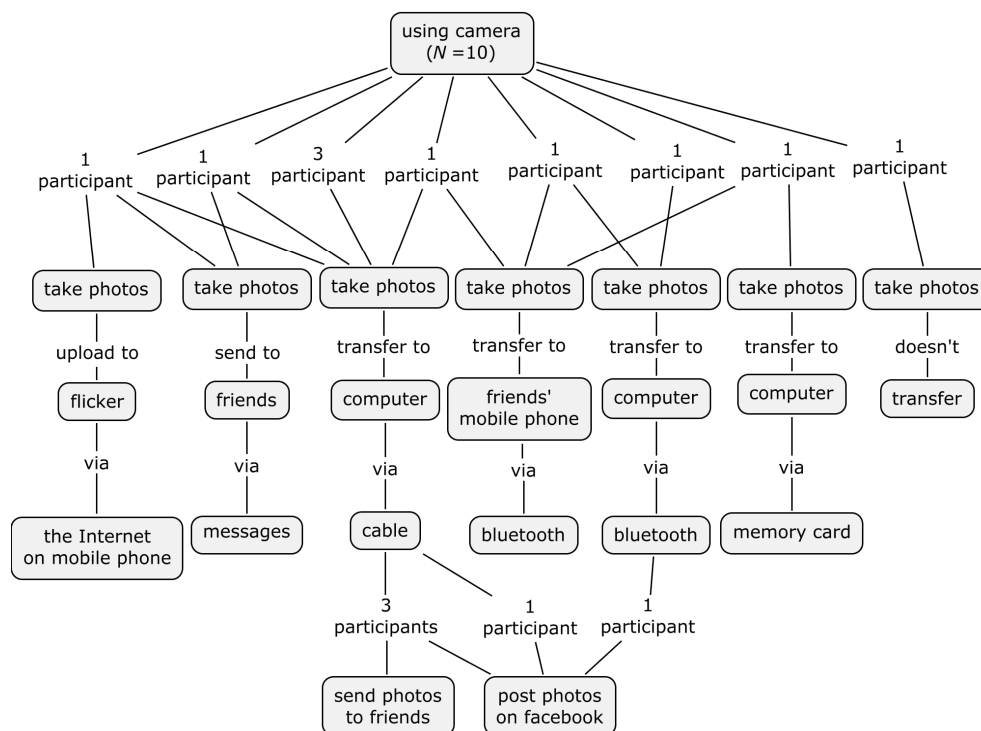


Figure 4-18 Concept map of using camera

To compare the three functions that the participants used most often with their own mobile phones, it seems that the users tend to achieve the goal by different routes if the task only requires a few steps. As can be seen from Figure 4-16, 4-17, 4-18, sending a message requires more steps than making calls and taking photos; thus more participants prefer to follow the same route to send messages.

To sum up the impact of individual differences on participants' operational behaviour with three mobile phones in this study; females and holists were more likely to follow the same route to achieve complicated tasks such as sending text message. Although the sample size of this investigation was small, the qualitative approach of concept map illustrates how gender and cognitive styles differences impact the individual's interaction with the mobile phone interfaces. Therefore, further studies of this research should move towards this direction. Such connection is necessary to clarify whether users perform better with the interfaces that are consistent with their cognitive style.

4.3.4.2 Post-interview

User experience is also an important factor that affects phone users' performance with interfaces as per the findings in chapter 4.3.3.3. A post-interview was thus

arranged to understand 1) how the users define 'easy to use' with mobile phones; 2) the trial experience with the three instruments in this study. This semi-structured post-interview was conducted after they completed tasks with three mobile phones. The interview attempts to understand the factors that affect the users' definition of 'easy to use' and their experience of using these three mobile phones. The collected data was thus categorised according to its similarity and the times the users mentioned the point.

Easy to use

It is important to understand how mobile phone users define 'easy to use' with the handsets for purposes of improving the design. Around half of participants mentioned that both the interface and keypad are important. In general, participants expect the interface to be clear to understand, more specifically, they expect functions to be represented by graphic icons along with text titles. Besides, 68% ($N=22$) participants were concerned with the number of steps to complete a task. The interface was not important for 14% ($N=22$) participants because they believed that they will adapt to unfamiliar interfaces eventually.

41% of participants ($N=22$) prefer to trial a mobile phone by sending a text message whilst they are interested in a mobile phone. Completing and sending a text message includes several actions such as inputting letters, numbers, punctuation marks and adding recipient(s). Participants also mentioned the factors that might affect their choice of a mobile phone:

- a) the number of functions: it is unnecessary to have too many functions with a mobile phone;
- b) the reaction time between pressing the keypad and the response from the phone;
- c) frustration: if a task can not be completed in a short time or the task can not be completed at the initial time;
- d) if the operation method of specific functions is inconsistent with the user's understanding of logic and previous experience;
- e) the size of the screen (the larger the better);
- f) weight;

- g) the quality of camera and mp3 player;
- h) the design of the handset;
- i) the price;
- j) the brand.

Trial experience with the instruments

This section presents the users' trial experience with the three instruments in this investigation. Overview, Users' experiences can be divided into two categories in relation to the hardware and the software.

Nokia 6120

The main problem with the Nokia 6120 is the difficulty of operating the keypad, more specifically, the navigation key. 73% ($N=22$) of participants spent some time on trying to find the key to access the menu. 33% ($N=22$) of participants mentioned that the keypad was too small and that too many buttons were squeezed into the small space. In contrast, with the Sony Ericsson C510, only 18% ($N=22$) of participants mentioned the same issue; and none of the participants complained about the navigation key and the keypad of Samsung M150. Users' complaints also mention that the screen of the Nokia 6120 is too small. In fact, the screen on Samsung M150 is slightly smaller than Nokia 6120.

Regarding the problems of the software with the Nokia 6120, the main concerns were caused by unclear instructions, confused categories, difficulty in cancelling the T9 text input facility, small fonts with the graphic icons and too many steps being needed to complete a task.

Samsung M150

Although the sub-menu of Samsung M150 presents functions with number and text instead of graphic icons, which looked old fashion; 50% participants thought the phone was easy to operate whilst 27% ($N=22$) participants mentioned that Nokia 6120 was easy to use. Participants' positive judgments of the Samsung mobile phone were more numerous than negative opinions due to the instruction for each icon being clear, and it being easy to understand how to operate the functions. Besides, this mobile phone provides some thoughtful functions for

users, such as the interface showing the sub-menu by slipping the page to right or left to represent whether the next operation will be moving toward or backward; it is also easy to set several alarms at once, the camera is quiet when taking photos, and the font size of the functions is easy to read.

Some participants prefer to input text without using T9 (the predictive input method). Samsung M150 requires the user to press the '*' button for a longer time to cancel T9 as opposed to using several quick presses on the '*' key with the Nokia 6120. Thus some of the participants failed at the task of changing the mode. This situation also happened when the users attempted to cancel T9 on the Sony Ericsson C510.

Sony Ericsson C510

What around half of participants mentioned initially with regard to the Sony Ericsson C510 was that it was easy to use. In addition, the font size of functions on the sub-menu is larger than on the Nokia 6120. However, the formats of sub-menus are not consistent with different functions. The graphic icons for the functions of calls, camera, and entertainment confused 32% ($N=22$) of participants due to the titles of the functions being shown on the top of the menu instead of in the form of text under each icon. Moreover, the categories of functions were not appreciated by 45% ($N=22$) users.

To sum up the participants' trial experience with the three mobile phones in this stage, users required clear instructions on the mobile phones, more specifically, the connection of the physical keys and the functions of the phone should be easy to understand. Although Samsung M150 mainly uses text to represent functions instead of graphical items, no participants complained about the problem of instructions.

4.3.5 Discussion

This study attempts to find evidence of correlation between users' individual differences and their performance when operating mobile phone interfaces. Although the descriptive statistical figures show the mean differences of gender, cognitive style with their performance, only partially significant outcomes were found between cognitive style differences and users' completion time and the

number of icons clicked with both tasks with the Sony Ericsson (Table 4-7, 4-8). In the meantime, the users' task completion time and the number of icons clicked were influenced by previous experience with similar interfaces on their current mobile phones.

Table 4-7 Significances between individual differences and completion time

Individual differences and completion time					
Task	Brand	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Task A	Nokia	Male	21.11	4.71	$p = .87$
		Female	22.31	2.83	
	Samsung	Male	21.11	2.29	$p = .46$
		Female	21.77	3.68	
	Sony Ericsson	Male	22.56	4.37	$p = .66$
		Female	17.92	2.61	
Task B	Nokia	Male	65.56	12.81	$p = .82$
		Female	62.69	11.68	
	Samsung	Male	59.89	7.01	$p = .89$
		Female	69.54	9.43	
	Sony Ericsson	Male	69.22	13.46	$p = .35$
		Female	61.46	10.75	
Total time		Male	259.44	21.42	$p = .91$
		Female	255.69	23.87	
Task A	Nokia	Holists	22.44	3.18	$p = .61$
		Serialists	20.17	3.68	
	Samsung	Holists	21.44	2.54	$p = .94$
		Serialists	21.67	5.60	
	Sony Ericsson	Holists	21.00	3.09	$t = 2.22, df = 8.89, p < .05, d = 0.47$
		Serialists	16.67	2.45	
Task B	Nokia	Holists	66.63	10.45	$p = .70$
		Serialists	56.50	14.70	
	Samsung	Holists	65.88	7.86	$p = .97$
		Serialists	64.83	10.09	
	Sony Ericsson	Holists	71.69	10.78	$p = .43$
		Serialists	45.83	4.36	
Total time		Holists	269.06	20.74	$p = .24$
		Serialists	225.67	18.80	

Table 4-8 Significances between individual differences and icon clicks

Individual differences and icon clicks					
Task	Brand	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Task A	Nokia	Male	9.89	1.95	$p = .72$
		Female	10.62	1.02	
	Samsung	Male	7.56	.88	$p = .38$
		Female	9.46	1.66	
	Sony Ericsson	Male	11.33	8.14	$p = .42$
		Female	9.00	5.32	
Task B	Nokia	Male	25.33	3.69	$p = .72$
		Female	23.54	3.14	
	Samsung	Male	20.78	2.90	$p = .55$
		Female	23.62	3.28	
	Sony Ericsson	Male	26.56	4.00	$p = .77$
		Female	25.00	3.35	
Total icon clicks		Male	101.44	7.62	$p = .98$
		Female	101.23	7.24	
Task A	Nokia	Holists	10.44	1.30	$p = .85$
		Serialists	10.00	1.03	
	Samsung	Holists	8.88	1.13	$p = .77$
		Serialists	8.17	2.57	
	Sony Ericsson	Holists	10.69	1.87	$p = .40$
		Serialists	8.00	1.00	
Task B	Nokia	Holists	25.75	2.99	$p = .32$
		Serialists	20.33	2.99	
	Samsung	Holists	28.75	3.05	$p = .62$
		Serialists	17.33	1.93	
	Sony Ericsson	Holists	28.75	3.05	$t = 3.16, df = 19.87,$ $p < .05, d = 1.35$
		Serialists	17.33	1.93	
Total icon clicks		Holists	106.25	6.167	$p = .12$
		Serialists	88.17	7.735	

Moreover, participants also mentioned the criteria that might affect their user experience with a mobile phone. Except for the design elements such as font, size, graphic, layout of the pages, it is also important that the phone is capable of communicating the operation process to the users. The findings indicate the importance of understanding users via trialling a phone, so users' operational experience can be thus expressed clearly. Therefore, a study was conducted for obtaining information about user experience with a mobile phone, as discussed in chapter six.

4.3.6 Summary and Conclusions

Hypothesis	Results
1) females complete tasks faster than males;	No significant results
2) females click fewer number of icons to achieve the goals;	No significant results
3) serialistic users complete tasks quicker than holistic users;	Task A with Sony Ericsson mobile phone; serialists completed tasks quicker than holists
4) serialistic users click fewer icons to complete tasks than holistic users;	Task B with Sony Ericsson mobile phone; serialists clicked fewer icons to complete tasks than holists
5) users who have experience of using similar phone interfaces complete tasks quicker;	Significant result was found, UX impacted the users' completion time with tasks
6) users who have experience of using similar phone interfaces complete tasks with fewer icon clicks;	Significant result was found, UX impacted the users to complete tasks with fewer icon clicks
7) the differences of cognitive styles affect the individual's preference of the mobile phone interface;	No obvious phenomenon was found with descriptive statistic
8) the differences of cognitive style also cause the individual to complete tasks by following the same route with three mobile phone interfaces;	Holists were more likely to follow the same route to operate complicate tasks

4.4 General discussion

This chapter seeks to understand phone users' operational behaviour from three aspects of individual difference: gender, cognitive style and UX. Two stages of studies were conducted. As mentioned in chapter 2, females are generally performing better than males in terms of motor dexterity (Kimura, 1993). Meanwhile, the effects of gender differences were also found within children's interaction with mobile phones (Ziefle and Bay, 2008). Based on the hypotheses a) females complete tasks faster than males; b) females click less number of icons to achieve the goals; females indeed spent less time to achieve the goals and clicked fewer icons than males with most tasks in these two studies.

Ford (1985) indicates that holistic and serialistic styles are linked to individuals' interaction with hierarchical structure. Based on the attributes of holist-serialist, this research establishes the hypotheses as: a) serialistic users complete tasks quicker than holistic users; b) serialistic users click fewer icons to complete tasks

than holistic users. To integrate the outcomes of both studies in this chapter, serialists spent less time and clicked fewer icons to complete tasks than holists. Besides, partially significant results were found between conditions. The phenomenon seemed related to the complexity of the task, such as sending messages and establishing contacts. Those tasks require more steps and information to complete, for instance, add the recipient(s), inputting text, changing input method and so forth.

User experience has become one of the crucial influences upon phone interface design in recent decades. Most previous studies in this area focus on understanding the users' experience from sociological perspectives (e.g. Kaasinen et al., 2009; Khattab and Love, 2008). This research adopts UX as one of the individual differences with which to examine the users' performance with phone interfaces. The hypotheses were set as: a) users who have experience of using similar phone interfaces in the past complete tasks quicker; b) users who have experience of using similar phone interfaces complete tasks by clicking fewer icons. To compare the users' performance in the two studies in this chapter, their performance when completing tasks was associated with frequently used functions and familiar interfaces. The outcomes therefore supported the hypotheses.

According to the literature review, researchers tend to establish the relationship between cognitive style and the individual's preferences of categories, such as alphabetical order-relevance of the content (Chen, Magoulas and Dimakopoulos, 2005) and thematically grouped menu-functionally grouped menu (Kim, Lee and You, 2007). In those studies, participants were only given two designed interfaces; however, practically speaking, the interfaces of those mobile phones with numeric keypads in the market are similar. In addition, it is possible that tasks could be completed via more than two routes. It is therefore difficult to identify users' cognitive styles based on their operational behaviour with such interfaces.

Overall, although the sample size was small in these two studies, the outcomes show the potential of categorising phone users in terms of cognitive style differences. In the mean time, it is necessary to examine individuals with phone

interfaces that match the attributes of the cognitive style-holist and serialist for further exploration.

4.5 Summary and Conclusions

This chapter consist of two stages to give an overview of the relationship between individuals' cognitive styles and their performance with numeric keypad mobile phones. The significant results of stage one present the phenomenon that individuals' interaction with phone interfaces might be affected by individual differences. More importantly, the effect of cognitive style on the users' performance was found to yield significant results whilst completing Task B and C. It provides the research direction for further exploration of the effects of individual differences on users' interaction with phone interfaces. Meanwhile, this research is concerned with how the variation of phone interfaces and keypad with different models might also impact upon the individuals' interaction with the handsets. Stage two was therefore designed to examine the impact of individual difference of gender, cognitive styles and user experience on their performance with different mobile handsets. In general, females and serialists spent less time than holists on completing most tasks with different phones. However, the independent samples t-test demonstrated only partially significant outcomes with the tasks that require more steps to complete. It might occur through the similarity of the interfaces of numeric keypad mobile phones. In addition, the operation processes of completing the tasks with different phones were similar. If the user had the obstacles of interacting with a numeric keypad phone interface, the individual might also have the same obstacles with the other numeric keypad phones. For some participants, the tasks were easy to complete due to the text instructions of icons and buttons being clear and the goals can be achieved within a few steps. The investigations in this chapter present the difficulty of identifying mobile phone users' cognitive style by their operational behaviour with numeric keypad mobile phones. It is thus essential to examine users with the interfaces which are consistent with the attributes of holistic-serialistic styles.

More importantly, the outcomes of this chapter imply that holists preferred to apply the same route to complete a task across different interfaces, whilst serialists seemed more flexible in using different icons and categories to complete

a task. It provides a direction for further research as the users' problem solving ability should be concerned as it might impact upon the users' operational behaviour whilst interacting with mobile phone interfaces.

CHAPTER 5 INDIVIDUAL DIFFERENCES AND USERS' OPERATIONAL BEHAVIOUR WITH TOUCH SCREEN MOBILE PHONES

Overview

The aim of this research is to reach a deeper understanding of mobile phone users, and more importantly, to establish the connection between individual differences and the users' operational behaviour with phone interfaces. According to the findings of chapter 4, only partial quantitative analysis shows a significant correlation between conditions. Meanwhile, connections were found between cognitive style and the users' performance. In addition to this, the relationship between individual difference-cognitive and the users' preferences of phone interfaces was also highlighted by previous studies (e.g., Nisbett, Peng, Choi and Norenzayan, 2001; Kim and Lee, 2007). This chapter therefore attempts to examine the impact of individual differences on the users' operational behaviour with phone interfaces consistent with the attributes of cognitive styles and to discover if individuals perform better with the suitable interfaces. Due to the similarities between the interfaces of numeric keypad phones, this investigation attempts to examine individuals' performance using touch screen mobile phones.

5.1 Introduction

According to the findings discussed in chapter 4, cognitive style differences might impact the users' operational behaviour with tasks that require more steps and information. In order to increase the veracity of this research, it is important to maintain the consistency of each study (Lincoln and Guba, 1985). This investigation follows the studies in chapter 4 and applies the individual differences of gender, cognitive style and UX in order to examine individuals' interaction with touch screen phone interfaces. However, only some significant differences were found in chapter 4 with regard to the relationship between cognitive style and UX differences and the users' performance. Therefore, this chapter focuses on the effects of cognitive styles and UX. The individuals' performance in terms of task-completion time and the number of clicking icons used to achieve the goals were obtained as quantitative data. To compare the

users' performance with predicted execution time of tasks, the Keystroke Level Model (KLM) (Card, Moran and Newell, 1983) was applied in this investigation. In addition, the routes used to seek the goals were recorded as qualitative data. More specifically, to improve the efficacy of data analysis in this investigation, the routes that participants followed to complete the tasks were analysed according to Hierarchical Task Analysis (HTA).

This study addresses the importance of interpreting qualitative data in terms of the results of quantitative analysis. The process of individuals' interaction with touch screen phone interfaces was thus filmed for further observation.

5.2 Focus question

Based on the findings of chapter 4, partial hypotheses were found between cognitive style and the users' performance. In addition, the users who have holistic style were more likely to follow the same route to complete a task across different phone interfaces. This investigation therefore emphasises the relationship between cognitive style differences and the users' operational behaviour with touch screen mobile phone interfaces:

- how cognitive style affects the users' operational behaviour in achieving the goal with different interfaces on touch screen mobile phones;
- how cognitive style affects the users' operational behaviour of seeking a target with unknown categories.

Moreover, participants mentioned in Chapter 4 that they prefer a phone interface that allows them to complete tasks with as few icon clicks as possible; as a result, this investigation also evaluates the relationship between the individuals' performance in tasks and their satisfaction with the phone interfaces:

- how the users' performance with completing tasks affects their satisfaction with a phone interfaces.

For the purpose of improving the consistency of investigations in this research, individuals' interaction with touch screen mobile phone interfaces was also examined in terms of gender difference, UX. Figure 5.1 and 5.2 were therefore drawn to clarify the relationships between conditions in this study.

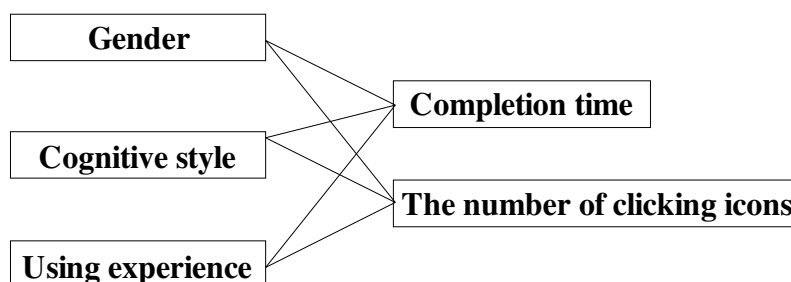


Figure 5-1 Hypotheses of individual differences and users' performance

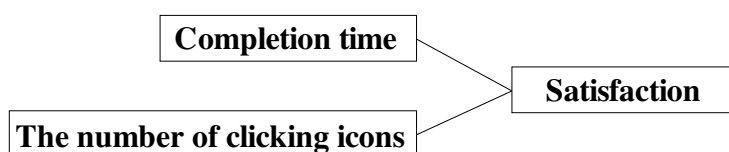


Figure 5-2 Hypotheses of users' performance and satisfaction with the interface

The hypotheses based on Figure 5.1 and 5.2 were thus set as follows:

- a) Users' gender will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- b) Users' gender will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces;
- c) Users' cognitive style will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- d) Users' cognitive style will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces;
- e) Users' level of experience will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- f) Users' level of experience will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces.
- g) A significant correlation will be found between users' satisfaction with the mobile phone interface and completion time of tasks;
- h) A significant correlation will be found between users' satisfaction with the mobile phone interface and the number of icons clicked during task completion.

5.3 Method

Mixed methods were also adopted in this investigation. Both quantitative and qualitative approaches were applied to examine the effects of individual differences on the users' operational behaviour with touch screen mobile phone interfaces. The users' completion time in set tasks and the number of icons clicked to achieve the goals was obtained as quantitative data. The routes the participants used to complete the tasks and their interaction process with the phone interfaces were recorded for qualitative analysis. This study was divided into two stages. Stage one addresses the effects of cognitive style on the users' performance with mobile phone interfaces by quantitative approaches. The results were used in developing an observation schedule in stage two for obtaining practical information about the users' operational behaviour whilst interacting with phone interfaces. This section discusses the selection of research approaches, instruments and the study procedure.

5.3.1 Design of the investigation

The study was a 2*2*6*3 (Gender*Cognitive styles*Using experience*Trial) mixed factorial design, where gender, cognitive styles and using experience were between-subjects factors and the trial was a within-subjects factor. Two types of dependent variable were evaluated (1) performance with three tasks across six emulators, and (2) satisfaction with the interfaces of six emulators. Participants were recruited from a British university. All participants were required to complete a questionnaire, three tasks with six emulators and the Questionnaire for User Interface Satisfaction (QUIS) after completing tasks on each emulator. Participants' task completion time and the number of icons clicked in goal achievement were recorded and tested by SPSS (SPSS package 15.0 for Windows). Furthermore, the routes that the individuals followed in task completion were also utilised as qualitative data for further analysis.

5.3.2 Task design

Crowd Science (2009) mentions that the most commonly used functions of smartphone are surfing the internet, followed by camera, E-mail, mp3 player, WiFi, GPS, Bluetooth, USB connectivity, picture messaging, games, and video recording (Figure 5.3). Compared with the numeric keypad mobile phones users

of chapter 4, participants were more likely to use the following functions: sending message, calling, setting alarm, camera, calendar, surfing the internet, games, mp3 player, clock, notes and calculator (Figure 5-4).

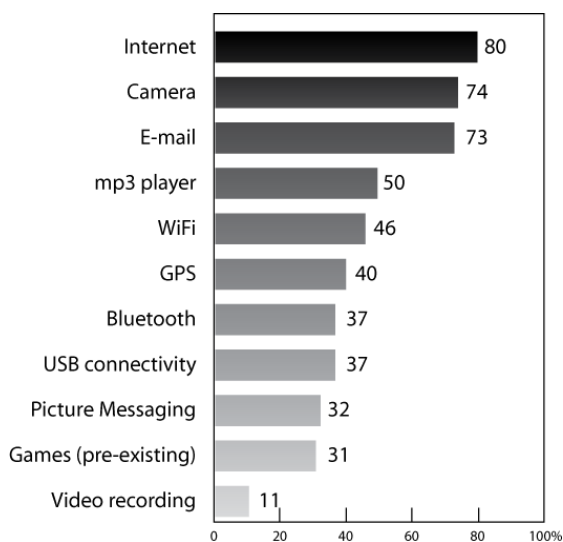


Figure 5-3 Most common uses functions of smartphone. (Source: Crowd Science, 2009)

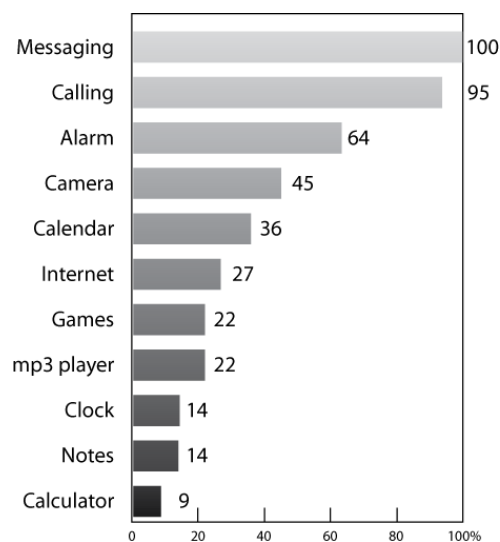


Figure 5-4 The result of previous study that most common uses functions on traditional mobile phone by students.

According to Kim, Lee and You (2007), sending an SMS or saving a contact might be a too basic task to utilise in the examination of the differences between cognitive style in task handling and the flow of interaction. Based on the number of steps to complete a task such as sending an SMS, this study set the task of sending message as being of medium difficulty level (Task 1). An easier task was checking specific date on the calendar (Task 2) as it required fewer steps to complete; whilst seeking a specific photo (Task 3) was the most difficult task in this study as it required more steps to complete.

Keystroke-Level Model (KLM)

For the purpose of understanding the time difference in completing the tasks between experts and novices; the Keystroke-Level Model (KLM) was applied in this investigation. KLM is a tool for predicting users' completion time of tasks with interfaces. According to Card, Moran and Newell (1983), keystroke level of human interaction with interfaces is part of GOMS (Goals, Operators, Methods, and Selection rules) models. Keystroke-Level Model (KLM) enables a system

designer to predict the completion time that a user requires to achieve the goal with a computer system. KLM was established in terms of the restrictions as shown below.

Table 5-1 Problems of time prediction of tasks (adopted from Card, Moran and Newell, 1983, p.260)

Given	<ul style="list-style-type: none"> • A task (possibly involving several subtasks); • The command language of a system; • The motor skill parameters of the user; • The response time parameters of the system; • The method used for the task.
Predict	<ul style="list-style-type: none"> • The time an expert user will take to execute the task using the system, providing he uses the method without error.

The process of completing a task can be described as four physical-motor operators: K - keystroking, P - pointing, H - homing and D - drawing; M - one mental operator, and R - a system response operator. In terms of the operators, the completion time of each operator was developed as the user is an expert and the task was completed without mistakes (Table 5-2). Based on the concept of KLM, Kieras (1993) adds an operator for each press or release mouse button as the action takes .1 sec.

Table 5-2 The operators of KLM

Operator	Action	Time (sec)
K	Press key or button	
	• Best typist (135 wpm)	.08
	• Good typist (90 wpm)	.12
	• Average skilled typist (56 wpm)	.2
	• Average non-secretary typist (40 wpm)	.28
	• Typing random letters	.50
	• Typing complex codes	.75
	• Worst typist (unfamiliar with keyboard)	1.20
P	Point with mouse to target on a display	1.10
H	Home hand(s) on keyboard or other device	.40
D (n_D , l_D)	Draw n_D straight-line segments of total length l_D cm.	$.9 n_D + .16 l_D$
M	Mentally prepare	1.35
R	Response by system	t

To apply KLM, it is essential to follow the heuristic rules below for inserting the mental operators (M) (Card, Moran and Newell, 1983, p.265).

- Rule 0: Insert M's in front of all K's that are not part of argument strings proper (e.g. text or numbers).
- Rule 1: If an operator following an M is fully anticipated in an operator just previous to M, then delete the M.
- Rule 2: If a string of MKs belongs to a cognitive unit (e.g. the name of a command) then delete all M's but the first.
- Rule 3: If a K is a redundant terminator (e.g. the terminator of a command immediately following the terminator of its argument) then delete the M in the front of it.
- Rule 4: If a K terminates a constant string (e.g. a command name) then delete the M in the front of it; but if the K terminates a variable string (e.g. an argument string) then keep the M in front of it.

In general, KLM is a tool that can be used to easily and quickly predict completion time of tasks. KLM has been applied for HCI projects and alternative fields (Stanton and Young, 1999; Kieras and John, 1994). Additionally, it was also applied in predicting task execution time on advanced mobile phone (Holleis, Heinrich Hubmann and Schmidt, 2007) and handheld devices (Luo, 2005). More importantly, Holleis, Heinrich Hubmann and Schmidt (2007) establish several operators that only suggest for predicting execution time on numeric keypad mobile phones (Table 5-3).

Table 5-3 KLM operators for numeric keypad mobile phone

Operator	Action		Time (sec)
A	Action-alignment of phone to a target, focus on the phone to take a picture		1.23
F	Finger movement		.23
G	Gestures		.80
I	Initial act	externally	5.32
		internally	3.89
		optimal setting	1.18
		no assumptions	4.61
S _{Macro}	Macro attention shift		0.36
	keypad ↔ display		0.14
	hotkey ↔ display		0.12
	keypad ↔ hotkey		0.04
	in general		0.14
X	Distraction	slight	6%
		strong	21%

This study therefore adopts both original KLM and the KLM that was revised by Heinrich Hubmann and Schmidt (2007). The original KLM was applied due to participants being required to complete task on emulators on a computer. In addition, the operator F and X that were developed for predicting phone users' executing time with numeric keypad mobile phones were also used to predict participants' completion time of tasks in this study.

Hierarchical Task Analysis (HTA)

Due to the layout and categories within the six interfaces varying in this study, the routes of each task with six touch screen mobile phone interfaces were present with Hierarchical Task Analysis (HTA). Moreover, the routes that the individuals applied to complete the tasks were analysed with the HTA plans. HTA is one of the task analysis methods and has been widely applied to human factor research. The validation of this method was confirmed by numerous studies in a variety of domains. It presents the description of the activity based on a hierarchy of goals,

sub-goals and plans (Annett, 2004). HTA consists of six steps (Stanton et al., 2005):

- Step 1: define task under analysis
- Step 2: data collection process
- Step 3: determine the overall goal of the task
- Step 4: determine task sub-goals
- Step 5: sub-goal decomposition
- Step 6: plans analysis

Each task in this study was therefore presented by HTA. The hierarchical structure of each task clarifies the steps and routes of completing the tasks. The routes that the users applied to achieve the goals were analysed in chapter 5.6.1.

5.3.3 Instruments

This study attempts to examine the differences in users' operational behaviour when operating the interfaces that are consistent/inconsistent with their cognitive styles. Previous chapters adopted numeric keypad mobile phones as instruments; however, the interfaces present similar layout, different categories and appearances. Since the touch screen mobile phones are currently popular, and in addition, the interfaces of touch screen mobile phones tend to be diverse in style in comparison to numeric keypad phone interfaces, six phone interfaces were selected for this investigation.

According to InfoWorld (2009), six smartphone platforms have been launched in the mobile phone market: Apple's iPhone, Google's Android, RIM's BlackBerry, Nokia's Symbian, Palm, and Windows Mobile. Furthermore, the platform of LG Arena 'has surpassed one millionth marks across the globe in mere five months since February 2009' (techshout.com). The global smart phone market share by OS in 2009 shows that Symbian occupied 46.9%; followed by RIM, Apple, Microsoft, Android and others (Gartner Inc., 2010; see Figure 5-5).

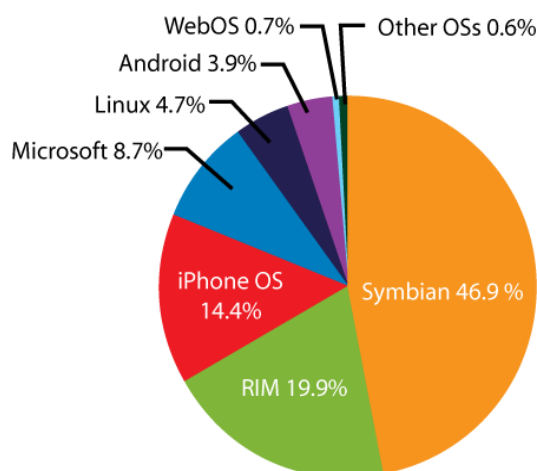


Figure 5-5 Global sales of smartphone to end users by operating system in 2009 (Thousands of Units) (Source: canalys.com, 2010)

Meanwhile, telecom companies in the UK such as O2, Vodafone, Orange, T-mobile and 3 sell more models of touch screen mobile phones (e.g. iPhone, Samsung OMNIA II, LG KM900) rather than touch screen-physical QWERTY mobile phones (e.g. HTC-G1, Nokia-N97) and QWERTY mobile phones (e.g. Blackberry 7 and 8 series, Nokia E71). As a result, this study thus examines users' operational behaviour with the interfaces of touch screen mobile phones. Regarding the application of the platforms that were mentioned in Figure 5-5, Symbian is mainly applied to Nokia phones; RIM is the platform of Blackberry mobile phones; iPhone OS is used on iPhone; Microsoft is applied on Samsung's touch screen mobile phones; Android is applied on the phone of HTC; the touch screen phone of LG applies its own platform. The six interfaces of Nokia, Blackberry, iPhone, Samsung, HTC and LG were therefore selected as instruments in this investigation.

According to reviewing literatures in chapter 2, holistic style represents the individuals who tend to apply global approach to learning, using simultaneous processor and span various levels at once when study; whilst serialists prefer to adopt local approach, apply linear processor and works step by step (Ford, 1985; Jonassen and Grabowski, 1993). Based on the criteria; six interfaces were divided into two groups based on the characteristics of holistic and serialistic styles. The interfaces of Group A display the most often used functions or all available functions on the desktop, delivering a global concept to users about the phones' functionality and providing broad relations on the same page and allowing users

to span various functions at once. In contrast, the interfaces of Group B show fewer icons on the desktop. The three interfaces shown here require users to access the menu for all functions and the operation process tends towards a more linear style which narrows the users' focus. In addition, the menu of the interfaces in the Group B phones list functions alphabetically or group icons by functions to narrow the relationships between icons (Figure 5-6).



Figure 5-6 Emulators of six smartphones

All six of the interfaces can be found on the internet with flash format (such as HTC's G1, LG's KM900 and Samsung's OMNIA II) and software development kit (SDK) (Blackberry, iPhone and Nokia). Thus all of the interfaces were running on a desktop environment as prototypes. This allowed participants to complete the tasks by simply clicking a mouse and avoided the variables introduced by actually operating the handsets such as the size of fonts and graphic icons. According Love's (2005, p.93) suggestion, to avoid the drawbacks of prototypes during the study, it is essential to make the prototypes look 'as real as possible'. In addition, Janes and Marsden (2005) also indicate the high-fidelity prototypes are required to evaluate the design of interfaces. This study adopts the six interfaces

and the emulators from the six phone manufactories. Therefore, this investigation should be able to observe the users' interaction processes with the phone interfaces in a close approximation of their operational behaviour with real handsets.

5.4 Data collection

The study was executed in the laboratory and both quantitative and qualitative approaches were applied. The individual's cognitive style of holist-serialist was examined by SPQ and the completion time of each task, the number of icons clicked and the routes by which the individual achieved the targets were recorded. The QUIS was administered after the completion of three tasks with each emulator. Each participant's interaction behaviour with the interfaces was filmed; the camera only focused on their hands and the computer screen and recorded their verbal commentary without showing their face. The routes that the participants applied to achieve the target were transformed to spreadsheet to compare with individuals' cognitive style differences. Details of the approaches were presented as follows.

5.4.1 Quantitative approaches

To maintain the consistency of the data collection process and data analysis between studies in this research, the users' interaction with touch screen mobile phone interfaces were examined with individual differences of gender, cognitive style and UX as the investigation in chapter 4. Individuals' cognitive style was identified by SPQ (see chapter 2.4.2.3 and Appendix B). Participants' completion time of tasks and the number of icons clicked were also recorded for further analysis with individual differences. As mentioned earlier in chapter 5.2, the participants in chapter 4 indicated that they would appreciate a mobile phone that allowed them to complete a task in the fewest possible steps. In this study, users' satisfaction with phone interface was thus evaluated with the Questionnaire for User Interaction Satisfaction (QUIS).

Questionnaires that aim to evaluate satisfaction with interfaces are rare. Lee et al., (2005) point out several questionnaires that have been proven to be valid and reliable, such as Questionnaire for User Interface Satisfaction (QUIS) (HCIL, 1988), Perceived Usefulness and Ease of USE (PUEU) (Davis, 1989), Computer

System Usability Questionnaire (CSUQ) (Lewis, 1995) and Software Usability Measurement Inventory (SUMI) (Kirakowski, 1994). However, with the exception of the QUIS, the questionnaires focus on evaluating the system rather than the system interface. The Mobile Phone Usability Questionnaire (MPUQ) (Ryu & Smith-Jackson, 2006) is a novice instrument in the evaluation of the usability of a mobile phone model. Nevertheless, it includes seventy-two questions that were collected from QUIS, SUMI, PUTQ, PSSUQ and other researchers. Therefore, this study adopts QUIS as the instrument to evaluate users' satisfaction with the six emulators, respectively.

The QUIS was established by a multi-disciplinary team of researchers in the Human-Computer Interaction Lab (HCIL) of the University of Maryland. The aim of QUIS is to measure users' satisfaction with the human-computer interface. The questionnaire includes a demographic questionnaire, a measure of overall system satisfaction, and nine hierarchically organised interface factors - screen factors, terminology and system feedback, learning factors, system capabilities, technical manuals, on-line tutorials, multimedia, teleconferencing, and software installation. 'Each area measures users' overall satisfaction with that facet of the interface, as well as the factors that make up that facet, on a 9-point scale' (QUIS website). Some questions of QUIS seem only suitable for the interface on a device or software that executes on computer rather than evaluating the interface of a mobile phone. However, HCIL points out that sections or items of QUIS can be dropped in order to customise the questionnaire to suit individual requirements. With regard to the overall reliability and validity, HCIL had published the established process and related research to prove QUIS is 'maintained with the 6 overall scales of user reactions and about 20 additional ratings on other aspects'.

The original version of QUIS includes twenty-seven questions; this study drops five questions that are irrelevant to phone interfaces, such as computer commands, help messages, supplemental reference materials, the noise that the system makes and correcting mistakes. Participants were therefore required to response 22 statements, with a 9-point response scale ranging from the tense of the description. Scores were recorded so that a high score denoted a factor which was highly satisfactory, and a low score indicated a more negative response.

5.4.2 Qualitative approaches

The qualitative approach of observation was applied to obtain the details of the participants' interaction with mobile phone interfaces based on the individual differences of cognitive styles. As mentioned in chapter 3.5.1.2, it is necessary to establish the schedule before conducting observation. According to the results of stage one, the observation schedule was thus set as follows:

- a) how cognitive style differences affect the manner in which an individual browses icons;
- b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface;
- c) how cognitive style differences affect the way an individual seeks the target photo within unknown folders of Task 3;
- d) how cognitive style differences affect whether or not the individual follows the same route to complete the task across different interfaces.

5.4.3 Study procedure

Participants were first required to answer the SPQ. The individual's cognitive style was then identified as holist or serialist in terms of Ford's (1985) measurement (see chapter 2.4.2.3). Before completing tasks for this study, individuals were asked whether it was necessary to adjust the height of the chair and monitor in order to attain a comfortable position to operate the computer. They were then presented with six interfaces of touch screen mobile phones on the computer one by one in order to examine their performance on three tasks. To minimise the order effects to this investigation, the six interfaces were shown to the participants at random. Their completion time in the tasks and the number of icons clicked in achieving the task goals were recorded. Then the participants were required to answer the QUIS after the completion of three tasks with each emulator. Additionally, their interaction behaviour with the mobile phone interfaces was filmed for further analysis during stage two (the camera only focused on their hands and the mobile phone and recorded their verbal commentary without showing their face). More importantly, the experimenter was not allowed to intervene in the participants' operation process.

5.4.4 Participants

All forty current touch screen mobile phone users were recruited from a British university. Twenty-two of them are male (55%); eighteen are female (45%). According to the SPQ, half of the participants have a holistic style, another half have a serialistic style. Ages ranged from 18 to 35 with a mean value of 25 ($SD=4$). Also, the participants were divided into 6 brand groups according to the mobile phone that they currently have, with 6-7 participants in each brand group of Blackberry, iPhone, LG, HTC, Nokia and Samsung.

5.5 Stage one-analysis of quantitative data

All collected data was analysed by the software package SPSS (SPSS 15.0 for Windows). The independent variables were the participants' gender, cognitive styles and the brand of their current mobile phones. The dependent variables evaluate the individuals' performance in terms of task completion time and the number of icons clicked in completion of the tasks. All effects were reported at a .05 level of significance.

In terms of participants' performance, on average, females and holistic users took more time to complete the tasks than males (Figure 5-7 and 5-8); females and serialistic users clicked fewer icons than males to achieve the goals (Figure 5-9 and 5-10). The KLM was also applied as quantitative data to compare the ideal completion time in tasks with the participants' performance.

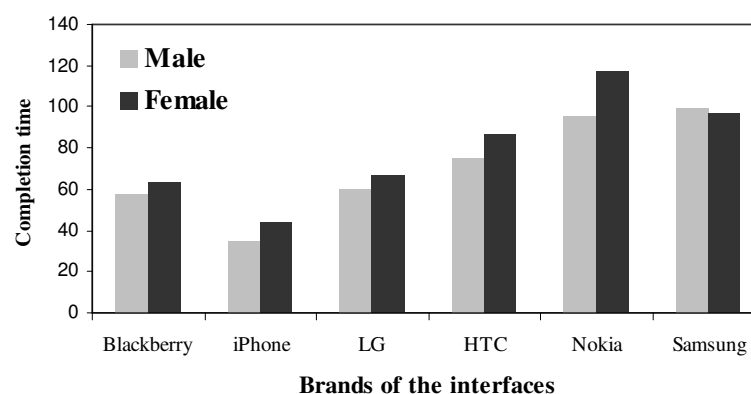


Figure 5-7 Comparison of male-female's completion time

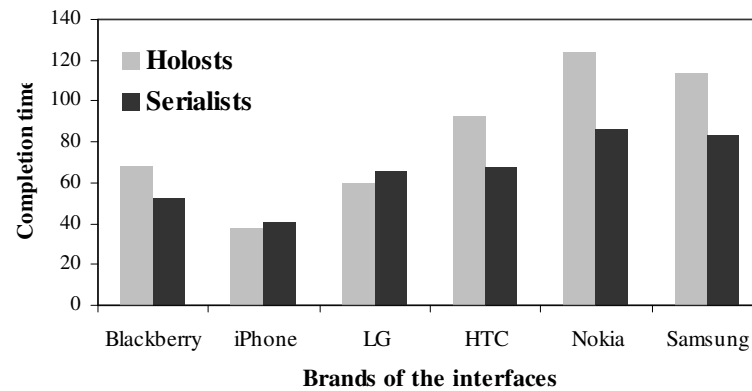


Figure 5-8 Comparison of holists-serialists' completion time

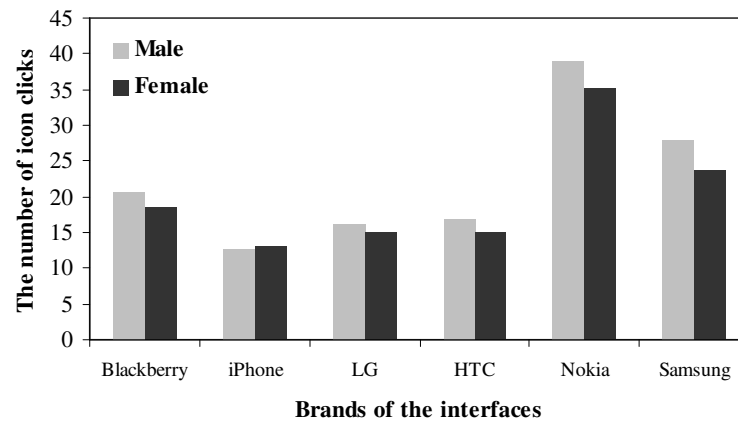


Figure 5-9 Comparison of the number male-female pressed icons to complete tasks

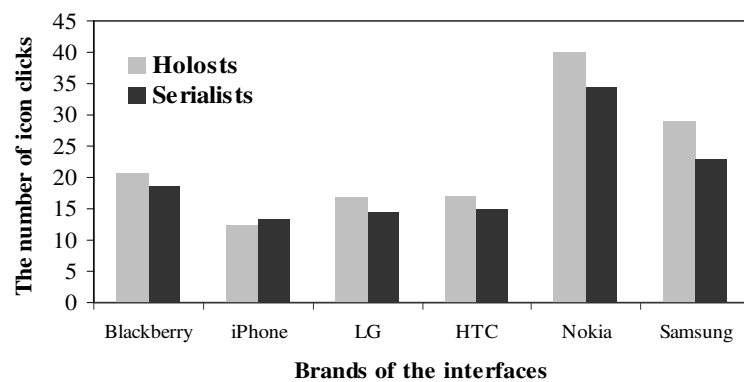


Figure 5-10 Comparison of the number holists-serialists pressed icons to complete tasks

In order to further understand the differences between ideal error-free completion time of task and the participants' performance, KLM was applied in this stage. As

mentioned in chapter 5.3.3, the original KLM and the KLM for predicting executing time with tasks on numeric keypad mobile phones were both applied in this investigation. The comparison of users' completion time of tasks and KLM show that participants took significantly more time to complete majority of tasks than the time of KLM (Figure 5-11 and 5-12). According to the observations recorded in this study, it might occur as a result of the users' time spent seeking icons and adapting the other elements of the interface, such as moving the page by slipping the screen and browsing the information with the scroll bar.

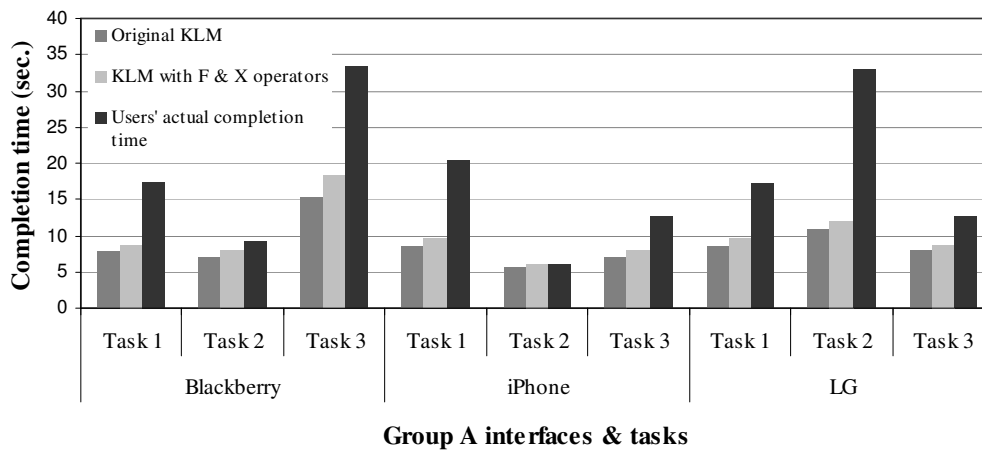


Figure 5-11 Comparing participants' actual completion time and KLM with Group A interfaces.

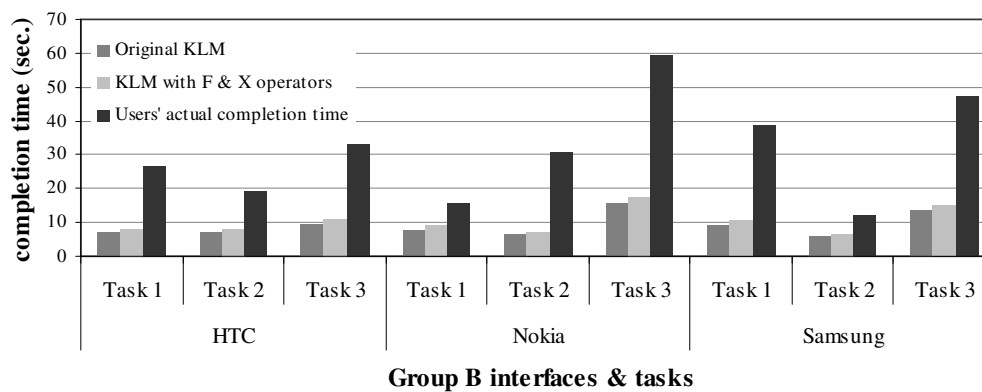


Figure 5-12 Comparing participants' actual completion time and KLM with Group B interfaces

This section therefore discusses the relationship between individual differences and their operational behaviour in terms of completion time and the number of icons clicked whilst completing three tasks with six mobile phone interfaces.

More importantly, they indicate how individual differences impact on the users' interaction with mobile phone interfaces.

5.5.1 Gender differences and performance with tasks

As mentioned in chapter 2.4.1, females have better motor dexterity while typing than males (Kimura, 1993; Halpern, 2000). However, females only performed better than males with partial tasks in chapter 4. This study thus also examines the users' performance based on gender differences to establish the consistency of users' operational behaviour. In terms of the research questions in this chapter, two hypotheses were set as follows:

- a) Users' gender will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- b) Users' gender will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces.

Gender and completion time

Chapter 4 mentioned that females performed better than males in some tasks using numeric keypad mobile phones. However, in this study, women completed most tasks slower than men except Task 1, 2 with Blackberry; Task 2 with LG and HTC, Task 2 and 3 with Samsung. Overall, females ($M=97.34$, $SE=10$) performed faster of completing three tasks than males ($M=99.16$, $SE=15.56$) (Table 5-4 and 5-5). The significant difference was only found whilst operating Task 2 with the interface of HTC as females ($M=14.91$, $SE=1.57$) spent less time than males ($M=22.94$, $SE=3.29$). The mean difference between conditions was 8.03 and the 95% confidence interval for the estimated population mean difference is between .58 and 15.47. The effect size was moderate ($d=.65$). An independent t -test showed that the difference between conditions was significant ($t = 2.20$, $df = 29.75$, $p < .05$, two-tailed).

Table 5-4 Descriptive statistic of gender and completion time-Group A

Gender differences and completion time-Group A							
Group A	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>	
	Blackberry	Task 1	Male	17.86	2.16	<i>p</i> =.70	
			Female	16.69	1.92		
		Task 2	Male	9.31	1.21	<i>p</i> =.92	
			Female	9.13	1.11		
		Task 3	Male	29.87	1.57	<i>p</i> =.11	
			Female	37.78	4.41		
	Total time			Male	54.80	3.42	<i>p</i> =.13
				Female	64.38	5.39	
	iPhone	Task 1	Male	17.69	1.99	<i>p</i> =.14	
			Female	23.82	3.52		
		Task 2	Male	5.86	.77	<i>p</i> =.41	
			Female	6.68	.53		
		Task 3	Male	11.93	1.64	<i>p</i> =.44	
			Female	13.68	1.44		
	Total time			Male	35.49	2.88	<i>p</i> =.13
				Female	44.17	4.48	
	LG	Task 1	Male	15.69	1.72	<i>p</i> =.36	
			Female	19.17	3.33		
		Task 2	Male	33.06	3.43	<i>p</i> =.94	
			Female	32.69	3.72		
		Task 3	Male	11.05	1.25	<i>p</i> =.10	
			Female	14.66	1.82		
	Total time			Male	61.03	4.15	<i>p</i> =.45
			Female	67.93	7.94		

Table 5-5 Descriptive statistic of gender and completion time-Group B

Gender differences and completion time-Group B							
Group B	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>	
	HTC	Task 1	Male	23.55	4.55	$p = .27$	
			Female	30.98	4.86		
		Task 2	Male	22.94	3.29	$t = 2.20, df = 29.75, p < .05, d = .65$	
			Female	14.91	1.57		
		Task 3	Male	26.90	4.59	$p = .25$	
			Female	40.71	10.81		
	Total time			Male	73.38	8.67	$p = .37$
				Female	86.60	12.15	
	Nokia	Task 1	Male	14.13	2.10	$p = .28$	
			Female	17.23	1.80		
		Task 2	Male	27.28	7.45	$p = .54$	
			Female	34.45	8.89		
		Task 3	Male	53.99	4.18	$p = .11$	
			Female	65.62	5.93		
	Total time			Male	93.71	10.02	$p = .13$
				Female	117.29	11.76	
	Samsung	Task 1	Male	33.88	6.47	$p = .25$	
			Female	44.64	6.49		
		Task 2	Male	13.26	4.32	$p = .66$	
Female			11.01	1.92			
Task 3		Male	52.02	9.33	$p = .41$		
		Female	41.69	7.31			
Total time			Male	99.16	15.56	$p = .93$	
			Female	97.34	10.92		

Gender and the number of clicking icons

In chapter 4, female participants clicked fewer icons to complete the tasks than males. In this study, females performed better than males with the tasks using Blackberry, iPhone and HTC interfaces whilst males clicked fewer icons to complete the tasks with the interfaces of LG, Nokia and Samsung (see Table 5-6 and 5-7). However, the significance was only found with Task 1 with the interface of HTC as females ($M=3.67$, $SE=.28$) pressed fewer icons to send a message than males ($M=4.73$, $SE=.42$), $t=2.09$, $df=35.14$, $p<.05$, two-tailed, $d=.63$. The effect size estimate indicates that the difference between genders and the number of icons clicked to complete the task represents a moderate effect.

Table 5-6 Descriptive statistic of gender and the number of clicking icons -Group A

Gender differences and the number of clicking icons-Group A						
Group A	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
	Blackberry	Task 1	Male	6.32	0.42	$p = .89$
			Female	6.22	0.60	
		Task 2	Male	3.27	0.19	$p = .16$
			Female	3.00	0.00	
		Task 3	Male	10.73	0.80	$p = .35$
			Female	9.78	0.54	
	Total number of clicking icons	Male	20.32	1.05	$p = .35$	
		Female	19.00	0.88		
	iPhone	Task 1	Male	6.55	0.72	$p = .77$
			Female	5.06	0.38	
		Task 2	Male	2.18	0.18	$p = .95$
			Female	2.17	0.17	
		Task 3	Male	4.55	0.42	$p = .50$
			Female	5.06	0.66	
	Total number of clicking icons	Male	13.27	0.88	$p = .41$	
		Female	12.28	0.75		
	LG	Task 1	Male	4.36	0.50	$p = .83$
			Female	4.50	0.32	
		Task 2	Male	6.41	0.78	$p = .24$
Female			8.50	1.53		
Task 3		Male	4.18	0.45	$p = .30$	
		Female	3.61	0.24		
Total number of clicking icons	Male	14.95	1.05	$p = .39$		
	Female	16.61	1.68			

Table 5-7 Descriptive statistic of gender and the number of clicking icons-Group B

Gender differences and the number of clicking icons-Group B						
Group B	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
	HTC	Task 1	Male	4.73	0.42	$t=2.09, df=35.14, p<.05, d=.63$
			Female	3.67	0.28	
		Task 2	Male	4.32	0.55	$p =.52$
			Female	4.83	0.55	
		Task 3	Male	7.91	1.08	$p =.22$
			Female	6.17	0.78	
	Total number of clicking icons		Male	16.95	1.15	$p =.18$
			Female	14.67	1.23	
	Nokia	Task 1	Male	5.23	0.41	$p =.93$
			Female	5.28	0.30	
		Task 2	Male	7.68	1.56	$p =.73$
			Female	6.83	1.92	
		Task 3	Male	22.55	1.46	$p =.08$
			Female	27.28	2.32	
	Total number of clicking icons		Male	35.45	2.37	$p =.33$
			Female	39.39	3.36	
	Samsung	Task 1	Male	7.59	1.24	$p =.18$
			Female	11.28	2.35	
		Task 2	Male	2.64	0.21	$p =.52$
Female			3.00	0.57		
Task 3		Male	13.86	2.14	$p =.98$	
		Female	13.94	1.99		
Total number of clicking icons		Male	24.09	2.61	$p =.32$	
		Female	28.22	3.18		

5.5.2 Cognitive style differences and performance with tasks

The results of chapter 4 show a partial correlation between cognitive style difference and the users' performance with tasks. This investigation therefore attempts to seek the same trend when the users interact with touch screen mobile phone interfaces. The hypotheses in this section are:

- c) Users' cognitive style will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- d) Users' cognitive style will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces.

Cognitive style and completion time

The comparison of cognitive style differences and completion time shows that holists only performed better than serialists of Task 1 and 2 with iPhone and LG's interfaces in Group A (Table 5-8 and 5-9). The completion time of serialists' interaction with Task 3 was significantly shorter than holists with the interface of Blackberry ($M=28.69$, $SE=2.71$; $M=38.18$, $SE=3.26$; $t=2.24$, $df=38$, $p<.05$, two-tailed, $d=.51$), Nokia ($M=51.53$, $SE=5.36$; $M=66.92$, $SE=4.25$; $t=2.25$, $df=38$, $p=.03$, two-tailed, $d=.72$) and Samsung ($M=33.55$, $SE=3.81$; $M=61.20$, $SE=10.81$; $t=2.41$, $df=23.66$, $p<.05$, two-tailed, $d=1.77$). The effect size estimate indicates that the differences between cognitive style and seeking the target photo with the mobile phone interfaces of Blackberry and Nokia represent a moderate effect, and show the large effect on the Samsung emulator.

Table 5-8 Descriptive statistic of cognitive style and completion time-Group A

Cognitive style differences and completion time-Group A							
Group A- Holistic interfaces	Brand	Task	Variable	M	SE	Significance	
	Blackberry	Task 1	Holists	19.58	2.25	$p=.12$	
			Serialists	15.08	1.74		
		Task 2	Holists	10.24	1.38	$p=.23$	
			Serialists	8.23	0.88		
		Task 3	Holists	38.18	3.26	$t=2.24$, $df=38$, $p<.05$, $d=.51$	
			Serialists	28.69	2.71		
	Total time			Holists	63.44	4.46	$p=.17$
				Serialists	54.80	4.25	
	iPhone	Task 1	Holists	18.86	2.67	$p=.42$	
			Serialists	22.04	2.89		
		Task 2	Holists	5.86	0.38	$p=.45$	
			Serialists	6.61	0.89		
		Task 3	Holists	13.44	1.82	$p=.52$	
			Serialists	12.00	1.28		
	Total time			Holists	38.15	3.53	$p=.64$
				Serialists	40.65	3.94	
	LG	Task 1	Holists	13.89	1.35	$p=.06$	
			Serialists	20.63	3.13		
		Task 2	Holists	32.33	3.28	$p=.82$	
Serialists			33.47	3.83			
Task 3		Holists	13.85	1.75	$p=.29$		
		Serialists	11.50	1.31			
Total time			Holists	64.96	6.28	$p=.85$	
			Serialists	63.31	5.78		

Table 5-9 Descriptive statistic of cognitive style and completion time-Group B

Cognitive style differences and completion time-Group B						
	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Group B- Serialistic interfaces	HTC	Task 1	Holists	34.16	5.00	$p = .27$
			Serialists	19.63	3.89	
		Task 2	Holists	21.21	2.96	$p = .36$
			Serialists	17.45	2.78	
		Task 3	Holists	37.28	9.79	$p = .46$
			Serialists	28.94	5.20	
	Total time		Holists	92.65	10.76	$p = .07$
			Serialists	66.01	8.97	
	Nokia	Task 1	Holists	16.08	2.45	$p = .70$
			Serialists	14.98	1.47	
		Task 2	Holists	40.78	10.69	$p = .08$
			Serialists	20.24	2.68	
		Task 3	Holists	66.92	4.25	$t = 2.25, df = 38,$ $p < .05, d = .72$
			Serialists	51.53	5.36	
	Total time		Holists	117.97	12.31	$p = .08$
			Serialists	90.68	8.77	
	Samsung	Task 1	Holists	39.39	7.12	$p = .88$
			Serialists	38.06	6.10	
		Task 2	Holists	12.90	4.77	$p = .80$
			Serialists	11.60	1.74	
		Task 3	Holists	61.20	10.81	$t = 2.41, df = 23.66,$ $p < .05, d = 1.77$
Serialists			33.55	3.81		
Total time		Holists	113.48	17.88	$p = .13$	
		Serialists	83.20	6.82		

Cognitive style and the number of clicking icons

To compare the effect of cognitive styles to the number of icons clicked to complete the tasks; on average, serialists clicked fewer icons to complete most tasks whilst interacting with six interfaces, except iPhone (Table 5-10 and 5-11). The significance was only found whilst sending message (Task 1) with Nokia's interface as holists ($M=4.65$, $SE=.24$) clicked fewer icons to send a message than serialists ($M=5.85$, $SE=.43$). The mean difference between conditions was 1.20 and the 95% confidence interval for the estimated population mean difference is between 0.20 and 2.19. The effect size was large ($d=.80$). An independent t-test showed that the difference between conditions was significant ($t = -2.451$, $df = 30.28$, $p<.05$).

Table 5-10 Descriptive statistic of cognitive style and the numbers of clicking icons- Group A

Cognitive style differences and the numbers of clicking icons-Group A							
Group A- Holistic interfaces	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>	
	Blackberry	Task 1	Holists	6.85	0.57	$p = .10$	
			Serialists	5.70	0.38		
		Task 2	Holists	3.30	0.21	$p = .16$	
			Serialists	3.00	0.00		
		Task 3	Holists	10.90	0.92	$p = .24$	
			Serialists	9.70	0.40		
	Total numbers of clicking icons			Holists	21.05	1.26	$p = .06$
				Serialists	18.40	0.48	
	iPhone	Task 1	Holists	5.40	0.61	$p = .29$	
			Serialists	6.35	0.64		
		Task 2	Holists	2.00	0.00	$p = .17$	
			Serialists	2.35	0.24		
		Task 3	Holists	4.80	0.66	$p = .95$	
			Serialists	4.75	0.35		
	Total numbers of clicking icons			Holists	12.20	0.80	$p = .30$
				Serialists	13.45	0.86	
	LG	Task 1	Holists	4.45	0.48	$p = .97$	
			Serialists	4.40	0.38		
		Task 2	Holists	7.95	1.19	$p = .47$	
Serialists			6.75	1.14			
Task 3		Holists	3.95	0.40	$p = .93$		
		Serialists	3.90	0.38			
Total numbers of clicking icons			Holists	16.35	1.46	$p = .50$	
			Serialists	15.05	1.23		

Table 5-11 Descriptive statistic of cognitive style and the numbers of clicking icons- Group B

Cognitive style differences and the numbers of clicking icons-Group B							
Group B- Serialistic interfaces	Brand	Task	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>	
	HTC	Task 1	Holists	4.15	0.36	$p = .72$	
			Serialists	4.35	0.43		
		Task 2	Holists	5.25	0.70	$p = .07$	
			Serialists	3.85	0.28		
		Task 3	Holists	6.80	0.81	$p = .65$	
			Serialists	7.45	1.14		
	Total numbers of clicking icons		Holists	16.20	1.11	$p = .75$	
			Serialists	15.65	1.31		
	Nokia	Task 1	Holists	4.65	0.24	$t = -2.451, df = 30.28, p < .05, d = .80$	
			Serialists	5.85	0.43		
		Task 2	Holists	7.25	1.74		$p = .97$
			Serialists	7.35	1.71		
		Task 3	Holists	25.70	2.04		$p = .46$
			Serialists	23.65	1.80		
	Total numbers of clicking icons		Holists	37.60	2.81	$p = .85$	
			Serialists	36.85	2.90		
	Samsung	Task 1	Holists	9.60	1.96	$p = .79$	
			Serialists	8.90	1.69		
		Task 2	Holists	2.45	0.17	$p = .21$	
Serialists			3.15	0.53			
Task 3		Holists	14.90	2.22	$p = .50$		
		Serialists	12.90	1.92			
Total numbers of clicking icons		Holists	26.95	3.06	$p = .63$		
		Serialists	24.95	2.71			

To sum up the outcomes of the participants' performance with six mobile phone interfaces, the significance was found whilst the options were uncertain for the users, such as seeking the icon to access the main menu with the interface of HTC. However, this phenomenon was not found when the instruction of physical buttons was not clear.

The participants' performance showed the most significant differences whilst seeking the target photo with the interfaces of Blackberry, Nokia and Samsung. Three of the interfaces include several folders; the target photo was saved in one of the folders and no relevant information was shown with each folder.

As mentioned earlier, holists/serialists apply different strategies to seek information. In this stage, holists tended to find the target photo by checking folders randomly and repeatedly, whilst serialists preferred to check the folders

one by one. It might occur as a result of the inherent characteristics of holists as they prefer to use analogies to make the connection between different aspects of the subjects. However, no linkage was found between the folders of the three interfaces. In contrast, serialists are more likely to emphasise the relationship between previous knowledge and current subjects and to make logical links. Therefore, they checked the folders one by one, saved the time and applied fewer clicks of icons to complete the tasks.

5.5.3 User experience differences and performance with tasks

According to the findings of chapter 4, the users' previous experience was one of the effects of their operational behaviour with numeric keypad phone interfaces. This study attempts to seek the consistent phenomenon. The hypotheses between conditions are shown as e) and f) in section 5.2:

- User's level of experience will be found to significantly affect their completion time of tasks using the mobile phone interfaces;
- Users' level of experience will be found to significantly affect the number of times they click icons to complete tasks using the mobile phone interfaces;

Previous user experience and completion time

This investigation also examines the users' using experience with mobile phones and their performance with the interfaces of Group A and B. Based on the brand of the user's current use mobile phones, the Mauchy's test of one-way within-subjects ANOVA indicates that the assumption of Sphericity had been violated, $X^2(20) = 127.51$, $p < .05$, thus degrees of freedom were corrected by Huynh-Feldt estimates of sphericity ($\epsilon = .53$). The brand of the users' current mobile phone was found to have a significant effect on individual's completion time across the six emulators, $F(6,234) = 41.4$, $p < .05$. Users' performed proved better with the interface which was similar to their own mobile phone.

Previous user experience and the number of icons clicked

In addition, the participants also clicked fewer icons to achieve the goal with the familiar interface. The Mauchly's test indicates that the assumption of Sphericity had been violated, $X^2(20) = 132.41$, $p < .05$, therefore degrees of freedom were

corrected by Huynh-Feldt estimates of sphericity ($\epsilon = .54$). The results show that the number of icons clicked to complete the tasks was affected by the brand of their mobile phones, $F(6, 234) = 87.67$; $p < .05$. Participants achieved the goals within fewer clicks of icons if the interface is similar with the interface on their own mobile phone.

5.5.4 QUIS and performance with tasks

Chapter 4 mentioned that participants expected to complete the tasks with fewer icons clicked. As a result, this investigation also examines the relationship between the users' satisfaction with the six touch screen mobile phone interfaces in terms of their completion time with tasks and the number of times they clicked icons to achieve the goals. The hypotheses in this section are shown as g) and h) in section 5.2:

- A significant correlation will be found between users' satisfaction with the mobile phone interface and completion time of tasks;
- A significant correlation will be found between users' satisfaction with the mobile phone interface and the number of icons clicked during task completion.

QUIS and completion time

As can be seen from the Scattergrams of Figure 5-13, participants' satisfaction with the interface tends to decrease whilst the completion time increased, especially the interface of LG and Nokia. There was a significant negative correlation between total completion time of three tasks and users' satisfaction of the interfaces of LG ($r = -.549$, $N=40$, $p < .05$, two tailed) and Nokia ($r = -.513$, $N=40$, $p < .05$, two tailed). It might be the case that the style of LG's interface is an unfamiliar interface to most of participants. Also, the image icon for accessing the menu may not deliver the meaning to the users appropriately. In addition, although the interface of Nokia phone provides more options to achieve a goal, the instructions were not clear to the participants.

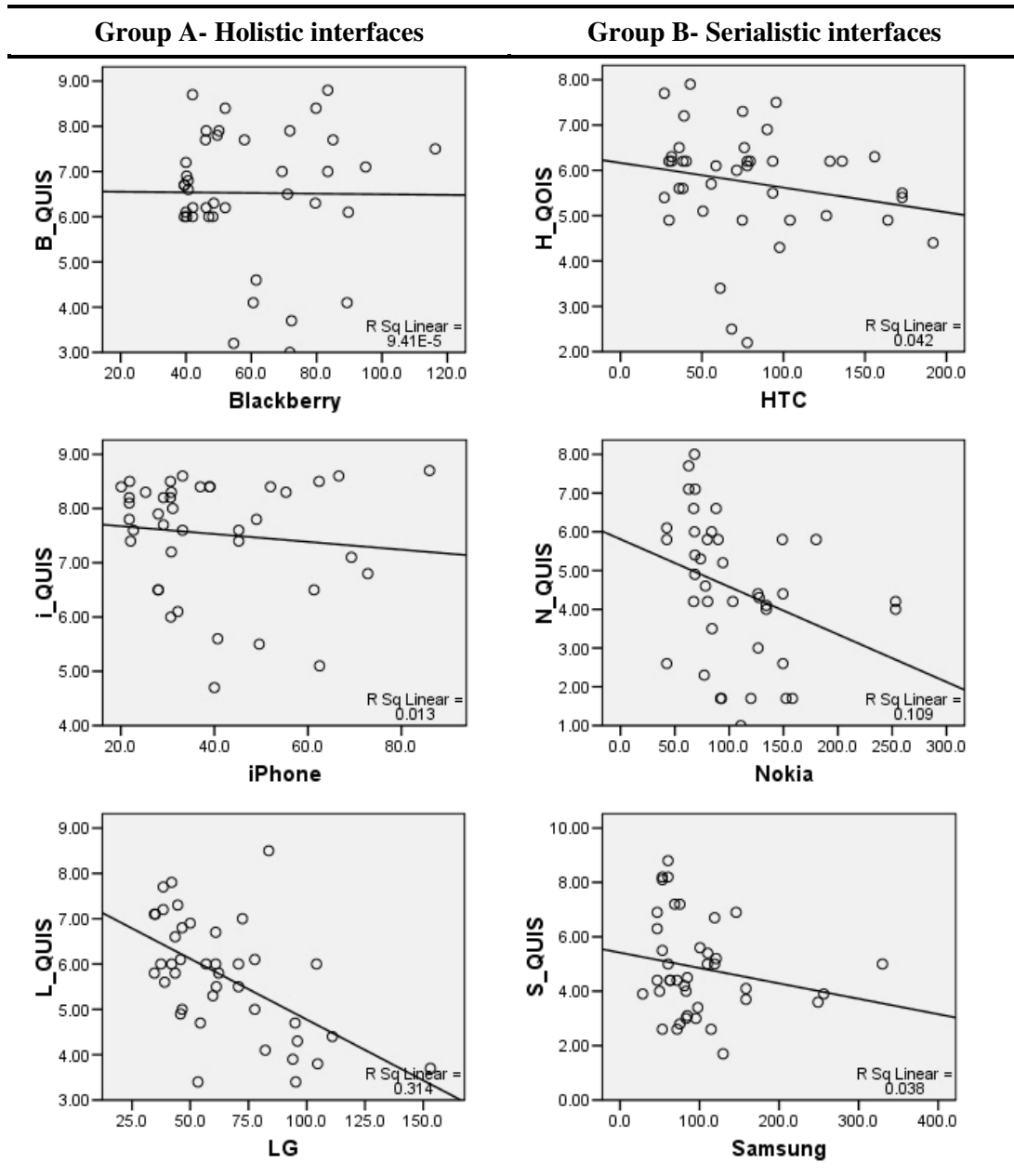


Figure 5-13 Correlation between completion time and QUIS

QUIS and the number of clicking icons

The Scattergrams of Figure 5-14 suggests that the participants' satisfaction tends to decrease by the total number of clicking icons to complete the tasks with LG, HTC and Samsung's interfaces. The negative correlation was found as a higher number of icons clicked resulted in lower satisfaction with the interface of LG mobile phone ($r = -.347$, $N = 40$, $p < .05$, two tailed). As mentioned earlier, the result might be as a result of the users' familiarity with the interface. For instance, the platform of LG was new and inclusive for the instrument in this investigation;

however, the platform- Symbian of Nokia has been applied to numerous of mobile phones. Moreover, the format of the initial page on LG is similar with iPhone, thus some of the participants were confused about how to find the other icons for the functions.

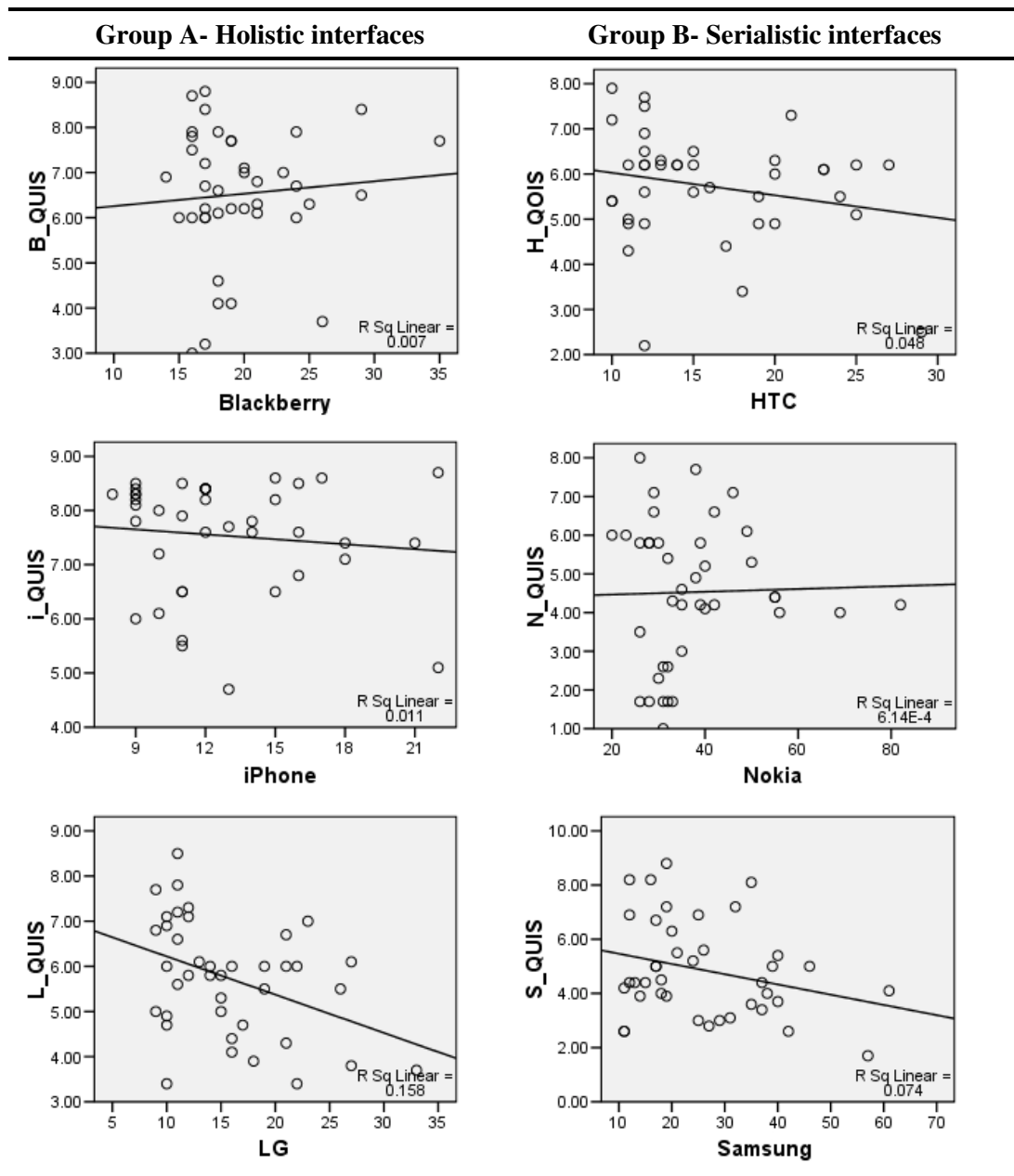


Figure 5-14 Correlation between times of pressing icons and QUIS

5.5.5 Correlation of completion time and the number of clicking icons

To examine the correlation between the participants' completion time and the numbers of icons clicked to complete three tasks, on average, the Scattergrams (Figure 5-15) shows that longer completion time was caused by clicking icons more often. However, no significance was found with parametric test.

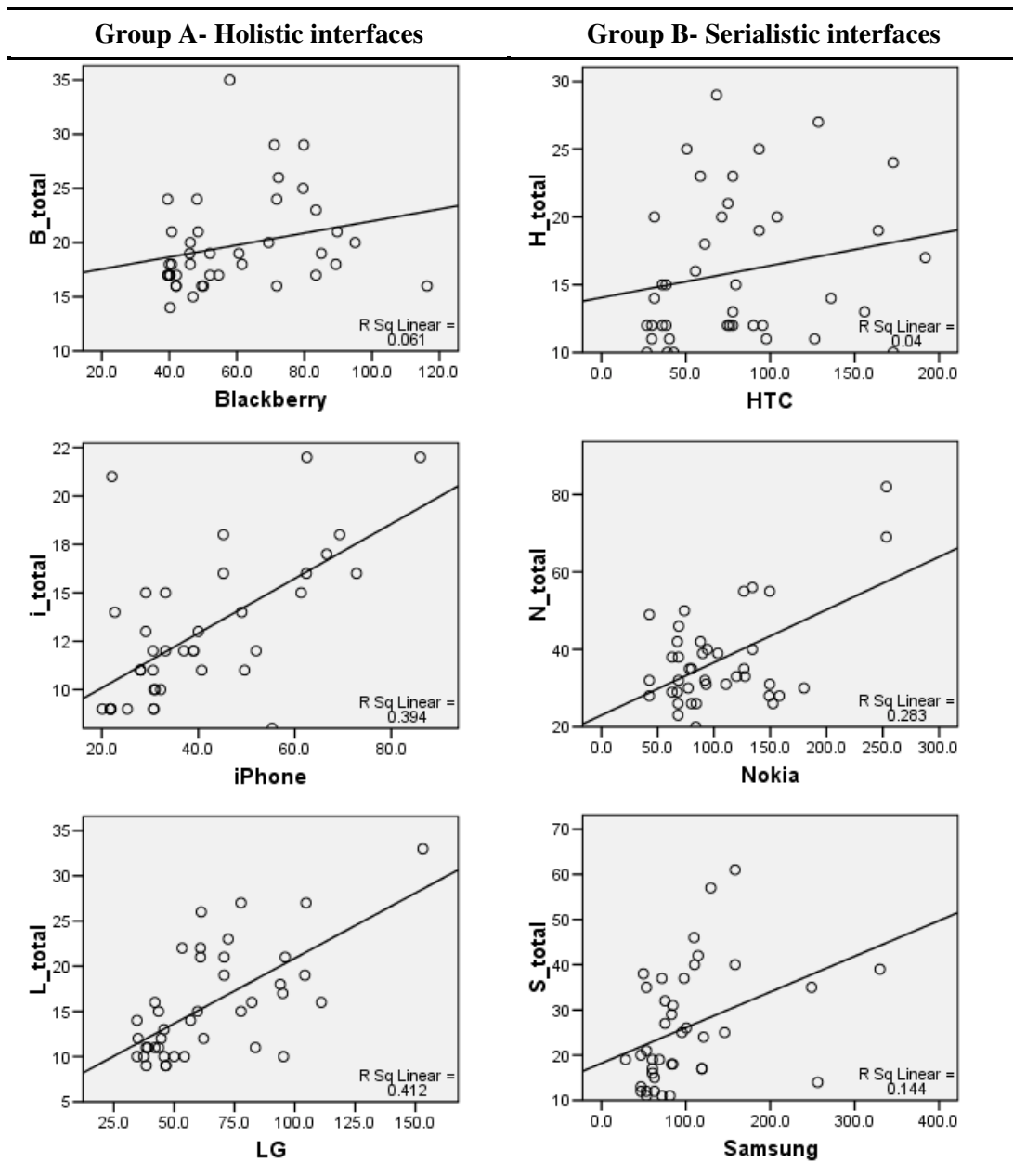


Figure 5-15 Correlation between completion time and the number of clicking icons

5.5.6 Summary

Table 5-12 Summarises the answers to the hypotheses of this study

Hypothesis	Significant results
1) A significant difference between user' gender and their completion time of tasks will be found with the mobile phone interfaces;	Task 2 with HTC
2) A significant difference between user' gender and the times they click icons to complete tasks will be found with the mobile phone interface;	Task 1 with HTC
3) A significant difference between user' cognitive style and their completion time of tasks will be found with the mobile phone interfaces;	Task 3 with Blackberry, Nokia, Samsung
4) A significant difference between user' cognitive style and the times they click icons to complete tasks will be found with the mobile phone interfaces;	Task 1 with Nokia
5) A significant difference between user' using experience and their completion time of tasks will be found with the mobile phone interfaces;	Significant effect of the brand of the user's current mobile phone on their total completion time with three tasks across six interfaces
6) A significant difference between user' using experience and the times they click icons to complete tasks will be found with the mobile phone interfaces;	Significant effect of the brand of the user's current mobile phone on the total times they clicked icons to complete three tasks across six interfaces
7) A significant correlation between users' satisfaction with the mobile phone interface and completion time of tasks will be found;	Longer completion time only reduces the users' satisfaction with the interface on LG and Nokia mobile phone
8) A significant correlation between users' satisfaction with the mobile phone interface and the times clicking icons to complete tasks will be found.	Clicking more icons only reduces the users' satisfaction with the interface on LG mobile phone

5.6 Stage two- analysis of qualitative data

This investigation attempts to analyse the users' operational behaviour in terms of the acquired quantitative data. The significances between individual differences were found with partial tasks as mentioned in Table 5-12. More specifically, the effects of cognitive style differences on the users' interaction were shown with Task 3-seeking a specific photo with three interfaces-Blackberry, Nokia and Samsung. For further analysis of how the cognitive style-holist and serialist impact the individuals' operational behaviour with phone interfaces, this section presents all the routes of that can be applied to completing each task by HTA. Meanwhile, the routes that the participants' applied to achieve the goals were analysed in terms of HTA.

5.6.1 Hierarchical Task Analysis (HTA)

This section presents the application of HTA in three tasks across six touch screen mobile phone interfaces, and then analyses the users' performance by the routes they applied to achieve the goals eventually. It is necessary to note that the participants' performance in terms of completion time and the numbers of icons clicked were excluded in this discussion.

5.6.1.1 Task 1 Sending a message

The task of sending text message can be operated via the functional icons of 'message' or 'contacts'. The two icons were set on the desktop with four interfaces in this study, the interfaces of HTC and Samsung only display the icon of 'contacts' and the other icons irrelevant to the task of sending a message. This task examines the individual's selection of icons, routes of completing the task. Due to the varying restrictions of each emulator, this task was terminated at editing the text content of the message.

Blackberry

Figure 5-16 shows the icons used in sending text messages with the interface of Blackberry. Five options lead to the other two pages involved in the process. The physical button leads to the menu list where all functional icons are listed. As can be seen from Figure 5-17, on average, five routes can be used to send text message, 6-9 steps were necessary.



Figure 5-16 The icons of sending text messages with Blackberry

Table 5-13 shows that 67.5% participants preferred to send a message via the functional icon of 'Messages' at the desktop. Both holists and serialists followed the route of clicking 1-Message ► 1.2- Compose ► 1.2.1-SMS ► 1.2.2.1-input the first letter of the recipient's name at the space after 'To' ► 1.2.2.1.2-select the recipient from pop-up list.

Table 5-13 Cognitive style-routes selection-Task 1-Blackberry

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1 ► 1.2 ► 1.2.1 ► 1.2.2.1 ► 1.2.2.1.2	60%	75%	67.5%
2 ► 1.2 ► 1.2.2.1 ► 1.2.2.2	15%	0	7.5%
3 ► 3.1 ► 3.2 ► 3.3	25%	25%	25%

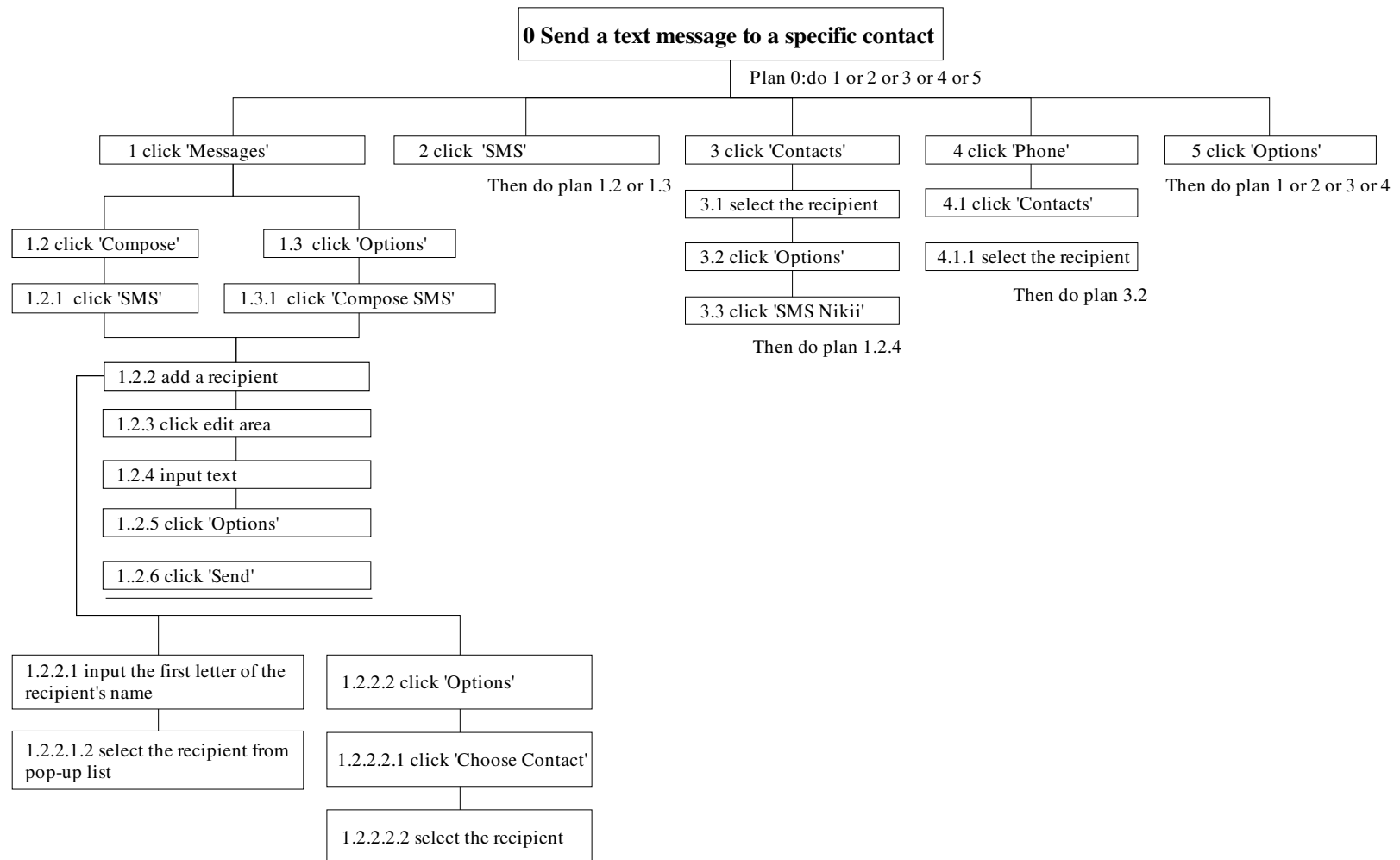


Figure 5-17 HTA of Task 1 on Blackberry

iPhone

Figure 5-18 marks the two icons used in sending message on the interface of iPhone. The two routes are linear and simple. Figure 5-19 presents the process of sending a message with iPhone. This task can be completed within 4-7 steps without making mistakes. The linear process simplifies the task and reduces the number of steps required to complete the task.



Figure 5-18 The icons of sending text messages with iPhone

Some of the participants selected the icon that shows an envelope initially. However, the icon represented the function of email. The majority of holists and serialists followed the route of clicking 1-Text► 1.1-graphic icon of writing a new message► 1.2-graphic icon of adding a recipient► 1.3-select a recipient (Table 5-14).

Table 5-14 Cognitive style-routes selection-Task 1-iPhone

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1►1.1►1.2►1.3	85%	90%	87.5%
2►2.1►2.2►2.3	15%	10%	12.5%

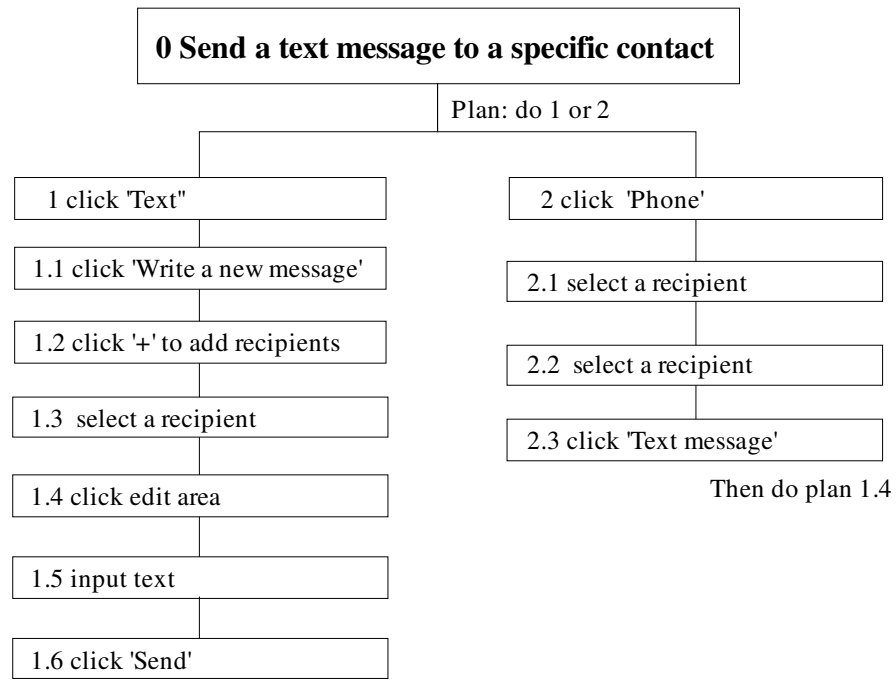


Figure 5-19 HTA of Task 1 on iPhone

LG

The desktop of the LG mobile phone was divided into two frames (Figure 5-20). The upper area provides seven functional icons and the bottom area provides three communicational icons: calling, contact list and sending messages and a blue icon situated at the bottom right of the screen which allows users to access the menu list. Three functional icons can be applied to send text message. Figure 5-21 shows the process of sending text message with the interface with LG mobile phone. Six to ten steps were necessary to complete this task by four routes. More options were provided for adding recipients before editing the message.



Figure 5-20 The icons of sending text messages with LG

Holists and serialists preferred different routes to send a message with the interface of LG. Sixty percent serialists tended to set the recipient first, followed by the route of 1-Contacts ► 1.1-select the recipient ► 1.2-Send message; whilst 85% holists selected the route of clicking 3-graphic icon of envelope ► 3.1-graphic icon of 'Write message' ► 3.2.1-text icon of 'To' ► 3.2.1.1-switch letters & numbers ► 3.2.1.2- input the first letter of the recipient's name at the space after 'To' ► 3.2.1.3-select the contact (Table 5-15).

Table 5-15 Cognitive style-routes selection-Task 1-LG

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1 ► 1.1 ► 1.2	10%	60%	35%
2 ► 2.1 ► 1.2	5%	5%	5%
3 ► 3.1 ► 3.2.1 ► 3.2.1.1 ► 3.2.1.2 ► 3.2.1.3	85%	35%	60%

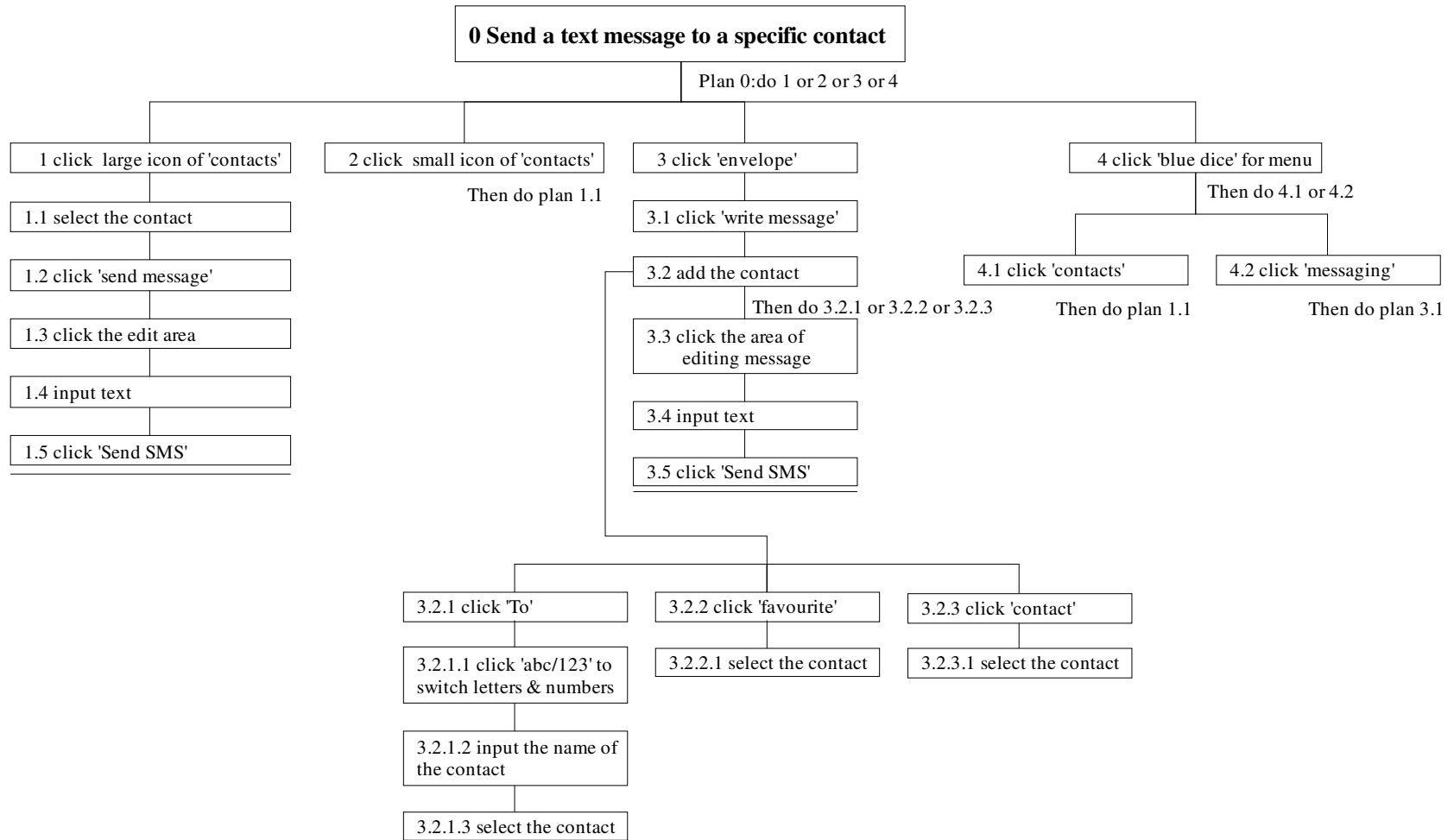


Figure 5-21 HTA of Task 1 on LG

HTC

The desktop of HTC presents five functional icons and a soft button to expand the main menu (Figure 5-22). The icons of 'Dallier', 'Contacts' and 'my Faves' can be used for sending messages. The functional icon of 'Messaging' can be found on the main menu. According to Figure 5-23, four routes can be used for sending messages on HTC. On average, this task can be completed within 6-8 steps. The operation process tends towards linearity and the users were not given extra options during the process.



Figure 5-22 The icons of sending text messages with HTC

Two routes were preferred by both holists and serialists to achieve the goal. More than half participants followed the path of selecting 2-contacts ► 1.2-the recipient's name ► 1.3-Send SMS/MMS; forty percent of users accessed the main menu and selected the functional icon of 'Messaging' by clicking 4-click right arrow on the desktop (to access the main menu) ► 4.1-Messaging ► 4.1.1-New message ► 4.1.2-To ► 4.1.3- the recipient's name (Table 5-16).

Table 5-16 Cognitive style-routes selection-Task 1-HTC

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
2 ► 1.2 ► 1.3	55%	60%	57.5%
3 ► 3.1 ► 3.2	5%	0	2.5%
4 ► 4.1 ► 4.1.1 ► 4.1.2 ► 4.1.3	40%	40%	40%

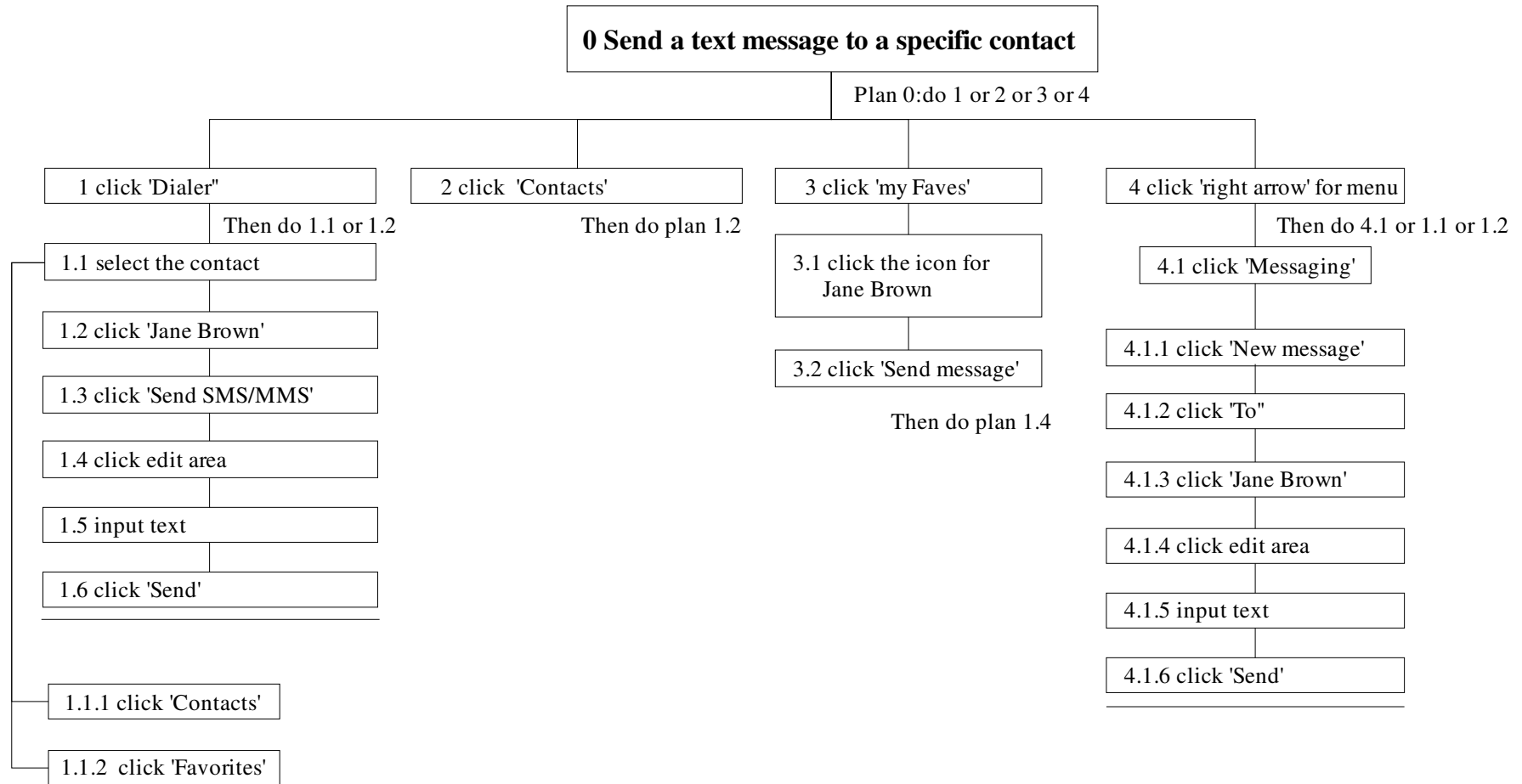


Figure 5-23 HTA of Task 1 on HTC

Nokia

The interface of the Nokia shows five graphic functional icons: two text icons, the date, time, mode of the phone and the music title. Including the physical buttons, a total of six icons and buttons can be used for sending messages (Figure 5-24). Five to seven steps were required to complete this task (Figure 5-25).



Figure 5-24 The icons of sending text messages with Nokia

Participants were more likely to edit a message via the graphic icon of ‘Messaging’ with the interface of Nokia mobile phone. The route starts at clicking 1-graphic icon of Messaging► 1.1-New Messaging► 1.2.1-the text icon of To► 1.2.2-graphic icon of adding recipients► 1.3.1-the recipient’s name► 1.4 OK. The difference between the two routes is adding the recipient via text icon of ‘To’ or the graphic icon that shows a symbol with a person (Table 5-17).

Table 5-17 Cognitive style-routes selection-Task 1-Nokia

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1► 1.1► 1.2.1► 1.3.1► 1.4	40%	40%	40%
1► 1.1► 1.2.2► 1.3.1► 1.4	30%	50%	40%
2► 2.1► 2.1.1► 2.3► 2.4	25%	0	12.5%
4► 4.2► 4.2.1► 1.2.2► 1.3.1► 1.4	5%	10%	7.5%

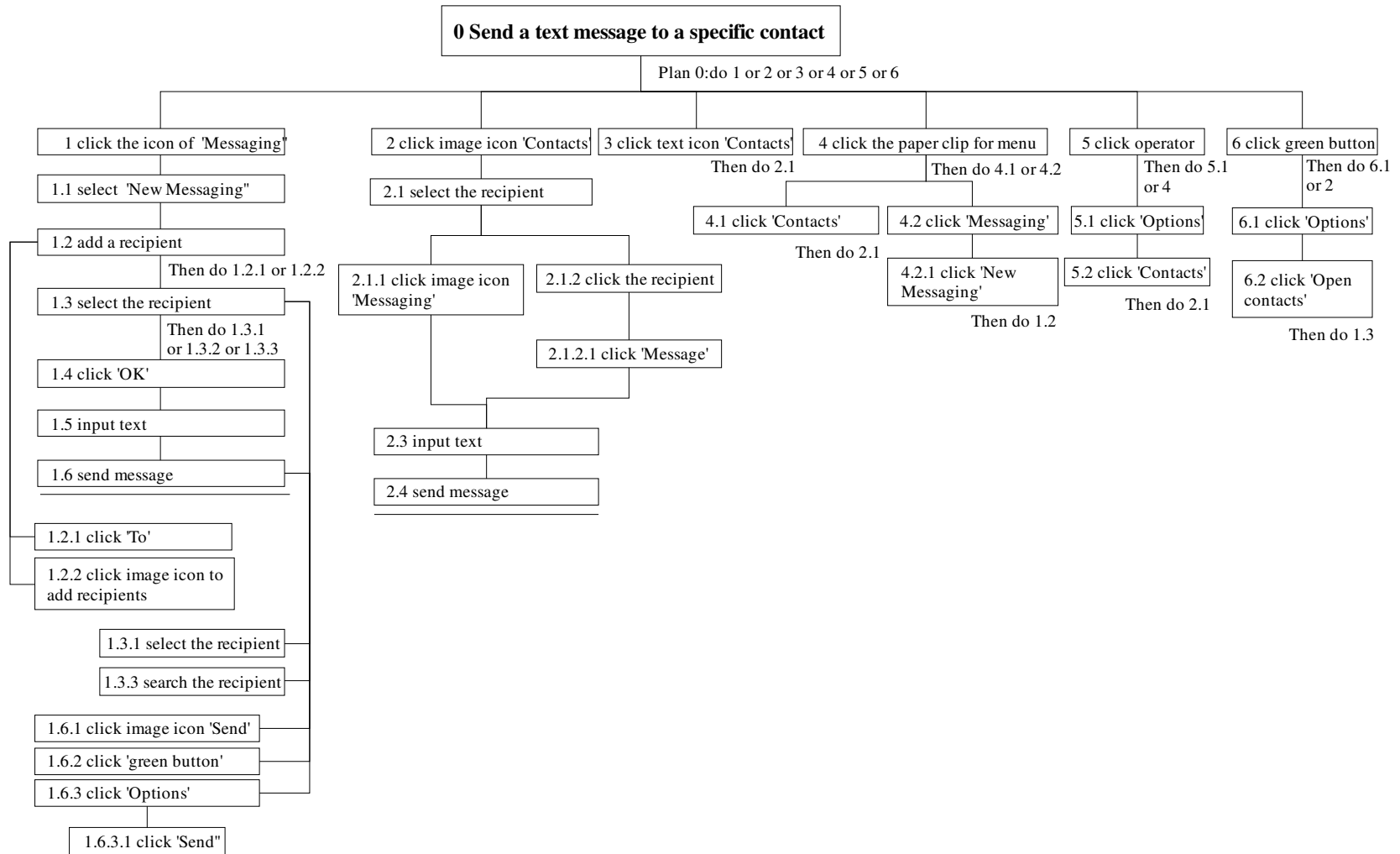


Figure 5-25 HTA of Task 1 on Nokia

Samsung

The process of completing this task tends towards linearity. The interface of the Samsung mobile phone provides five routes to access the page of editing message (Figure 5-26). However, the functional icon of ‘Messages’ was not shown on the desktop. Users have to select the recipient first or select the functional icon of ‘Messages’ on the main menu for this task. In addition, the icon of ‘Messages’ was allocated at one of the four pages of the menu, it is also necessary to know how to slip the page whilst seeking the functional icon. As can be seen from Figure 5-27, on average, users were required to complete sending a text message in 6-8 steps.



Figure 5-26 The icons of sending text messages with Samsung

Both holistic and serialistic participants tended to apply the same routes to edit a message with Samsung mobile phone. Around half of the participants accessed the menu list to complete this task by clicking 3-hexagon button (to access the main menu) ► 3.2-slip the page twice ► 3.2.1-Message ► 1.2.1-the graphic icon of ‘write a new message’ ► 1.2.2-tap to add recipients ► 1.2.3-Phonebook ► 1.2.4-select the contact. Another half of the participants used the text icon on the desktop of 4-Phonebook at the desktop, then 1.1.1-selecting the contact ► 1.1.2-clicking the text of ‘Send text message’ (Table 5-18).

Table 5-18 Cognitive style-routes selection-Task 1-Samsung

Routes	Holists	Serialists	Total
	<i>N=20</i>	<i>N=20</i>	<i>N=40</i>
1 ▶ 1.2 ▶ 1.2.1 ▶ 1.2.2 ▶ 1.2.2 ▶ 1.2.4	0	10%	5%
3 ▶ 3.1 ▶ 1.1.1 ▶ 1.1.2	5%	0%	2.5%
3 ▶ 3.2 ▶ 3.2.1 ▶ 1.2.1 ▶ 1.2.2 ▶ 1.2.3 ▶ 1.2.4	40%	50%	45%
4 ▶ 1.1.1 ▶ 1.1.2	55%	40%	47.5%

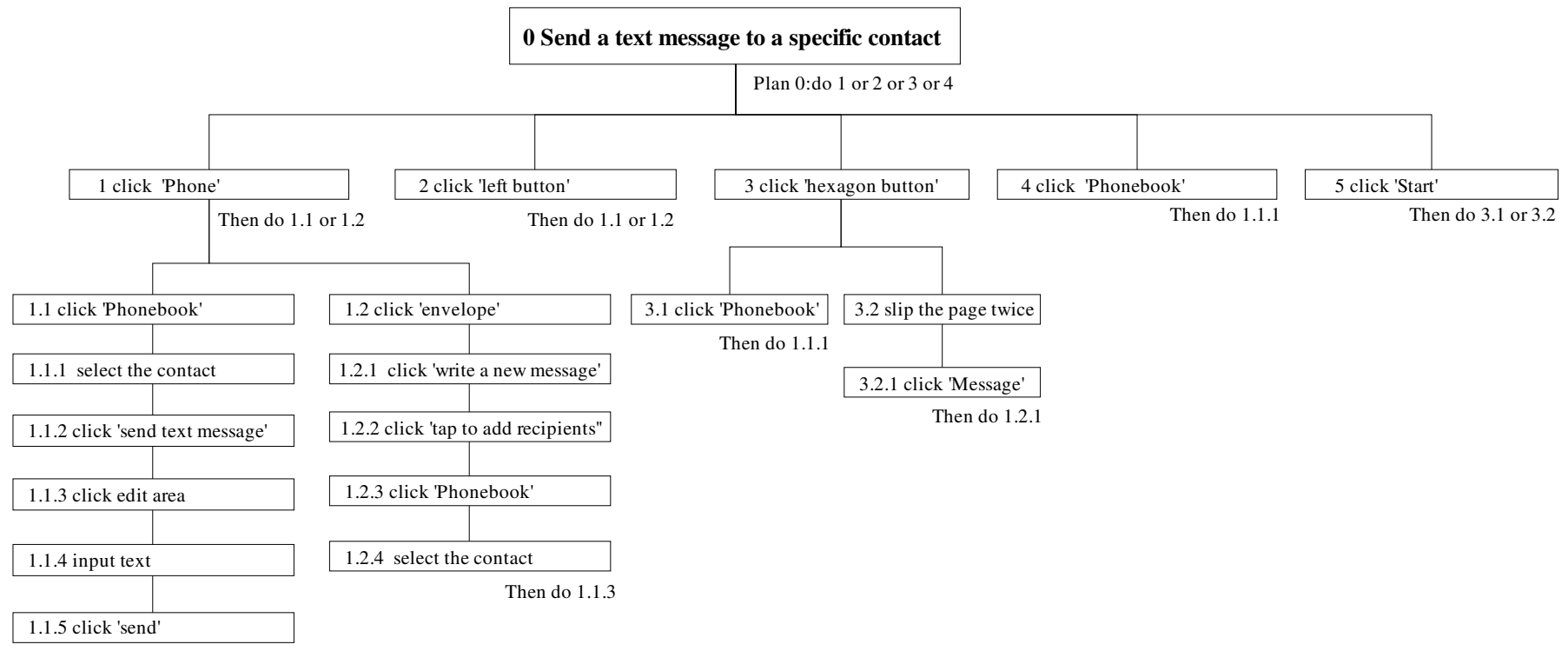


Figure 5-27 HTA of Task 1 on Samsung

5.6.1.2 Task 2 Checking a specific day on the calendar

Participants were required to point out a date on the calendar. The icon of calendar was shown on the desktop with all six interfaces except for the Nokia mobile phone. All the users applied the same route to check the date with iPhone, LG and HTC mobile phone. Holists and serialists' preferences in completing this task were slightly different, especially with the Samsung interface.

Blackberry

Accessing the calendar on Blackberry can be conducted via the icon of 'Calendar' on the desktop or the main menu (Figure 5-28). The calendar shows the daily schedule initially, so in order to check the target date of this task, users were required to press the icon of 'View Month'. The whole process takes 3-5 steps (Figure 5-29).



Figure 5-28 The icons of checking calendar with Blackberry

All participants selected the icon of 'Calendar' on the desktop, only 10% ($N=40$) of individuals switched the page from daily schedule to monthly from the expanded list shown after clicking 'Option' (1.2►1.2.1) (Table 5-19).

Table 5-19 Cognitive style-routes selection-Task 2-Blackberry

Routes	Holists	Serialists	Total
	$N=20$	$N=20$	$N=40$
1►1.1►1.1.1	80%	100%	90%
1►1.2►1.2.1	20%	0	10%

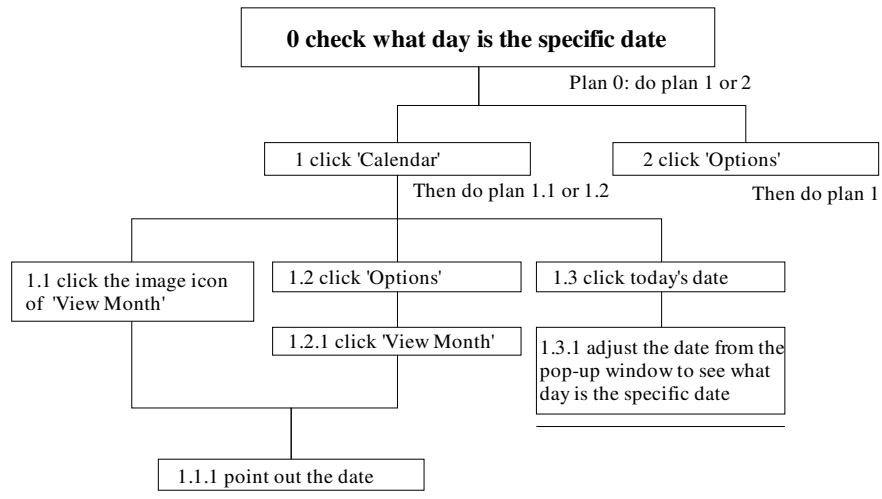


Figure 5-29 HTA of Task 2 on Blackberry

iPhone

Checking the calendar on iPhone only takes two steps. The icon of 'Calendar' was shown on the desktop (Figure 5-30). The monthly calendar shows the date and the current month. Only one route can be used to complete task (Figure 5-31).



Figure 5-30 The icons of checking calendar with iPhone

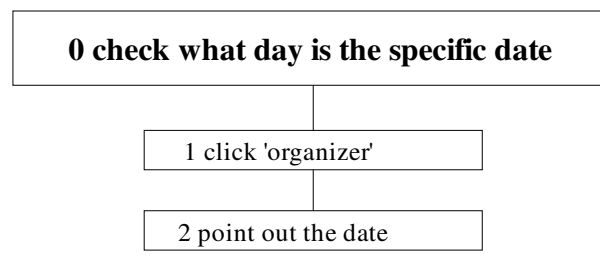


Figure 5-31 HTA of Task 2 on iPhone

LG

The functional icon of 'Calendar' was located in the main menu. Users have to access the main menu via the blue icon at the bottom right of the screen (Figure 5-32). Only one route can be used to complete this task. Three steps were required (Figure 5-33).



Figure 5-32 The icons of checking calendar with LG

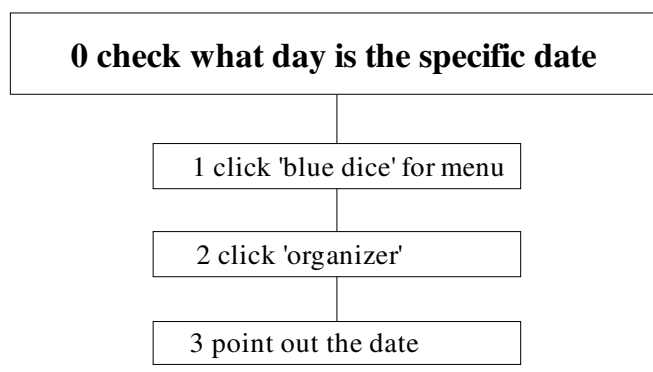


Figure 5-33 HTA of Task 2 on LG

HTC

Users must access the main menu and find the functional icon of 'Calendar' to complete this task with the HTC interface (Figure 5-34). Only one route can be taken in order to achieve the goal (Figure 5-35).



Figure 5-34 The icons of checking calendar with HTC

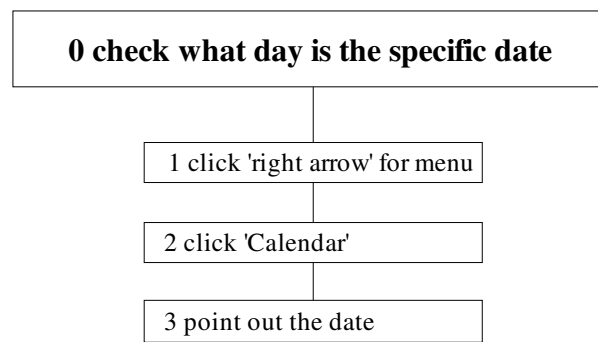


Figure 5-35 HTA of Task 2 on HTC

Nokia

Three paths can be used for checking the date on the Nokia interface. Both the date and event reminder on the desktop were linked to the calendar instead of situating the 'Calendar' icon on the main menu (Figure 5-36). However, the two items do not look like icons. Two to five steps are necessary to complete this task with the Nokia mobile phone (Figure 5-37).



Figure 5-36 The icons of checking calendar with Nokia

Sixty-five percent of participants ($N=40$) accessed the calendar via the functional icon on the main menu. The route requires the users to click 2-the physical buttons of paper clip (to access the main menu) ► 2.1-calendar ► 2.2-point out the date (Table 5-20).

Table 5-20 Cognitive style-routes selection-Task 2-Nokia

Routes	Holists	Serialists	Total
	$N=20$	$N=20$	$N=40$
1 ► 1.1	30%	25%	27.5%
2 ► 2.1 ► 2.2	60%	70%	65%
3 ► 3.1 ► 3.2 ► 3.3 ► 3.4	10%	5%	7.5%

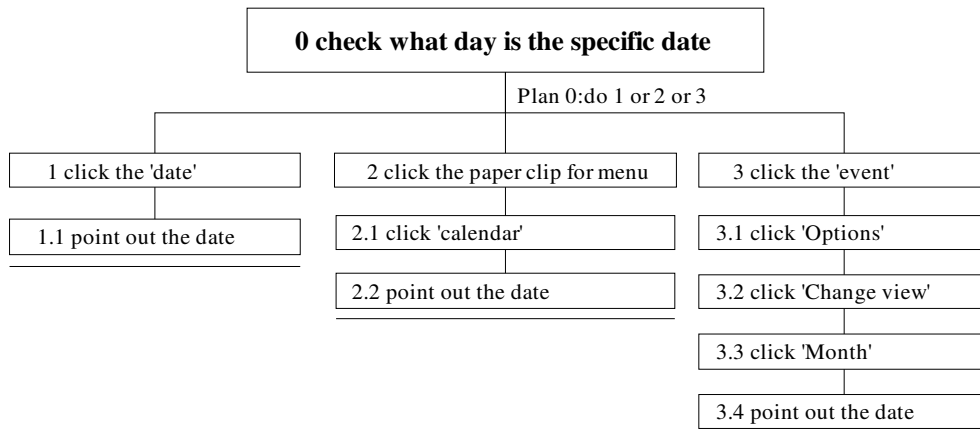


Figure 5-37 HTA of Task 2 on Nokia

Samsung

The shortcut of calendar on the desktop provides a simple version of the calendar to check the date and the current month (Figure 5-38). The further functions of ‘Calendar’ were accessible from the main menu within 3 steps (Figure 5-39).



Figure 5-38 The icons of checking calendar with Samsung

Eighty percent of holists were more likely to check the date via the shortcut on the desktop (1 ► 1.1); whilst more than half serialists followed the path of clicking 2-hexagon button (to access the main menu) ► 2.1-schedule ► 1.1-point out the date (Table 5-21).

Table 5-21 Cognitive style-routes selection-Task 2-Samsung

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1 ► 1.1	80%	40%	60%
2 ► 2.1 ► 1.1	20%	60%	40%

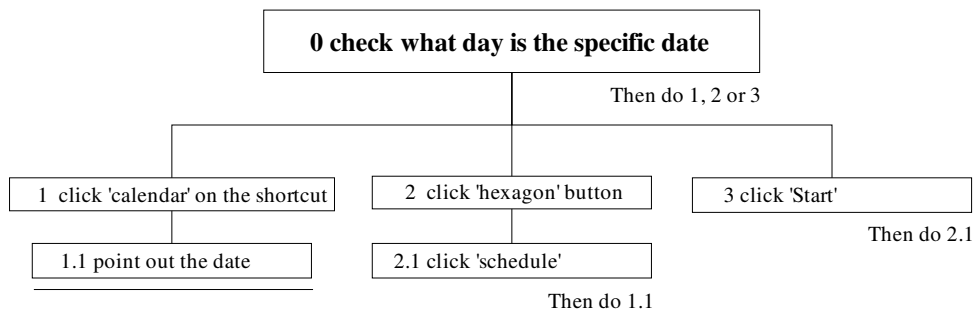


Figure 5-39 HTA of Task 2 on Samsung

5.6.1.3 Task 3 Seeking a target photo

This task requires participants to seek a target photo across the six mobile phone interfaces. The interfaces of iPhone, LG and HTC present all photos thumbnails on one page; in contrast to this, the interfaces of Blackberry, Nokia and Samsung show more sub-categories under the category of viewing photos. This task also observes how the users seek a photo within an uncertain context.

Blackberry

Seeking a specific photo with Blackberry is achieved by selecting the ‘Media’ icon on the desktop or by accessing the main menu by pressing the physical button. The ‘Pictures’ sub-category is one of the items in the ‘Media’ menu. The ‘Pictures’ category includes the function of ‘Camera’ and three folders: ‘All Pictures’, ‘Picture Folders’ and ‘Sample Pictures’. The target photo was saved in the ‘Sample Pictures’ folder. The folders did not show details of their content (Figure 5-40 and 5-41). The task of finding the target photo takes 4-6 steps to complete (Figure 5-42).



Figure 5-40 The icons of checking calendar with Samsung

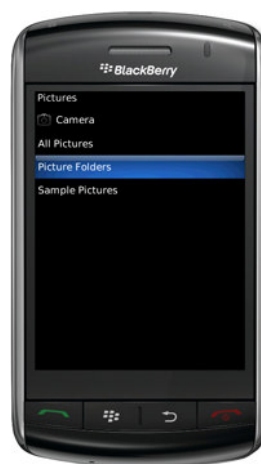


Figure 5-41 Sub-category of ‘Pictures’

All participants completed this task via the route of 1 ► 1.1 ► 1.1.2 ► 1.1.3. The difference was the order in which they checked the folders of the ‘Pictures’ sub-category. Sixteen holists checked the three folders in the sub-category randomly; whilst fifteen serialists preferred to check the folders one by one.

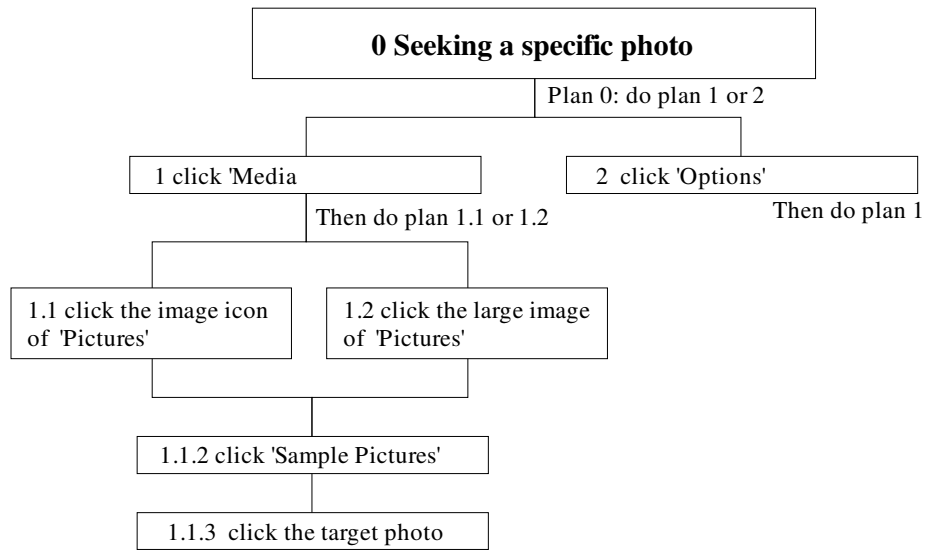


Figure 5-42 HTA of Task 1 on Blackberry

iPhone

Locating the photo with iPhone is a linear process. Only the 'Photos' icon can be used to complete task (Figure 5-43 and 5-44). Users can find the target photo within 3 steps. The target photo was found by all participants using this route (Figure 5-45).



Figure 5-43 The icons of checking calendar with iPhone



Figure 5-44 Sub-category of 'Photos'

The target photo was found by all participants by clicking 1-photos ► 2-Photo Library ► 3-target photo.

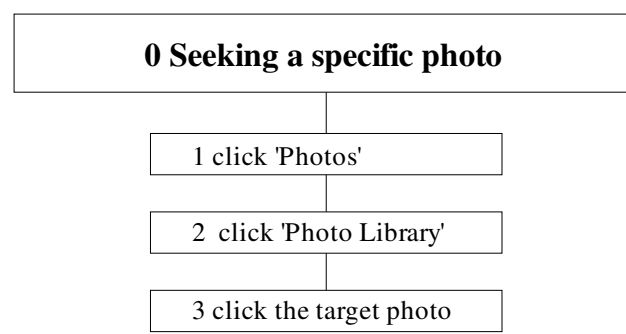


Figure 5-45 HTA of Task 1 on iPhone

LG

The ‘Gallery’ icon was shown on the desktop of LG and the icon can also be found on the main menu (Figure 5-46). Photos were presented as thumbnails on one page (Figure 5-47). This task requires participants to slip the page up to find the target photo. Two routes and 3-4 steps are necessary to find the target photo (Figure 5-48).



Figure 5-46 The icons of checking calendar with LG

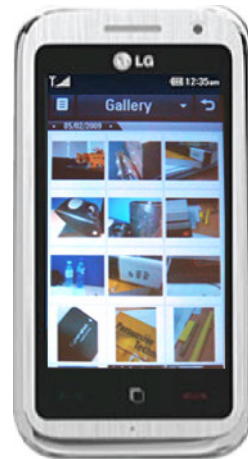


Figure 5-47 Sub-category of ‘Gallery’

The majority of participants preferred to seek the target photo by clicking on 1-Gallery on the desktop of LG mobile phone, then 1.1-slipping the list up► 1.2-clicking the target photo (Table 5-22).

Table 5-22 Cognitive style-routes selection-Task 3-LG

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1► 1.1► 1.2	85%	90%	87.5%
2► 2.1	15%	10%	12.5%

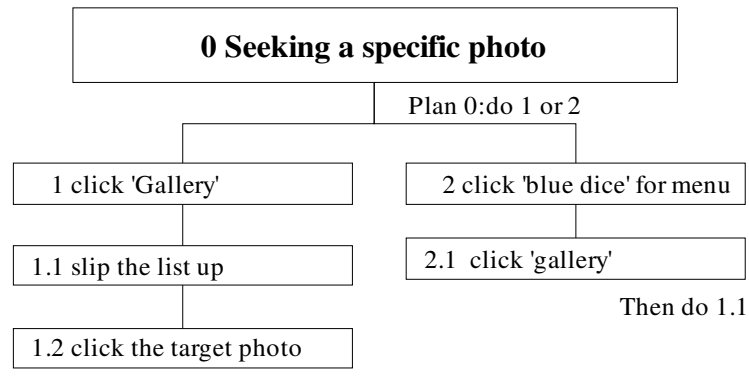


Figure 5-48 HTA of Task 1 on iPhone

HTC

The functional icon of ‘Pictures’ was located on the main menu; in addition, the photos could be reviewed via the function of ‘Camera’, and the function of setting wallpaper by pressing the physical ‘Menu’ button (Figure 5-49 and 5-50). The process takes 4-5 steps (Figure 5-51).



Figure 5-49 The icons of checking calendar with HTC



Figure 5-50 Sub-category of ‘Pictures’

Participants preferred to search for the target photo using 2-main menu. Both functional icons of 2.1-Camera and 2.2-Pictures lead the users to the photo album. Around half of the holists were more likely to apply both routes whilst seventy percent of serialists preferred to seek the target photo via the category of ‘Picture’ (Table 5-23).

Table 5-23 Cognitive style-routes selection-Task 3-HTC

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1 ► 1.1 ► 1.2 ► 1.3	5%	0	2.5%
2 ► 2.1 ► 2.1.1 ► 2.1.2 ► 2.1.3	40%	25%	32.5%
2 ► 2.2 ► 2.2.1 ► 2.2.2	55%	75%	65%

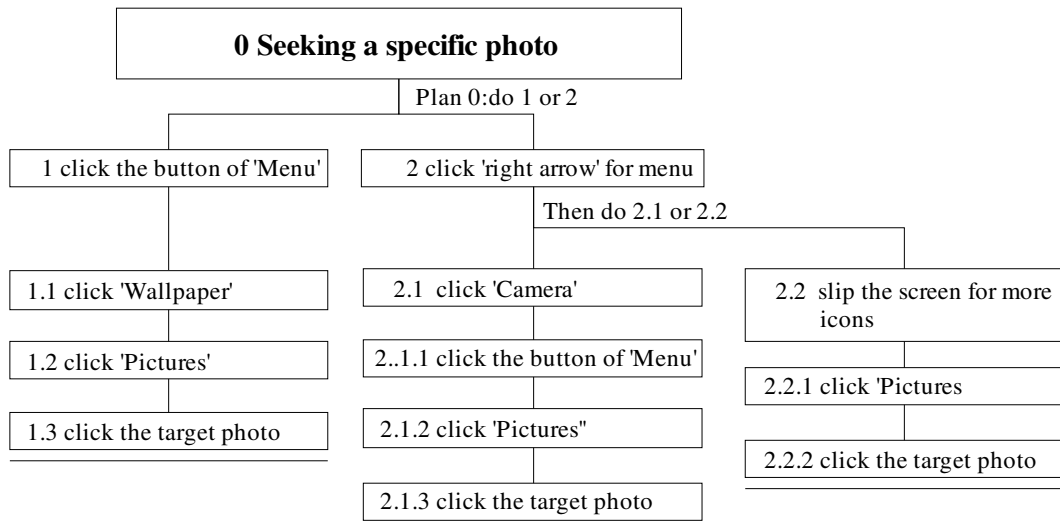


Figure 5-51 HTA of Task 1 on HTC

Nokia

Finding the target photo using the Nokia interface can be achieved via the graphic icon on the desktop or functional icon on the main menu (Figure 5-52). The function of 'Photos' includes five folders in the sub-category. The target photo was saved in the 'Download' folder. Each folder presents a summary when the icon is pressed once (Figure 5-53). The task can be completed in 3-4 steps (Figure 5-54).



Figure 5-52 The icons of checking calendar with HTC



Figure 5-53 Sub-category of 'Photos'

Over half of holists and serialists accessed the photo albums via the graphic icon on the desktop. The target photo was saved in the folder of 'Downloads' located at the end of the list. Participants clicked 1-graphic icon of Photos on the desktop ► 1.1-Downloads ► 1.2-the target photo. Due to participants uncertain about the location of the target photo, 80% serialists checked the albums on the list one by one. In contrast, 75% holists checked albums randomly and repeatedly (Table 5-24).

Table 5-24 Cognitive style-routes selection-Task 3-Nokia

Routes	Holists	Serialists	Total
	N=20	N=20	N=40
1 ► 1.1 ► 1.2	65%	70%	67.5%
2 ► 2.1 ► 1.1 ► 1.2	35%	30%	32.5%

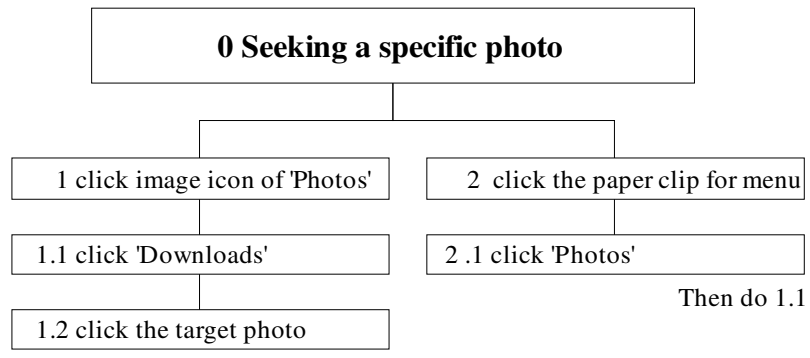


Figure 5-54 HTA of Task 1 on Nokia

Samsung

Due to the restrictions of the Samsung emulator, the function of viewing photos via the graphic icon on the desktop would not work. Therefore, participants were required to find the target photo via the functional icon of ‘Photos’ on the main menu. The hexagon button and the ‘Start’ icon on the desktop both provide access to the main menu (Figure 5-55). The category of ‘Photos’ includes customised photo albums with a thumbnail photo and a text title (Figure 5-56). The target photo can be found with 5 steps (Figure 5-57).



Figure 5-55 The icons of checking calendar with HTC

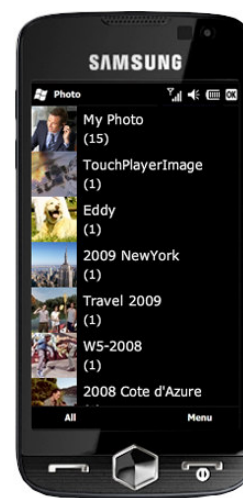


Figure 5-56 Sub-category of ‘Photos’

Seventy percent of holists tried to seek the target photo using the shortcut icon from the desktop first. In contrast, sixty percent of serialistic participants ignored the shortcut. They accessed to the main menu by clicking 2-hexagon button then 2.1-slipping the page ► 2.2-click Photo ► 2.3-find the category of the target photo ► 2.4-clicking the target photo (Table 5-25). In the mean time, 65% ($N=20$) of holistic users slipped the sub-categories page before checking the photo in the folders, with only 20% ($N=20$) of serialists doing the same.

Table 5-25 Cognitive style-routes selection-Task 3-Samsung

Routes	Holists	Serialists	Total
	$N=20$	$N=20$	$N=40$
1 ► 1.1	70%	40%	55%
2 ► 2.1 ► 2.2 ► 2.3 ► 2.4	30%	60%	45%

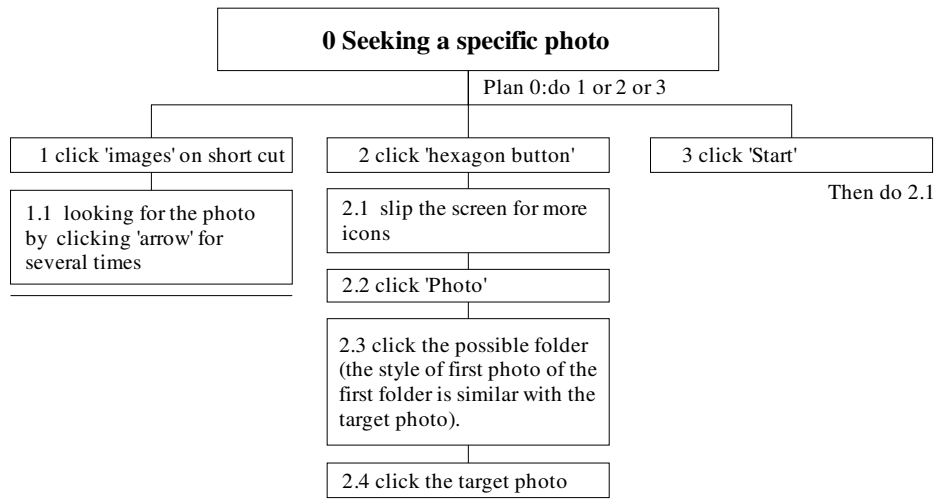


Figure 5-57 HTA of Task 1 on Samsung

5.6.2 Observations

The route that the individuals applied followed in achieving the goals listed based on the hierarchical structure of the menu with each interface and the time of moving to next icon was also recorded. This section summarises the results of the observation schedule that was mentioned at chapter 5.4.2. Moreover, it establishes the link between the mobile phone users' practical operational behaviour and the attributes of holistic and serialistic styles.

a) how cognitive style differences affect an individual browses icons

According to Ford (1985), holists tend to apply a global approach to learning; conceptually oriented and with broad description building (Jonassen and Grabowski, 1993.) Serialists tend to have a local approach, narrowing the focus on procedures before describing the overall picture and working step by step (Ford, 1985). In this investigation, holistic participants preferred to skim icons from the desktop firstly. During the process of completing the tasks, over half of holists reported that they could not find the icon required to complete the task when the available icon was located on the desktop. Some of them performed nervous moves of the mouse to check icons without any order. In contrast, serialists approached the task more carefully. They moved the mouse to check icons one by one, slowly.

b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface

In terms of the theoretical attributes of holist and serialist, they apply different strategies to interact with hierarchical structures (Ford, 1985). Whilst holists tend to establish top-down links, the participants tended to complete the task via the icons they were familiar with. Meanwhile, serialists tend to establish bottom-up links. In this investigation, the users seemed to have an understanding of how to complete the tasks when they clicked the icons, and kept establishing links with the other icons that could be applied to achieve the goals. According to the users' performance in sending message, the most commonly selected icon used to complete the task is the graphic functional icon with the relevant title, such as 'Message', 'Text', 'Messaging'; then the graphic functional icon of 'Contact', followed by the graphic icon such as an

envelope, paper and pen, and then the text icon of 'Contacts' and 'Phonebook'. Holists and serialists also performed differently with selecting icons used to complete the tasks.

Holists tended to be function-oriented and preferred to select known icons on the desktop to complete the tasks. If the necessary icon was not found on the desktop, holists tended to click available icons randomly and double checked the icons that they had just clicked on.

Serialists were more goal-oriented and preferred to complete the tasks using routes where they were certain of the consequence. They preferred to access the main menu to seek the icon that could be used to achieve the goal.

c) *how cognitive style differences affect how an individual seeks the target photo within the unknown folders of Task 3*

According to the attributes of holists, they tend to apply analogies to develop the connection between different aspects of the subjects (Ford, 1985), and prefer high order relations between objects (Pask and Scott, 1972). In contrast, serialists prefer to apply a step-by-step strategy, establishing connections between data via low order relations (Ford, 1985; Pask and Scott, 1972). Therefore, their performance in this investigation was illustrated as follows:

Holists displayed panic whilst interacting with unknown icons, buttons, and folders, especially whilst seeking the target photo. They then checked the possible functional icons randomly and repeatedly.

Serialists reviewed icons one by one on the page instead of quick skimming and selected the possible icon that they understood to be one of the sequence steps; additionally, they checked uncertain icons, buttons, and folders one by one with order. Their behaviour was more orderly.

Based on the users' behaviour, it is necessary to confirm the relationship between individuals' cognitive styles and the ability to operate within hierarchical structure.

d) *how cognitive style differences affect whether or not the individual follows the same route to complete the task across different interfaces*

Based on the participants' performance as discussed above, it shows a trend as holists tend to apply one strategy to complete a task across six interfaces rather than serialists. The phenomenon was found with Task 1: sending a message. Table 5-26 shows that half of holists completed Task 1 following the same pattern, selected the same categories. To contrast, serialists were more flexible. Only half of them apply the same strategy to complete Task 1 across 3 interfaces.

Table 5-26 Holists and serialists' selection of categories to complete Task1

	Holists	Serialists
Select the same category to complete Task 1 with 6 interfaces	25%	10%
Select the same category to complete Task 1 with 5 interfaces	50%	30%
Select the same category to complete Task 1 with 4 interfaces	15%	10%
Select the same category to complete Task 1 with 3 interfaces	10%	50%

Holists tended to complete the three tasks via the same categories and routes across all six interfaces.

Serialists showed a greater tendency to apply different categories when completing the tasks across different mobile phone interfaces.

The phenomenon suggests that holistic-serialistic style might also affect the individual's problem solving ability with regard to the rigidity of mental set.

Holists pressed more irrelevant icons during the investigation when they could not find the icons, buttons, and folders to achieve the goal. Serialists clicked icons more often due unfamiliarity with operating certain interface, such as slipping the page or moving the scroll bar. This study thereby assumes that holists tend to functional-oriented whilst serialists are more likely goal-oriented.

As a result, the participants' operational behaviour can be linked to the attributes of holistic and serialistic styles as follows (Table 5-27).

Table 5-27 Linkage between holists and serialists' attributes and operational behaviour

Holist		Serialist	
Operational behaviour	Theoretical attributes	Theoretical attributes	Operational behaviour
Skimmed icons quickly, neglected the target sometimes.	Focus on several aspects of the subject at the same time.	Step by step approach.	Reviewed icons carefully instead quick skimming.
Preferred to select known icons on the desktop to complete the tasks. If no known icons were available to achieve the goal, the tendency was to select any available icon rather than accessing the menu to check for all functional icons. As a result, there was sometimes initial difficulty completing the task and instead time was spent seeking the known icons for the completion of the tasks.	Establish relationships between objects by using complex links, using top down approach.	Serialists concentrate on the chunks of information that are sequentially ordered and better defined.	Serialists were more goal-oriented and preferred to complete the tasks following routes where they certain of the consequences.
When there is no clue for finding the target within unknown folders, holists preferred to double check the folders in a random manner. It seemed that they do not remember which folders had been reviewed and there was difficulty establishing the order within unknown folders.	Likely to use analogies to make the connection between different aspects of the subjects.	Use a bottom-up approach.	Serialists preferred to apply the icons via the main menu. In the meantime, they tended to clarify the function of each icon before moving on to next step.
Tended to complete the task following the same categories and routes across all six interfaces.	Relate concepts to prior experience.	Relates characteristics within a concept.	Also tended to complete the tasks based on their comprehension of the interface in the context. They performed more flexibly of achieving the goal via different categories and routes.

Based on the participants' performances, the impact of cognitive style on individuals' seeking of unknown icons with mobile phone interfaces is illustrated in Figure 5-58. It seems that serialists' operational behaviour tends to be more predictable than holists. The difference is highlighted by the strategy of checking unknown items randomly (holist) or one by one (serialist).

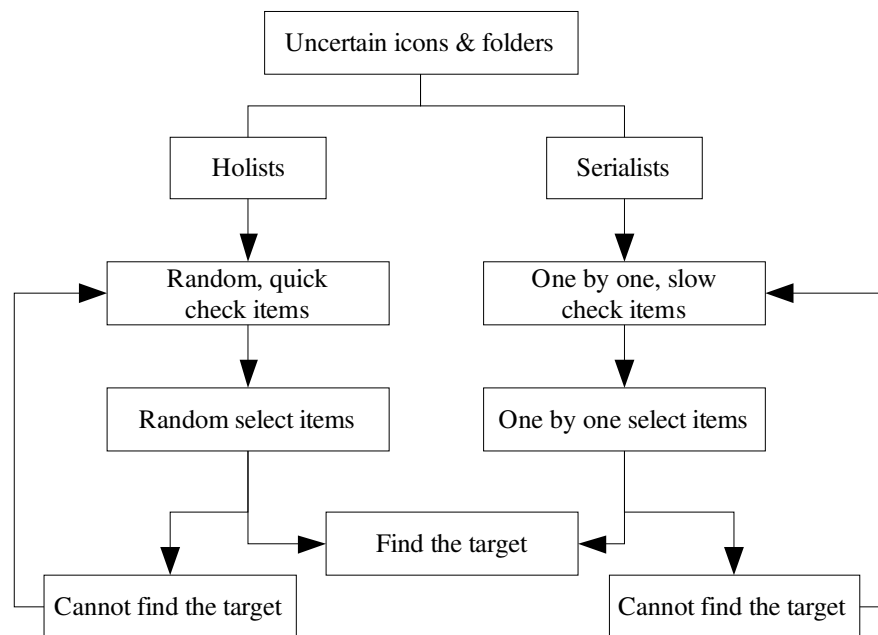


Figure 5-58 The impact of cognitive style differences to seeking uncertain items on touch screen mobile phone interfaces

5.7 Discussion

This chapter intends to establish the link between individual differences in phone users' operational behaviour when using touch screen mobile phone interfaces. More specifically, this investigation presents the effects of cognitive style on individuals' interaction with phone interfaces. In terms of the findings in chapter 4, cognitive style differences seemed to be a factor in the users' operational behaviour with phone interfaces. This investigation therefore attempts to examine individuals with phone interfaces in terms of two groups to displaying the attributes of differing cognitive styles - holistic and serialistic. Although different types-numeric mobile phones and the emulators of touch screen mobile phones were applied in chapter 4 and in this study; this research focuses on the users' interaction with the interfaces. Therefore, the formats of the interfaces of the instruments were being addressed more than the differences of psychical handsets.

Additionally, this study examines individuals' performance with phone interfaces according to gender and UX in order to develop the consistency of this research.

In terms of literature review, women seemed to perform better than men in tasks that required fine motor manipulations (Halpern, 2000). According to the findings of chapter 4, females indeed completed tasks faster and clicked fewer numbers of icons to achieve the goals than males with numeric keypad mobile phones. However, in this investigation, females performed slower than males with most tasks using touch screen mobile phone interfaces. This may be as a result of this study being conducted using prototype interfaces on computers. Based on Passig and Levin's (2001) study, boys were more familiar with computer games, and thus performed better than girls with tasks involving computer interfaces. In addition, males displayed better computer skills than females according to the factors of experience (Arenz and Miheon, 1990), self confidence (Chen, 1985), attitude (Arenz and Miheon, 1990, Wilder, Mackie and Cooper, 1985) and so forth. Due to the instruments of numeric keypad mobile phones were applied in chapter 4; prototypes of touch screen mobile phone interfaces were interacted within the computer environment for the purposes of this investigation; it is difficult to ascertain if females would perform better than male in completing tasks using touch screen mobile phones.

Based on the findings of chapter 4, cognitive style seemed to be one of the factors which impacted the users' interaction with phone interfaces. In addition, previous studies address the users' difference between variables via quantitative data (e.g. Lee, 2005; Unsworth, 2005; Kim, Lee and You, 2007; Kim, Lee and You, 2007; Chen, Magoulas and Dimakopoulos, 2005). This research reveals a weakness in interpreting how the theoretical attributes reflect on the users' interaction with computer or mobile phone interfaces. This study thus focuses on the effects of cognitive style differences on phone users' interaction with touch screen phone interfaces. Two stages of data analysis were included in this chapter. Stage one analyses the impact of individual differences on the participants' performance with quantitative approaches; the qualitative analysis of stage two establishes detailed descriptions to point out how cognitive style-holist and serialist reflect on the individuals' operational behaviour with phone interfaces.

For the understanding of the users' performance between ideal error-free completion time of task and practical operation, KLM was applied in this investigation initially. According to the comparison, the users apparent spent more time to complete tasks than expected. The phenomenon might occur as a result of the users' time spent seeking items and adapting the other elements of the interfaces. In general, holists performed better with Group A interfaces that have holistic style. However, serialists performed better not with Group B interfaces that are compatible with a serialistic style, but also in parts of tasks with Group A interfaces. The significant differences between conditions were therefore focused for further analysis by HTA.

Previous studies tended to examine the relationship between cognitive style and the users' performance with their preferences of different categories within designed interfaces (e.g. Masuda and Nisbett, 2001; Unsworth, 2005; Kim, Lee and You, 2007.) However, based on the phone interfaces in the market, the users' performance seemed more relevant to the number of steps taken to complete the tasks. Holists and serialists' operational behaviour was found to be the significant difference between cognitive style and Task 3-seeking a specific photo with the interfaces of Blackberry, Nokia and Samsung touch screen mobile phones. This research was then applying HTA to present the steps of completing tasks with the six phone interfaces. According to the analysis, the Task 3, seeking a specific photo requires more steps to complete than the other two tasks; more specifically, the menu on the three phone (Blackberry, Nokia and Samsung) interfaces present several folders with text titles that are irrelevant to the target. Whilst comparing the routes that the users applied to complete the tasks in this investigation, two phenomena were found and might be examined with two psychology tests.

In response to the hypothesis of how cognitive style affects the users' operational behaviour of achieving the goal with different interfaces on touch screen mobile phones; holists tended to complete a task with the same strategy across six touch screen mobile phone interfaces, whilst serialists seemed more flexible in completing a task with different routes with different interfaces. The phenomenon seems related to individuals' rigidity of mental set as sometimes people apply one

strategy or hypothesis to similar tasks even when better alternative solutions were obvious (Bernstein, Roy, Srull and Wickens, 1991).

Furthermore, in response to the hypothesis of how cognitive style affects the users' operational behaviour in seeking the target with unknown categories; the significant results were found. In terms of the findings, serialists completed objectives faster than holists in Task 3 (seeking a specific photo) that involves multiple folders with the interfaces of Blackberry, Nokia and Samsung. According to the observations of this investigation, serialists seemed to be taking advantage of the 'step by step' strategy and concentrating on the sequence of the operation whilst interacting with the hierarchical structure within phone interfaces. Meanwhile, holists tended to seek the target photo via checking the multiple folders randomly.

Both the phenomena were linked to individuals' problem solving ability as it is 'a specific situation or set of related situations to which a person must respond in order to function effectively in his environment' (D'Zurilla and Goldfried, 1971, p.107). Based on the concept of understanding phone users with mixed methods by placing the users as the core of design process, the users' interaction with phone interfaces was therefore linked to fundamental psychology, to approach design from an alternative perspective. Further discussion was shown in chapter 7 that focuses on the connection of holistic-serialistic cognitive style and individuals' problem solving ability.

Finally, the users' interaction with phone interface was compared with the theoretical attributes of holistic and serialistic styles. The descriptions of phone users' operational behaviour that were coherent with holistic and serialistic attributes were thus developed.

User experience was also involved in this research, based on the findings of chapter 4 and this investigation, UX was indeed affecting the participants' performance with phone interfaces. The similarity of interfaces was the crucial factor impacting the users' interaction with phone interfaces. In the meantime, the quantitative data was not able to interpret the necessary elements that influence

individuals' UX with phone interfaces. As mentioned in chapter 2.4.3, UX consists of three aspects as it is beyond the instrumental, including emotion and affect, and the experiential (Hassenzahl and Tractinsky, 2006). In terms of the aim of deeply understanding users, this research thus intends to obtain detailed UX, to understand the users' requirements of mobile phones. A novel methodology-Taxonomy of Experience (ToE) was therefore applied in this research, further exploration was discussed in chapter 6.

5.8 Summary and Conclusions

This chapter not only establishes the linkage between individuals' cognitive style and their operational behaviour with touch screen mobile phone interfaces, but also provides an alternative aspect to develop the linkage between holistic-serialistic style and individuals' problem solving ability. The findings provide a clearer picture of how to categorise holistic and serialistic users based on their interaction with mobile phone interfaces. Due to UX showing a significant impact on the users' operational behaviour with phone interfaces, chapter 6 then discusses how to obtain UX, in order to understand the necessary elements that the users care about the most. In terms of the findings in this study, the relationship between cognitive style and problem solving ability was investigated in chapter 7. More importantly, the categories that describe phone users' operational behaviour consistent with theoretical attributes of holist-serialist were examined in chapter 8 for further confirmation of its application.

More specifically, the concept of categorising phone users in terms of their operational behaviour, and then providing a customised interface to improve the usage of a phone might be accomplished from this point of view.

CHAPTER 6 TAXONOMY OF EXPERIENCE (ToE)

Overview

The effect of UX on the users' performance with phone interfaces was found in chapter 4 and 5 as the familiarity of interfaces is a crucial factor. More importantly, the users' points of view with regard to defining 'easy to use' vary in chapter 4. The research questions were raised about how to obtain UX and what elements the users care about the most. Most approaches of understanding users tend to collect and to analyse data as qualitative format, such as interviews, questionnaire, observation, diary, focus group and so forth (see Table 2-8 in chapter 2). However, the application of those approaches tends to obtain and to analyse the understanding of users for specific purposes; more importantly, only the purposes were be noticed and discussed. Besides, researchers attempt to transform UX such qualitative data into quantitative analysis, there is a lack of detailed descriptions to understand users' needs. This research aims to understand phone users from the root, to concern the users' requirements of mobile phones from their points of views. A novel methodology-Taxonomy of Experience (ToE) and its analytic process of SEEing was introduced in this research to further understand the impact of UX on individuals' operational behaviour with mobile phones. In terms of the effects of cognitive style on the users' strategies in operating phone interfaces, to focus on the information on the interfaces, this investigation also attempts to categorise UX by their cognitive style differences.

6.1 Introduction

User experience was found to have a significant impact on phone users' completion time and the number of icons clicked to complete tasks in chapter 4 and 5. Participants performed better with the interface that was similar to their own phones. Meanwhile, they contributed the criteria of defining an 'easy to use' mobile phone. As mentioned in chapter 4.3.4.2, the users expected a phone with a few functions, a sensitive screen, easy task completion and so forth. Based on the aim of understanding phone users deeply, it is therefore necessary to describe the

users' operational behaviour with phone interfaces, and to find the elements that the users care about the most. Furthermore, design guidelines for phone interfaces have been well established by mobile phone manufacturers. It includes the design principles of content, layout, colour, font size, text and terminology and so forth. It is also necessary to understand the users' requirements from the users' perspective. As the market for touch screen mobile phones continues growing, understanding both experienced users' thoughts and novices' expectations of mobile devices is essential to allow manufacturers to provide better solutions for future design.

With regard to general qualitative approaches of understanding users, it is necessary to set key questions to analyse the data (Silverman, 2005) and to categorise the data by themes (Farsides, 2010). However, the literature outlining qualitative methodologies lacks clear instruction on how to define themes for UX (e.g. Bryman and Teevan, 2005; Silverman, 2005). In general, researchers have to define and code the phenomena before analysing the qualitative data depending on their requirements of the subjects. As mentioned in chapter 2, user experience is subjective, and represents more implications than the usefulness and usability of a product (Alben, 1996). Due to user experience being comprised of diverse aspects, it is difficult to measure and to evaluate. The methodology-Taxonomy of Experience (ToE) was therefore introduced in this research because it has established the themes for categorising the collected UX. It is a tool that was developed by Coxon (2007) to categorise UX by the users' verbal commentary when trialling an object. Its analytic tool-SEEing represents the process of analysing the users' verbal commentary. The term attempts to differentiate the role of analysis from the processes of thinking, but still associates it with the thinking processes. ToE-SEEing is a qualitative methodology used to further understanding of the user's experience. It provides the categories to refer UX into different levels of themes. The results present the distilled elements that the users care about the most.

6.2 Background of Taxonomy of Experience (ToE)

ToE is a qualitative method which helps to understand the user's experience with a product via analysing their verbal commentary to find the deep meanings hidden from the verbal commentary. It combines empirical (Brezet, Vergraght and Van der Horst, 2001) and academic (Feenberg, 2000; Glanville, 1999) perspectives. Previous studies that relate theory and practical concepts of user experience (Schmitt, 1999) provide a good foundation to establish this methodology (Coxon, 2007). The structure of the ToE is based on philosophy, methodology and design theory; thus the ToE provides a multi-layered method for understanding user experience. In developing the initial concept for understanding the experience of transportation vehicles, Coxon realised the importance of 'understanding the experience of those people already involved in designing and using the vehicle' (Coxon, 2007, Ch.3 p.2). Therefore, Coxon discussed positivism, idealism, realism (Higgs, 1997), and applied phenomenology as a methodology to understand individual lived experience. Whilst Coxon (2007) reviewed the video that recorded his own trial experience of an electric vehicle, it helped to recall the deep aspects of the experience that he was not particularly conscious of while personally trialling the vehicle. The process of transcribing the sequence of the dialogue and other activities once again brought the experience more vividly into focus. Figure 6-1 is the framework for understanding an experience from four perspectives. The experiential event impacts the user's cognition (thinking and acting), engages sensorial aspects, and impacts one's emotions and feelings. These elements are all taking place within an existential framework of temporality, spatiality, relationality and corporeality (Coxon, 2007).

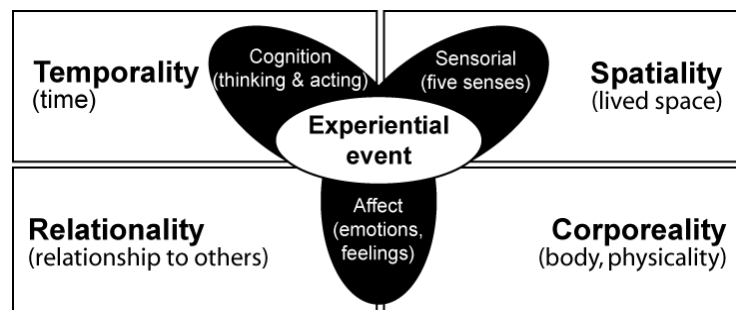


Figure 6-1 Framework of an experience

Coxon (2007) thus develops the multi-layered analysis process of SEEing for understanding users deeply that is also supported by van Manen (1997). The SEEing process suggests that when writing about 'lived experience descriptions', the descriptions should be able to a) describe the experience as it is lived without asking why; b) describe the experience from the inside, the feelings, mood, and emotions; c) focus on a particular example of the experience and to describe it; d) focus on an example that stands out, as it was the first time; e) aware how the body feels, smells, sounds and so forth; and f) avoid trying to beautify the illustration with flowery language or terms. Overall, the ToE-SEEing process brings an experience to a comprehensible and visible format rather than an abstract concept. The outcomes therefore provide the distilled, important, categorised, necessary elements of the object by a summarised phase and short paragraphs to describe those elements. It has been applied to some students' projects to understand UX with teaching, developing an avatar, using mobile phones and so on. This research aims to understand phone users deeply and to describe the users' requirements of a phone. ToE-SEEing provides a platform to categorise the collected UX and to select the useful, necessary elements for improving design. The nine steps of conducting ToE-SEEing are as follows:

Step 1: Gathering data and establishing structures

It is important that the researcher 'gets to know' the experience, becoming familiar with the experience by understanding its 'language'. This stage emphasises the need for the researcher to immerse themselves in the experience completely (Csikszentmihalyi, 1991; Hanington, 2000). The data of people's experience can be collected from observations, interviews, and contextual studies that are captured in creative ways. The information of images, sounds, samples or the other type of information collected might be useful to the researcher to help recall the user's experience and to write the descriptions for further analysis at a later stage.

Step 2: Descriptive narratives

This is the process of transforming the data collected in *Step 1* into a textual format for analysis. This stage also breaks the experience into fragments as small as a single word, or a phrase, and puts them through the SEEing process.

Step 3: Sorting fragments into themes

This step includes meta-themes and sub-themes. Meta-themes in the SEEing process include somatic, affective, cognitive and contextual factors; the sub-themes include senses, positive/negative affect, internal/externalised cognition, and many contextual categories. Each theme has a collection of fragments, and provides the researcher with the feeling of the story that they are telling.

Step 4: Developing meaning(s)

This step requires the researcher to look at each fragment of information carefully and to find other deeper ‘meanings’ behind the fragment. This process helps to ‘tease out’ the text into different meanings. It is not yet time for the researcher to judge or to interpret what they think the meanings of the fragment ‘should be’ or ‘could mean’. Rather, the aim of this process is to accept all ‘possible’ meanings that are contained within the fragment.

Step 5: Essential elements

This step helps to filter out the less important meanings. The researcher has to determine if the meanings in *Step 4* are incidental or vital to the essential nature of the experience. It is necessary to know the importance of the experience, whether if the element is essential to the experience, or if the experience might be different without the element.

Step 6: Super-ordinary elements

This step distils the super-ordinary essence of the experience, i.e. the unexpected, novel and hidden aspects of the experience. Aside from the functional, form oriented, and everyday aspects; this stage isolates those elements of the experience that might not have been seen as an important part of the original design. However, those elements are still an important part of the experience. This process searches for the surprising elements, the unintended impacts of the experience.

Step 7: Weighting of super-ordinary elements

This is a weighting process to consider which super-ordinary elements are the more ‘powerful’ of the essential elements of the experience. The researcher

evaluates the super-ordinary elements using his understanding of the language of the experience, with the aim of describing it on a subjective numerical scale using a Likert rating (1-7, 1 is low) to determine a relative level of intensity.

Step 8: Super-ordinary summary words

The sorted super-ordinary elements in descending order provide a ranking of the essential super-ordinary elements of the experience by intensity. This stage uses word metaphors to synthesise ‘*what is the collective meaning behind these elements*’? For example, the super-ordinary element of ‘no risk means no fun’, could essentially be a statement about ‘freedom to enjoy danger’.

Step 9: Summary word descriptions

The previous step summarised the super-ordinary elements; this stage focuses on ‘explaining’ the summary. It concludes the work of *Step 6-8*. One or two narrative paragraphs helps to communicate an understanding of the experience to someone who does not understand the meaning of the super-ordinary words.

6.3 Study design

This is the first trial of applying ToE-SEEing to obtain mobile phone users’ UX. This research realises the importance of understanding phone users in context (Jones and Marsden, 2005). Nevertheless, this is the first trial of applying ToE-SEEing to obtain mobile phone users’ UX. For the purpose of simplifying the variables to make sure the collected data is clear and precise, this investigation was conducted in the laboratory. Due to one of the aims in this investigation being categorisation of the users’ UX based on the differences of cognitive styles, participants were also given the SPQ to identify their cognitive style. As technology improves, touch screen mobile phones are the growing trend in the market. In addition, more significant results between individual differences and their operational behaviour were found in chapter 5 when touch screen mobile phone interfaces were applied as instruments. This study therefore utilises touch screen mobile phone to obtain phone users’ UX. The participants’ interaction with the phone was filmed for further analysis. The camera only focused on their hands and the mobile phone, and recorded their verbal commentary without showing their faces.

6.3.1 Task design

According to Coxon (2007), it is important to have participants' verbal commentary about the users' experience of the object for conducting ToE. Participants were given five minutes to free trial a touch screen mobile phone. The only constraint was that participants were not allowed to damage the phone.

6.3.2 Instruments

The SPQ was applied in this investigation to identify the participants' cognitive style. The aim of this study is to understand how UX affects phone users' requirements of a mobile phone; therefore, an unfamiliar instrument is necessary in order to obtain the users' experience with an unfamiliar interface. Touch screen mobile phones have become a trend in the market in recent years. A Vodafone 541 mobile phone (Figure 6-2) was thus selected due to the fact that it is a previous generation touch screen mobile phone; besides, according to the investigation in chapter 5, most users preferred phone brands of iPhone, Blackberry, Nokia, Samsung, HTC, LG and so forth. As a result, operating the Vodafone 541 should be a new experience for most participants. More importantly, the hardware and software are not advanced enough to compete with new generation phones, such as the iPhone. This selection attempts to provide the participants with more opportunities to talk about the experience of using this phone.



Figure 6-2 Vodafone 541

6.3.3 Data collection

This interview was conducted in a laboratory. To analyse UX of participants, it is necessary to collect data from their whole experience of trialling the instrument. Meanwhile, participants were required to apply the approach of 'think aloud' to express their UX when operating Vodafone 541. The participants' interaction process with this phone was filmed for further analysis.

6.3.4 Study procedure

Participants were firstly required to answer SPQ to identify their cognitive style tended toward holistic or serialistic in terms of the measurement that was established by Ford (1985). Then the observer demonstrated to participants how to apply the approach of 'think aloud' by trialling a touch screen camera that was operated by a similar method to a touch screen mobile phone. Participants were also given the touch screen camera to practice the 'think aloud' protocol. The practice intends to help the participants to get used to expressing their experience while trialling the Vodafone 541 mobile phone. Before starting to trial the phone, participants were asked if they were in a comfortable position to operate the phone. Finally, participants had five minutes to free trial the phone as they wished. Their interaction behaviour with the mobile phone was filmed for the ToE-SEEing analysis. A camera was set up for recording the movements of individuals' fingers and the methods they apply to complete each task. More importantly, the observer was not allowed to intervene in the participants' operation.

6.3.5 Participants

Twelve participants were recruited from a British university. Half of them currently use touch screen mobile phones, whereas the other half currently use numeric keypad mobile phones. In addition, this investigation aims to have an equal number of UX and holists-serialists in each group. Overall, half of the participants are female, half are male, aging 18-30, with a mean value of 25 ($SD=3.7$).

6.4 Data coding and analysis

All collected data at *Step 1* of ToE-SEEing was transcribed to Microsoft Excel 2007 at *Step 2*. The participants' interaction with Vodafone 541 and verbal commentary were reviewed as video clips and transformed to text. More importantly, the observation from the observer was also included in this step. For the purpose of understanding the context of the users' operational behaviour, this study also orders the users' commentary and the observations. In terms of the themes that were developed by Coxon (2007) in step 3, the data was referred into the categories (Appendix G).

As mentioned earlier, *Step 3* includes two layers of themes (meta-themes and sub-themes). Firstly, each participant's verbal description of the experience was coded into different themes. The meta-themes include the body-somatic experience (sensorial experiences, sound, touch-feel, sight, smell, taste, comfort-ergonomics, and appearance-aesthetics); the heart-affective experience (positive-negative emotions); the head-cognitive experience (conation-reflective thought-external-doing, conscious cognition-reflective thought-internal-thinking.); as well as a range of contextual factors (environmental, regulatory, social factors), and existential factors (time, space, corporeality body, and the relationship to others). Most of the participants' usage experiences with the touch screen Vodafone 541 mobile phone strongly relate to the sub-themes of sight and cognitive experiences. As mentioned in chapter 6.2, *Step 4* aims to develop meanings of the users' commentary and the observation from this investigation. *Step 5 and 6* then distil the essential, super-ordinary elements. Those elements were given Likert ratings (1-7, 1 is low) to weigh the power of the elements of the trialling experience with Vodafone 541 in *Step 7*. The rated elements were then given word metaphors in *Step 8* to indicate the main collective meaning behind those elements. All the summarised super-ordinary elements were explained in *Step 9* with the narrative paragraphs to present the understanding of the experience. Finally, the participants' trial experience was given work metaphors to clarify the collective meaning behind the essential, super-ordinary elements. The followed section presents the users' UX that was summarised in *Step 9*.

6.5 Results

In terms of Step 7, the elements of the experience that the users cared about the most were weighted according to how 'powerful' they were them. Then, in this research, the elements were also concerned with the number of times the individuals mentioned. Then this section therefore presents the elements ranked by the importance of what the users cared about the most when using Vodafone 541 based on Step 8 and 9. More importantly, this section also points out how the elements might impact upon the users' performance with a phone interface.

Understanding-from the head

According to the participants, it was important to understand how to operate an interface before using it. Clear instructions, titles of buttons/icons and the feedback from the system are the criteria which deliver the information from the phone system. Participants' verbal commentaries regarding this concept were listed as follows:

- It is important to see that the 'graphic icon and its title are consistent, and represent the function clearly'. Clear feedback is given confirming whether or not the operation was successful.
- It will be good to see clear title/sign of buttons/icons.
- Clear feedback is necessary for confirming whether or not the operation succeeded.
- It is essential to show instructions for unique features of the phone, maybe demonstrating how to operate the feature, or making it easy to get 'help' information.
- The popular icons should be highlighted.
- Most participants trial the phone by sending a text message.
- The interaction process should fit the user's operational habits and logic.
- Sensitivity of the touch screen is crucial, and should fit the user's pace when operating the phone.
- It will help to reduce mistakes if the phone can highlight what the mistake was, to detect the failed task automatically, and then provide help and instructions on how to complete the task correctly before the user has to ask for help.

- The user would like to dominate, to trust the phone, and to fully understand the operation process before using the phone.

Experienced and familiar-from daily life and history

Familiarity with an interface from everyday life and previous interaction with devices also impact on the participants' operation with Vodafone 541. The experience is not only limited to the interaction with interfaces, but also the methods of operating devices. Participants thus indicated how previous experience influences their operational behaviour with the phone interface.

- Previous experiences of operating the computer and other phones might impact users' adaptive ability when interacting with an unfamiliar mobile phone.
- The way to operate the scroll bar on Vodafone 541 should be the same as using the scroll bar on a computer.
- From previous experience of using a mobile phone with a 12 button keypad, it would be good to see that the icon becomes highlighted when browsing the icon on the menu.
- The camera is important in every day life.
- Comparing the interface of Vodafone 541 with iPhone.

Freedom-from the operation

It was also important to have freedom whilst using a mobile phone. The freedom includes operating functions without going back to the main menu and considerations such as the size of the phone.

- The phone should provide links between different functions, rather than having to go to the menu to execute another function.
- The size of the phone provides the freedom for the user to carry it all the time, and allowing the user to hold the phone in the hand easily without worrying that the phone might slip from their grasp.

Specific-from the physical

The physical nature of a handset also informs the position from which the device is operated, as well as affecting how to test the device, if the phone is easy to use and whether if the individual is familiar with the device or not.

- Operating the phone with specific position or method might make it easier to complete the task.
- Trial an unfamiliar phone with daily used functions to understand the usability of the phone.
- The phone is not advanced and might mean that the phone is easy to use.
- Showing the brand of the phone might provide information about how to use the phone.

Share-from the mind

Sharing the pleasure with a handset with friends was also one of the important elements which influenced the user's UX.

- Easy to carry the phone (small and light weight) and share the enjoyment with friends.
- Would like to show the phone often.
- A good phone might make the user more likely to share more fun with friends and family.

Intimacy-from the combination

A handset should generate intimacy with a user, be of assistance to them and be easy to carry all the time.

- Link the phone with the user's life as it is a good assistant.
- The size of the phone might affect if the phone is easy to hold in hand(s) and this may influence the user's desire to use it more often.

Comfortable-from the mind

Feeling comfortable using a mobile phone was also an important element to the users. The feeling comes along with the user's expectation of the physical handset, the operation process and the information that the handset delivers to the user.

- Users expected the operation process to be easily performed without thinking, and easy to learn.
- Physical keypad gives the user direct confirmation of pressing; clear locker sign showed the way to turn on the phone; feel comfortable with the qwerty keypad.
- The size of the phone might affect users' secure feeling when holding the phone in their hands.
- Operating the familiar buttons from the same position on the phone;
- If the phone is not advanced it will be unnecessary to worry about breaking the phone or getting it lost in the system.
- Keep positive mood to trial the phone.
- Showing the capacity of the battery helps to understand how to manage time to charge and to use the phone.

Enjoyment-from the entertainment

Enjoying entertainment functions with the mobile phone was also a concern of the users, such as playing games when having a seat or standing, operating the game with one hand or both hands, using keypad or a touch screen to interact with the game; and how to quickly access the games.

- Multimedia functions bring more fun to the user's life, no matter the position to operate on the phone; it should be able to achieve the goal immediately.

The elements that participants were concerned about were sorted by the importance as above. Those elements should have to be concerned when designing mobile phone interfaces. For the purpose of differing those elements from design guidelines of the industry, further comparisons are shown in chapter 9.3.1.2. Meanwhile, the data in this investigation was also analysed based on the differences of cognitive style and if the individual was currently using a touch screen mobile phone. However, users' requirements of Vodafone 541 showed a similar tendency without the difference between conditions. Holists-serialists, touch screen mobile phone users and the users who currently use numeric keypad mobile phones are concerned with similar elements that are useful for improving the design of Vodafone 541.

6.6 Discussion

The importance of UX has been focused on in the phone industry in the last decade. Moreover, the investigations in chapter 4 and 5 also found that UX is one of the effects on the users' performance with phone interfaces. To achieve this research's aim of understanding phone users deeply, and to explore how individual differences impact the users' operational behaviour; participants expressed their UX with the instruments in chapter 4. There is a lack of an effective tool to analyse the users' UX with mobile phones and to understand the necessary elements that impact the users' experience with mobile phones. This investigation therefore introduces and applies ToE-SEEing to obtain and to categorise phone users' UX with a mobile phone.

The participants' trialling experience with Vodafone 541 was categorised into eight super-ordinary elements. The priority is the understanding of the meaning of functions that was presented by graphic icons and text. In terms of the participants' UX, to release the meaning of graphic icons, the text title of icons, the progress of the operation, and the response from the handset are crucial. Comparing the users' operational behaviour in chapter 4, seventy-three percent ($N=22$) participants spent some time searching for the button to access the menu. It was the case that the graphic representation of the button was unfamiliar and no text was applied to the button. Meanwhile, this criterion was only mentioned when they spent more time seeking functional icons. It is necessary to note that the users expected the mobile phone to be able to highlight, to detect the failed task and then provide instructions to complete the task without asking for help. According to the observation in chapter 5, some participants spent a long time seeking the functional icons and targets to complete the tasks. It would be better to provide help when the user is struggling to achieve a goal.

In addition, the familiarity of the phones and using experience from every day life and history also impact the users' UX. More importantly, the effect of UX on the users' operational behaviour was examined in chapter 4 and 5 and the significant results show that the users' previous experience with the same brand of mobile phone conducted a shorter completion time and a fewer number of icons clicked

when performing familiar tasks. Based on the UX with operating a computer, highlighting the icons that the users are reviewing was also a concern of the users.

Participants in this investigation also mentioned the importance of accessing functions without going back to the main menu. For most of the mobile phones that were used in this research, it is necessary to return to the main menu to access the other functions. Although the most popular mobile phone (iPhone) provides a searching function to seek applications and data, the users are still required to leave the current application, go back to the main menu, and then turn on the other application.

Furthermore, the size of a handset affects the users' operation from physical as well as psychological aspects. The small size of a handset might impact the method and the gesture used in its operation. The users would like to show off to friends, to carry the phone often and to spend more time with the phone if the phone size is small. However, it must be pointed out that very small sized phones might not provide the feelings of security to the users when they hold it in their hand.

The validity of ToE has been examined with extensive observation data collected from video clips and interviews during the development process (Coxon, 2007). This method might be questioned due to its explicit subjectivity; nevertheless, as mentioned earlier, the nature of an experiential encounter is subjective, situated, complex and dynamic. Therefore, the ToE-SEEing process presents the function of distilling the true meaning that lies behind the verbal description of such a complex event. Overall, the results of applying ToE-SEEing provide detailed UX from the users' trial with the instrument that beyond the usefulness and usability. According to Norman (Anderson, 2000), UX is a sequence of experience since the user hear about the product until maintain and upgrading the product. ToE-SEEing provides a platform to categorise and to analyse the UX when the users interacted with the phone in the five minutes. The outcomes consist of diverse aspects and were not limited with hardware and software. The necessary elements were more emphasised the interaction between the users and the phone; the users'

internal state, the characteristics of the designed system and the context of the usage (Hassenzahl and Tractinsky, 2006).

6.7 Summary and Conclusions

This chapter introduces a novel methodology-Taxonomy of Experience (ToE) to understand the necessary elements of UX with a touch screen mobile phone. It is a useful tool to present the users' UX with a handset in this research and more importantly, to categorise the users' UX into clearer concepts of how UX affects the users' operational behaviour with a handset. In terms of the correlations between UX and the users' performance that were found in chapters 4 and 5, this investigation distils the prior essential elements to improve phone users' UX from the understanding of the presentation of icons and the similarity of interfaces and the methods used in operating a phone.

CHAPTER 7 COGNITIVE STYLE AND PROBLEM SOLVING ABILITY

Overview

Based on the findings of chapter five, users' interaction with the interfaces of touch screen mobile phones was affected by differences in cognitive styles, more specifically, when seeking the target photos within unknown folders. It implies that cognitive style might be one of the elements which impact individuals' problem solving ability. The aim of this chapter is to develop the connection between those conditions, more importantly, to confirm the phenomena that were found in chapter 5. This chapter thus introduces the theoretical background of problem-solving and two psychological tests for developing the link between holistic-serialistic styles and individuals' problem solving abilities.

7.1 Introduction

Chapters 4 and 5 examine the impact of individual differences in users' operational behaviour when operating numeric keypad and touch screen mobile phones. In terms of the findings of chapter 5, the categories for identifying a user's cognitive style were thus established based on the theoretical characteristics of holistic-serialistic styles. Additionally, the outcomes also imply that individuals' problem solving abilities might be affected by holistic-serialistic style differences.

According to the users' performance in chapter 5, whilst holists tended to apply one strategy to complete a task across different phone interfaces, serialists displayed more flexibility in applying different routes to achieve the goals. The phenomenon seems related to individuals' rigidity of mental set as people might apply one strategy or hypothesis to complete similar tasks, even when better alternative solutions were obvious (Bernstein, Roy, Srull and Wickens, 1991).

Furthermore, Ford (1985) emphasises that holists and serialists adopt different strategies to interact with hierarchical structure. In chapter 5, holists tended to seek useful icons and randomly check unknown folders for the targets. In contrast, serialists were more likely to apply a 'step by step' strategy to check icons and

folders in order and concentrated on the sequence of the operation with the hierarchical structure of mobile phone interfaces.

This chapter therefore firstly reviews literature and previous studies to clarify the definition of problem solving ability. Two psychological tests: *Luchins's jar problem* and *Tower of Hanoi* were applied to develop the link between holistic-serialistic style and individuals' problem solving abilities.

7.2 Literature review

7.2.1 Definition of problem solving

D'Zurilla and Goldfried (1971, p.107) refer to the term of problem as 'a specific situation or set of related situations to which a person must respond in order to function effectively in his environment'. They define the behavioural process of problem solving as firstly making a variety of potentially effective and available response alternatives for the problematic situation and then increasing the probability of selecting the most effective response from the various alternatives. In addition, problem solving was described as when 'a person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it' (Newell and Simon, 1972, p.72). Newell and Simon (1972) describe problem as comprising of an initial state, a goal state and operators (a series of intermediate states) for problem solvers to transform the initial state to the goal state. Moreover, some rules of allowable operations of constraints are also included (Chi and Glaser, 1985). Each operator has constraints that must to be satisfied before applying them to the problem solving process. The states, operators and constraints are referred to as a set of 'problem space'; the problem solving process can thus be characterised by the paths of linking the initial state and the goal state. The 'problem space' includes the initial, intermediates, and goal states of the problem and the solver's knowledge of the task and experiences (Anderson, 1985).

Kahney (1986) describes the concepts of problem and problem solving as each problem specifying a goal and the problem solver in each case as not being able to achieve the goal directly. The problem might produced by the lack of resources,

information and so on; the action that the people perform in achieving the goal is problem solving.

7.2.2 Problem solving process

D’Zurilla and Goldfried (1971, p.107) identify the five stages of the problem solving process as ‘a) general orientation or ‘set’, b) problem definition and formulation, c) generation of alternatives, d) decision making and e) verification’.

Problem starts with the different initial state and ends with the final goal state. The process of solving problems requires a number of cognitive operations (Wickens, Lee, Liu and Gordon-Becker, 2004). In general, the action of troubleshooting may occur before implementing a solution. However, problem solving might also occur through the actions of trial and error or the solution might appear accidentally. Gick and McGraay (1992) point out that the initial failure of a solution to the problem can often improve the solutions for the second problem. The phenomenon suggests that human learning ability can result from making mistakes.

7.2.3 Problem solving and cognitive styles

Ford et al. (2002) conducted a study in which they examined one hundred and eleven postdoctoral researchers to establish the link between cognitive styles and an individual’s problem solving ability with information-seeking behaviour. The study was conducted based on Kuhlthau’s (1993) search process model regarding feelings towards the work’s progress, extra information-seeking activities and the uncertainty of the searching. As can be seen from Table 7-1, holists exhibited a tendency towards exploring activity whilst seeking information. In addition, they were more serendipitous in obtaining the information and weak at explaining problems. A familiarity with domain language was also important to holists.

Table 7-1 Evidence that support Ford's hypotheses of cognitive style and problem-solving of seeking information (adapted from Ford et al., 2002)

Hypotheses	Evidence
Holists will display more exploratory behaviour	<ul style="list-style-type: none"> • Holists report more engagement in Kuhlthau's exploring activity. • Holists report more valuing of serendipitous information encounters. • But fewer changes in questioning as perceived by the intermediary.
Holists will desire a more comprehensive information search	<ul style="list-style-type: none"> • No evidence.
Holists will employ more personalized and/or idiosyncratic forms of explanation	<ul style="list-style-type: none"> • Poorer explanation by holists of the problem perceived by the search intermediary. • Despite intermediary's perceived higher understanding of holists' problems and intermediary's perception of holists as having higher familiarity with domain language.
Holists will report greater uncertainty in their problem solving	<ul style="list-style-type: none"> • No evidence.

To compare with the findings of chapter five, holists displayed a tendency towards checking icons on the desktop or main menu randomly when the icon that they were familiar with was not obviously situated. It seemed that they were exploring the possibility of achieving the goal by alternative routes. However, they were more likely to achieve the goal by following the familiar categories of icons and routes. Additionally, the observation in chapter five found that holists seemed to struggle to develop the relationship between unknown folders of Task 3 that requires participants to seek a target photo within several unknown folders. More holists exhibited panic and expressed the difficulty in finding the photo due to no useful clues being provided along with the graphic icon. Therefore they accessed the folders randomly. The phenomenon implies that holistic-serialistic styles might also affect an individual's problem solving ability when dealing with a hierarchical structure. The phenomena were therefore connected to two psychological tests: *Luchins's jar problem* and *Tower of Hanoi*. The following sections introduce the background of the two tests and develop the link with holistic-serialistic styles and the application of the tests in this investigation.

7.2.4 Problem solving ability of mental set

Based on the observation in chapter 5, holists were more likely to achieve the goal via the same route across six mobile phone interfaces than serialists. The behaviour was in keeping with the attributes of holistic-serialistic style as holists tend to develop connections between concepts based on prior experience. Serialists were more likely to establish the linkage between concepts based on the characteristics within a concept (Jonassen and Grabowski, 1993). Bernstein, Roy, Srull and Wickens (1991) indicate that sometimes people apply one strategy or hypothesis to the similar tasks even though better alternative solutions were obvious. The phenomenon can be examined using *Luchins's jar problem*.

Luchins's jar problem requires the individual to use three jars of differing capacities to obtain a certain amount of water. As can be seen from Table 7-2, the goal of the first problem is to obtain 100 pints of water by using three jars that have capacities of 21, 127 and 3 pints, respectively. The solution is to fill Jar B with 127 pints of water, to pour the water to Jar A to its capacity of 21 pints and to reduce the remaining 106 pints by filling Jar C to its capacity of 3 pints twice, leaving 100 pints water in Jar B. The equation can be written as $B-A-2C$. This strategy can be applied to the remaining problems 2-6. The problem 7 can also be solved by the simpler strategies of $A+C$ and $B-A-C$; problem 8 can only be solved by $A-C$. The mental set was established whilst the individual solves problem 1-6, it 'consists of a tendency to stick with a strategy or solution that worked in the past' (Bernstein, Roy, Srull and Wickens, 1991, p.358). Previous experience of problem 1-6 might produce functional fixedness, thus the aim of problem 7-8 is to understand the individual's tendency towards using old patterns.

Table 7-2 The Luchins's jar problem (Luchins, 1942)

Problem	Goal to obtain (pints)	Capacities of the jar		
		Jar A (pints)	Jar B (pints)	Jar C (pints)
1	100	21	127	3
2	99	14	163	25
3	5	18	43	10
4	21	9	42	6
5	31	20	59	4
6	20	23	49	3
7	18	15	39	3
8	25	28	76	3

Luchins's jar problem has been applied to numerous studies to examine people's creativity (Amabile, 1989), Einstellung rigidity (Cunningham, 1965), behavioural rigidity (Knight, 1963), primary process thinking and flexibility (Russ, 1982), cognitive styles of assimilators-explorers and adapters-innovators (Goldsmith and Matherly, 1985), personal need for structure (Schultz and Searleman, 1998) and so forth. However, researchers applied different capacities to the water jars and different methods to evaluate people's performance.

The water jar problems have been applied using the formats of paper-and-pencil, computer version, real jars and an actual source of water. The capacities of jars, the amount of liquid required by the goal and the number of problems were varying in previous studies. Parts of studies might involve a problem that is solvable by the equation of $A-C$ or $A+C$, respectively. Participants' performance can be evaluated by completion time, the number of problems that were solved by different solutions and whether the mental set has developed or not within a series of problems.

Russ (1982) adapted Luchins's water jar problem to measure 8-9 year old children's flexibility in solving problems. Participants in the study were given paper-and-pencil tests with 4 trial problems and another 16 items to score their performance. The 16 items include critical items that can be solved with two strategies a) $B-A-C$ or b) $A+C$; and extinction items that can only be solved by Strategy b) $A+C$. Participants' direct solutions of 16 items were scored for further

analysis. The 4 trial items established the Einstellung rigidity of an individual; the 16 items examine how often and how quickly the individual breaks the mental set.

Schultz and Searleman's (1998) applied the water jar tasks to examine the relationship between the personality variable of personal need for structure and problem solving ability. Participants' performance was scored according to their development of the mental set. The individual who developed the mental set with B-A-2C solution was given a score of 1 and those who could not form the set were given a score of 0. The completion times of solved problems were used for statistics analysis with the effects of stress.

In Goldsmith and Matherly's study (1985), participants were categorised as assimilators-explorers or adaptors-innovators by the strategy they applied to solve each water jar problem, respectively. Furthermore, Crooks and McNeil (2009) score the individuals' performance by correct, incorrect, single-step or multi-step solutions and the completion time achieved in each water jar problem.

7.2.5 Problem solving with hierarchical structure

According to the observations made in chapter five, when participants seeking the target photo that was saved in an unknown folder within several folders, holists tended to check the possible folders randomly. If the selection was wrong, most holists returned to previous page and proceeded to check the other folders randomly. In contrast, more serialists checked folders one by one to seek the target photo. This series of actions can be interpreted with Wickelgren's (1974) state-action tree (Figure 7-1).

Wickelgren (1974) illustrated the state-action tree as Figure 7-1 to define the correct path (action sequence) between the goal and sub-goal and how to reduce the search. The search in the figure includes eight action sequences and two steps, respectively. The grey area of the figure restricts the search to one portion. In most problems, the branch is much longer and more complex than shown in this sample.

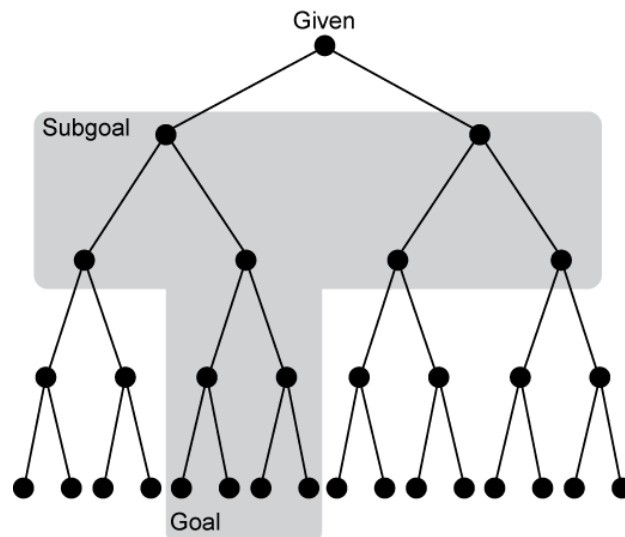


Figure 7-1 State-action tree (adapted from Wickelgren, 1974, p.93)

Anderson (1985) lists the characteristics of problem solving as:

a) goal directedness

Human's behaviour and activities were examined as it 'directed toward achieving some goal or purpose'.

b) sequence of operations

A sequence of mental operations or steps necessary to describe an activity as 'problem solving'.

c) cognitive operations

The process of solving the problem-achieving a solution required for various cognitive operations and physical and mental operations.

d) sub-goal decomposition

Each step in the sequence of operations might be a goal and sub-goal at the same time. A subgoal is an intermediate goal that was applied to 'replace a single difficult problem with two or more simpler problems' (Wickelgren, 1974, p.91). The problem solving process is to break down the overall goal into sub-goals, and then achieving the sub-goals, or their smaller sub-goals until the final solution is achieved. Thus the problem solving process tends to be a hierarchical or nested structure (Anderson, 1985).

Problem starts with the different initial state and ends with the final goal state. The process of solving problems requires a number of cognitive operations

(Wickens, Lee, Liu and Gordon-Becker, 2004). In general, the action of troubleshooting may occur before implementing a solution. However, problem solving might occur through the actions of trial and error or the solution might appear accidentally. Gick and McGraay (1992) point out that the initial failure solution of the problem can often improve the solutions to the second problem, the phenomenon presenting human's ability to learn from mistakes. The attributes of serialists' learning styles tends to build procedure, whilst holists preferred to build an overall description of the content (Jonassen and Grabowski, 1993). Therefore serialists might find the mistakes and solutions more quickly than holists as well as avoiding making the same mistake when solving problems.

Newell et al. (1962) and Minsky (1963) identify that the intermediate states of operators can be used to 'decompose a problem and significantly reduce search' (Knoblock, 1991, p.1). Therefore, hierarchical problem solving skill is one of the approaches to finding the intermediate states (Newell and Simon, 1972; Sacerdoti, 1974). In this case, the attributes of a serialistic style show how the skills of a step by step approach and consideration of the sequence of operations might help to solve problems quicker.

Knoblock (1991, p.1) defines hierarchical problem solvers as they use 'abstraction spaces in various ways and employ a variety of techniques for refining an abstract plan'. Firstly, the problem solver situates the given problem in the most abstract space by deleting literals and goals that are irrelevant to the abstract space at the initial stage. Secondly, the problem solver finds a solution to solve the abstract problem. The intermediate states in the abstract plan serve as goals for the sub-problem at the next level in the abstraction hierarchy. Then the problem solver solves each of the intermediate sub-problems by using its final state as the initial state for the next sub-problem. The intermediate state of the new level serves as the goal for the next level. The process is continued until the plan is refined into the ground space. The attributes of a serialistic style tend to lead towards concentration on chunks of information that are more clearly defined and sequentially ordered; serialists seem to be able to perform better than holists.

The puzzle is one of the problem forms. It requires less background knowledge and might not make it easy to solve the problem. Chi and Glaser (1985, p.231) indicate that in puzzle tasks, ‘differences in individual’s abilities to solve problems can be attributed to differences in some basic underlying problem solving process rather than to greater or lesser subject-matter knowledge’. Therefore, puzzle problems shows the underlying solution processes by illustrating the sequence of operations from the initial state to the goal state. The Tower of Hanoi puzzle (Figure 7-2) is a typical example used to examine individuals’ interaction with hierarchical structure. It was established by Édouard Lucas (1883); many solutions to the problem have been given (Hinz, 1999). It consists of three pegs and a set of differently sized discs. In the initial state, the discs were set on the first peg in order of decreasing size (like a pyramid). The goal is to move all the discs to the third peg and to keep the pyramid. The constraints of moving a disc are a) it is not allowed to place a larger disc on the top of a smaller one, b) only one disc can be moved at once.

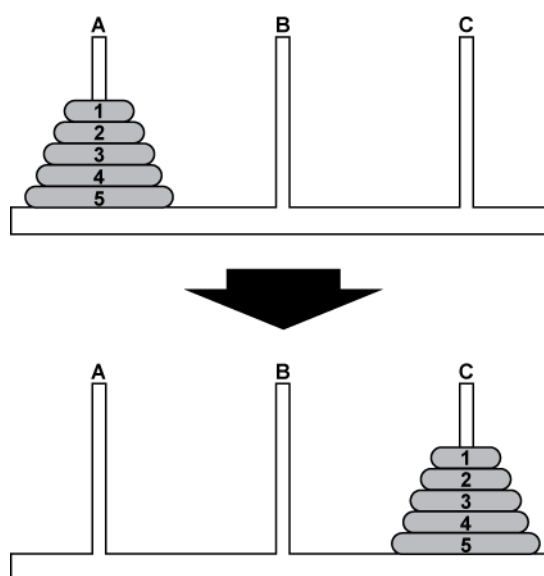


Figure 7-2 Tower of Hanoi

This is one of the important examples of using a sub-goal method to solve the problem. It requires the individual to solve the problem by determining the difference between current position and the goal or sub-goal position before applying an operator to reduce the difference (Achcraft, 2006). Five sequence steps were necessary to solve the Tower of Hanoi problem (Achcraft, 2006, p.546).

- a) set a goal or sub-goal.
- b) search through the differences between the current position of discs and the goal or sub-goal position of discs.
- c) seek an operator that can be used to reduce or eliminate the differences between current position and goal position and may be useful in setting up a new sub-goal.
- d) apply the operator.
- e) apply step b through d repeatedly until the goal and all sub-goals are achieved.

The goal of a Tower of Hanoi problem is to move all discs from peg A to peg C (Figure 7-2). Based on the constraints that were mentioned earlier, it is easier to represent the problem solving process by giving names to each disc and the peg (Wickelgren, 1974). It is clearer to divide the problem into sub-goals with codes. For instance, solving a five discs problem from peg A to C is equivalent to solving a four discs problem from A onto B, to move the fifth disc to C, and to move the disc 1-4 from peg B to C. To implement the process, working memory and counter-intuitive moves are necessary (Wickelgren, 1974; Bull, Espy and Senn, 2004). The concept of sub-goal indeed provides a good insight to the structure of solving the Tower of Hanoi problem.

According to Bishop (2001), the Tower of Hanoi has been applied in some medical studies to examine patients who have frontal lesions resulting in pronounced impairments (Owen et al., 1990; Goel and Grafman, 1995), people with autism or Asperger syndrome (Ozonoff, Pennington and Rogers, 1991) and children with intellectual disabilities (Borys, Spitz and Dorans, 1982). It was also utilised in a range of psychological research. In addition, the scoring systems of evaluating participants' performance varied.

There are several methods which can be used to examine and to score participants' performance on Tower of Hanoi. The general types of Tower of Hanoi tasks can be categorised as a) to remove all discs from one peg to another peg; b) to remove the discs from an initial configuration to the goal configuration.

The methods of scoring vary, for example recording the number of moves and completion time and awarding points for the successfully completed tasks.

In a study that tested the impact of individual's age difference on their ability to complete the Tower of Hanoi, the five-disc task was applied (Rönnlund, Lövdén and Nilsson, 2001). Based on the rules of moving discs from one peg to the other peg, participants were given 20 minutes to complete a five-disc task. Any illegal moves were pointed out and recorded by the experimenter. The disc was then returned to the prior state before the error. This study evaluates the correlation between the age group across 35-85 years and their performance on the Tower of Hanoi by whether or not the participant completed the task in time (20 minutes).

The other study also applied five-disc problem on the Tower of Hanoi to examine the individual's working memory, inhibition and fluid intelligence (Zook, Davalos, Delosh and Davis, 2004). The task was presented via the Colorado Assessment Tests (CATs-a computer software). Participants were required to move 5 discs from the left peg to the right peg whilst keeping the pyramidal configuration. The minimum number of moves required to complete the task is 31. Four trials were given to participants. The trial terminated once the problem was solved or if the participant reached 100 moves. The final score was the average number of moves in excess of the minimum moves (31) across the four trials.

Welsh, Satterlee-Cartmell and Stine (1999) applied 12 tasks to examine if the Tower of Hanoi and the other similar test – the Tower of London - contribute the same theory for measuring the same cognitive processes. The 12 tasks in this study include 6 tasks of three-discs items (two 7-move, two 11-move and two 15-move problems) and 6 tasks of four-disc items (two 7-move, two 11-move, and two 15-move problems). Six trials were given to participants for each task. They were awarded points for solving the problem correctly on two consecutive trials. The participant received 6 points for successfully completing the task on trials 1 and 2; 5 points for successfully completing the task on trials 2 and 3; 4 points to 2 points until the sixth trial (see Table 7-3). The participant received 0 points for failure to solve the problem on two consecutive trials and the entire task was

terminated. In addition, the participant received 1 extra point whilst solving the task on their first attempt.

Table 7-3 Scoring system of Tower of Hanoi

points	solution on trials
6	1 & 2
5	2 & 3
4	3 & 4
3	4 & 5
2	5 & 6

Bishop et al. (2001) also applied a similar method to examine the relationship between cognitive planning ability and the Tower of Hanoi, Verbal IQ and the ability to inhibit a prepotent response by children participants. In this study, problem A and B consists of 3-move problems and increasing up to 9-move problems, respectively. Each problem requires the individual to move discs from the specific configuration to another configuration. The test terminated if two consecutive problems were failed. The numbers of moving discs were counted and the final score was determined by the highest level of successfully completed task. An extra half point was given if the moves of both tasks at the same level were passed.

Handley, Capon and Harper (2002) applied the Tower of Hanoi to investigate the relationships between verbal as well as spatial measures of working memory capacity and performance with the Tower of Hanoi and a conditional reasoning task. This study adapted Lehto's (1996) measurement of 7 problems. Participants were allowed to instruct the plan before moving discs. The timing was stopped once an error was made, and the experimenter reset the apparatus to the initial state before timing recommenced. This study attempts to provide the total solution time (includes the time the participant could see the problem, to plan and to execute moves) across 7 problems.

Bull, Espy and Senn (2004) applied a similar problem set as Bishop et al. (2001) to compare participants' performance across the Tower of Hanoi and the Tower of London. However, Bull, Espy and Senn (2004) allocate points to tasks by an alternative method, with the participant receiving 2 points for solving the 2 move problem successfully, 3 points for solving the 3 move problem and so forth. The

final score is the sum of all the points of awarded for successful completion of move problems.

Based on the literature review above, more studies adopted the problem tasks by requiring the participants to remove the discs from a specific initial configuration to the goal configuration. Welsh and Huizinga (2001) argued the internal consistency of the previous problem tasks was not valid, and revised the Tower of Hanoi to extend the problems from 12 to 22 items. However, whether it be the 8-item problems (Lehto, 1996), 12-item problems (Bishop, 2001) or the 22-item problems (Welsh and Huizinga, 2001), the maximum moves required to solve the problem is 15. Besides, most of the studies discussed earlier invited children, teenager or undergraduate students as participants; only Rönnlund, Lövdén and Nilsson's (2001) study involved adult participants.

7.3 Focus questions and hypotheses

According to the outcomes of chapter five, holists were more likely to complete a task followed by the same categories and routes across six mobile phone interfaces. Therefore, this investigation assumes that holists' mental set tends more towards rigidity than serialists. In addition, holist checked uncertain icons and folders without order, whereas serialists applied a 'step by step' strategy. Based on these phenomena, the research questions were raised about whether cognitive style impacts the method by which an individual deals with problems, and the ability to achieve a goal within a hierarchical structure. Besides, the links between problem solving and holistic-serialistic styles were established in chapter 7.2.5, as serialistic style might prove conducive to effective problem solving. Table 7-4 lists the techniques of problem solving and the attributes of holistic and serialistic style that might affect individuals' problem solving abilities. The hypotheses of this investigation were thus developed:

- a) serialists tend to be able to solve *Luchins's jar problem* with the best solution rather than following previous strategy;
- b) serialists completed the tasks of Tower of Hanoi quicker than holists.

Table 7-4 Problem solving techniques and attributes of holistic-serialistic style

Holists	Problem solving	Serialists
Build overall description of the content	Initial failure; solution of the problem can often improve the solutions on the second problem; the phenomenon presents human's learning ability from mistakes	Tend to build procedure with the operation
Spans various levels at once, establish complex relationships with hierarchical structure	Hierarchical problem solving skill is one of the approaches to find the intermediate states	Step by step and consider the sequence of operations
Focus on several aspects of subject at the same time	Abstraction spaces in various ways and employ a variety of techniques for refining an abstract plan (Knoblock, 1991, p.1)	Concentrate on the chunks of information that were more clearly defined and sequentially ordered; intolerant of irrelevant information

7.4 Study design

This study consists of quantitative approaches. One questionnaire and two psychological tests were conducted for examining the relationship between cognitive style and problem solving ability. The two psychological tests applied to this investigation were *Luchins's jar problem* and the *Tower of Hanoi*. For the purpose of collecting more data from individuals, this investigation was conducted as an online survey.

7.4.1 Method

This is a between-subjects study; the independent variable being participants' cognitive style – holist or serialist, based on responses to an established questionnaire of SPQ (Ford, 1985) as mentioned in chapter 2.4.2.3. Dependent variables are related to performance on two classic psychological tests of problem-solving – Luchins's water jar problem (Luchins, 1942) and the Tower of Hanoi (e.g., Zook et al., 2004). All data was collected online via internet versions of the SPQ and the psychological tests.

7.4.2 Task design

The hypotheses of this investigation were developed in chapter 7.3. With regard to the effect of holists-serialist on their performance with Luchins's jar problem, the hypothesis is: serialists tend to be able to solve Luchins's jar problem with the best solution rather than following previous strategy. To simplify the test, this research suggests examining mobile phone users with the original Luchins's water jar problem (See Table 7-5; Luchins, 1942).

Table 7-5 Luchins's jar problem (Luchins, 1942)

Problem	Goal to obtain (pints)	Capacities of the jar		
		Jar A (pints)	Jar B (pints)	Jar C (pints)
1	100	21	127	3
2	99	14	163	25
3	5	18	43	10
4	21	9	42	6
5	31	20	59	4
6	20	23	49	3
7	18	15	39	3
8	25	28	76	3

Based on Crooks and McNeil's study (2009), problems can be categorised as being one of three types: a) set problems, b) critical problems and c) extinction problems (see Table 7-6). To analyse the original Luchins's water jar problem; problem 1-5 belong a type of problems, problem 6-7 belong b) critical problems; problem 8 is a c) extinction problem.

Table 7-6 The strategy types of Luchins's water jar problem

	Strategy type	Solution (s)
a) set problems	multi-step strategy	B-A-2C (Einstellung method)
b) critical problems	multi-step strategy	B-A-2C
	single-step strategy	A-C or A+C (direct method)
c) extinction problems	single-step strategy	A-C or A+C

To score the individual's performance in this investigation, the participant received 1 point for every problem solved correctly, 1 point extra for solving the b) critical problem correctly with single-step strategy, and 1 point extra for solving c) extinction problem correctly at the initial time.

The Tower of Hanoi test was applied to examine the hypothesis as serialists completed the tasks of Tower of Hanoi quicker than holists. This investigation tends to simplify the variable to ensure consistency with the other series investigation; the participants were invited from a British university aged over 18. According to the literature review, Rönnlund, Lövdén and Nilsson's (2001) study was designed to examine individuals between the age group across 35-85 years; the problem type was thus adopted from this investigation. However, participants in a university are, in general, younger than 35 years, so the scoring method of Zook, Davalos, Delosh and Davis's (2004) work was adopted for this data collection. In addition, participants were not only given the 5-disc problem, but also 4-disc and 3-disc problems for further data comparison. Three problems were presented in several counterbalanced orders across participants to avoid an order effect. A total of 32 participants were recruited.

To score the individuals' performance on the Tower of Hanoi, participants were required to trial each task 4 times. Each trial was terminated once the problem was solved or after 100 moves. The final score is the average number of moves that exceed the minimum required moves (31) across the four trials. The scoring method was revised from Zook, Davalos, Delosh and Davis's (2004) study.

7.5 Data collection

7.5.1 Study procedure

Upon recruitment, participants were given a secure link to the study website. The first pages show the participant information sheet and informed consent, which were signed electronically. Basic information about the participant's gender, age, and the model of the mobile phone that the participant currently uses were also collected at this point. Following this, participants were presented with the SPQ to identify whether the individual tends toward holist or serialist.

The second part presents Luchins's water jar problem (Luchins, 1942.) A sample problem and a solution that differs from the main test was shown to participants first by way of instruction (see Figure 7-3). Participants moved on the next problem by clicking 'Done'. They were not allowed to return to previous problems. The text data of the participant's solution were recorded automatically by the web applet.

The screenshot shows a web browser window titled "Water Jar - Windows Internet Explorer". The address bar shows the URL: <http://people.brunel.ac.uk/~mapgwj/waterjar.php>. The page content includes:

JAR A **JAR B** **JAR C**

Instructions:
The picture shows three different capacities of jars (not to scale); Jar A - 8 pints, Jar B - 35 pints, Jar C - 3 pints.

The goal is to obtain an exact volume of 16 pints of liquid by filling and emptying the jars into each other. The jars do not have any markings on them, so you can only be sure of a volume of liquid by completely filling a jar. You have an unlimited supply of liquid, so you can fill or empty each jar as many times as you want.

Please input, as a text equation, your solution to obtaining 16 pints of liquid by using the 3 jars.

Problem	Goal	Jar Capacity			Workings Out
		Jar A	Jar B	Jar C	
Example	16	8	35	3	35-8-3; B-A-C-A or B-2A-C

Note: Please show all your working too - so if you input a wrong formula, please just insert a semi colon (;) to separate it from your next try. Please do not delete your calculation process.

Problem No.	Goal	Jar Capacity			Workings Out	Done
		Jar A	Jar B	Jar C		
1	100	21	127	3		Done
2	99	14	163	25		Done
3	5	18	43	10		Done
4	21	9	42	6		Done
5	31	20	59	4		Done
6	20	23	49	3		Done
7	18	15	39	3		Done
8	25	28	76	3		Done

Buttons: Submit, Quit

Figure 7-3 The test of Luchins's water jar online

The third part of the study required participants to complete three Tower of Hanoi tasks. The Tower of Hanoi task consisted of three pegs and a set of different sizes of discs (Figure 7-4). In the initial state, the discs were set on the first peg in order of decreasing size (like a pyramid). The goal was to move all the discs to the third peg and to keep the pyramid form intact. Participants were given three tasks of different levels of difficulty – that include 3 discs, 4 discs and 5 discs, respectively. Tasks were presented in a counterbalanced order across participants.

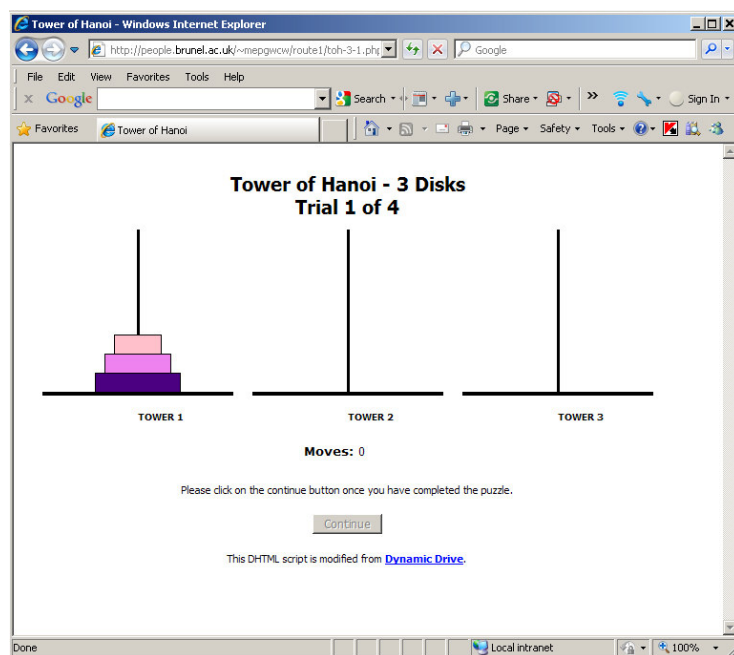


Figure 7-4 The test of Tower of Hanoi online

7.5.2 Participants

Participants were recruited from a British university via a research participation invitation on the intranet. This study recruited 32 participants with an equal number of males and females in each of the holists and serialists groups (i.e., eight participants in each group—males with holistic style, males with serialistic style, females with holistic style, females with serialistic style; aging 18 to 35 with a mean value of 25 ($SD=4.6$)).

7.6 Data analysis

Luchins's water jar problems

On average, serialists ($M=8.56$, $SE=.29$) received higher points than holists ($M=7.19$, $SE=.59$). An independent t-test showed that the difference between conditions was significant ($t = -2.11$, $df = 30$, $p < .05$) (Table 7-8). The sample mean for holists is 7.19, and this study can be 95% confident that the population mean falls between 5.9 and 8.4. The sample mean for serialists is 8.56 and this study can be 95% confident that the population mean falls between 7.9 and 9.2 (Figure 7-5). According to Cohen (1988), the effect size was large ($d=.79$).

Table 7-7 Significances of cognitive styles and solving Luchins's water jar problems

Water jar problem				
	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Cognitive style	Holists	7.19	.59	$t = -2.105, df = 30,$ $p < .05, d = .79$
	Serialists	8.56	.29	

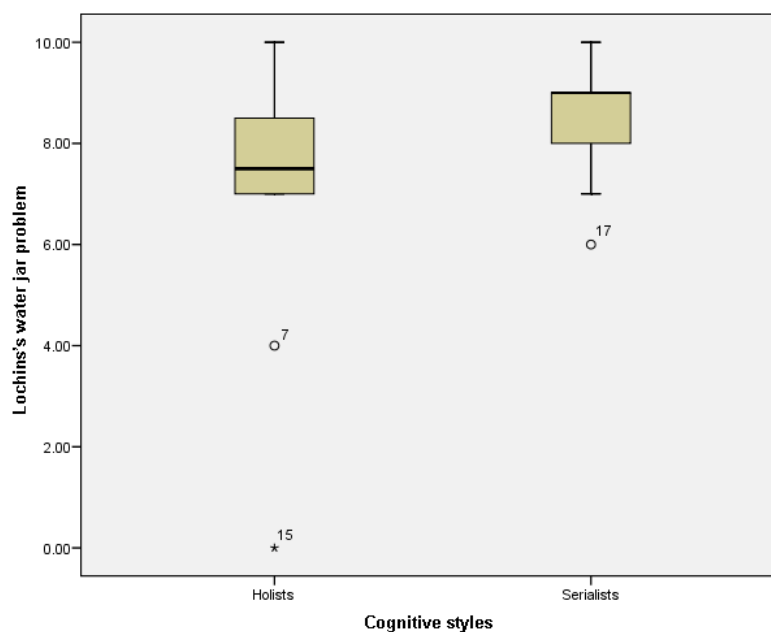


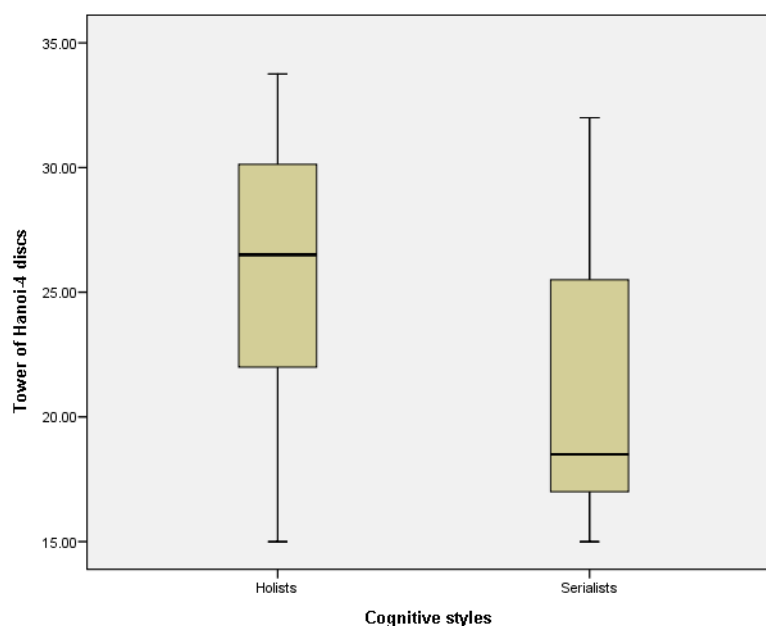
Figure 7-5 Sample mean for the relationship between cognitive style and the participants' performance with Luchins's water jar problems

Tower of Hanoi problems

To compare the effects of cognitive styles to the individual's problem solving abilities, in general, serialists completed three tasks with fewer moves than holists. The significance was found in the task of moving 4 discs from the initial peg to the third peg. As can be seen from Table 7-8, serialists ($M=20.98, SE=1.35$) moved the discs fewer times than holists in completing the task ($M=25.86, SE=1.36$) (Figure 7-6). The significance was found between conditions ($t = 2.54, df = 30, p < .05$). The sample mean for serialists is 20.98 and this study can be 95% confident that the population mean falls between 23.0 and 28.8. The sample mean for holists is 25.86 and this study can be 95% confident that the population mean falls between 18.1 and 23.9. The effect size estimate indicates that the participants' problem solving abilities in completing 4 disc problem of Tower of Hanoi represents a large ($d = .90$), and therefore significant effect.

Table 7-8 Significances of cognitive styles and solving Tower of Hanoi problems

Tower of Hanoi					
	discs	Variable	<i>M</i>	<i>SE</i>	<i>Significance</i>
Cognitive style	3 discs	Holists	8.06	0.49	$p > .05$
		Serialists	7.61	0.32	
	4 discs	Holists	25.86	1.36	$t = 2.540, df = 30,$ $p < .05, d = .90$
		Serialists	20.98	1.35	
	5 discs	Holists	59.13	5.80	$p > .05$
		Serialists	49.84	6.22	

**Figure 7-6 Sample mean for the relationship between cognitive style and the participants' performance with Tower of Hanoi problems**

7.7 Discussion

This investigation was conducted based on the findings of chapter 5. Whilst holists preferred to apply one strategy to complete a task across different phone interfaces, serialists performed more flexibly by applying different routes to achieve the goals. This phenomenon was linked to one of the problem solving abilities - the rigidity of mental set as sometimes people apply one strategy or hypothesis to the similar tasks even though better alternative solutions were obvious. The effect of individuals' holistic-serialistic styles on their problem solving ability was then examined using a psychological test- Luchins's jar problem. The significant result indicates that holists were more likely to follow a previous strategy to solve problems, whilst serialists tended to apply the best solution to each problem. The outcome was consistent with the attributes of

holistic-serialistic styles as holists tend to develop connections between concepts based on prior experience while serialists were more likely to establish the link between concepts based on the characteristics within the concepts (Jonassen and Grabowski, 1993). In this research, holists used to follow the same categories and routes to achieve the goals that they are familiar with based on their experience; serialists were more addressed to understand the context and choose the items and routes that they were more certain to reach the goals. The hypothesis was thus accepted in this research. More importantly, the outcome highlights the necessity to ascertain whether or not the process of completing tasks is the same with most of the similar devices when designing phone interfaces for holists. Holists might benefit from achieving goals without obstacles. In terms of the users' different operational behaviour of seeking targets, parts of the users might have to click more icons to achieve the target. As mentioned in chapter 5.5.4, the users' satisfaction of interfaces might affect by the number of clicking icons. With regard to the consequence, the holistic users might present higher satisfaction with the phone that provide the interface that they familiar with.

In terms of individuals' performance in chapter 5, holists tended to seek useful icons when randomly checking unknown folders for targets. In contrast, serialists preferred a 'step by step' strategy to check unfamiliar icons and unknown folders in an ordered fashion and concentrated on the sequence of the operation with the hierarchical structure of mobile phone interfaces. Based on Ford's (1985) illustration of holistic-serialistic styles in terms of their interaction with hierarchical structure; serialistic attributes of tending to build procedure with the operation, step by step strategy, considering the sequence of operations, concentrating on the chunks of information that were more clearly defined and sequentially ordered, and intolerance of irrelevant information were highlighted in chapter 7.2.5. These attributes were linked to the problem solving ability of avoiding mistakes by initial failure solution, seeking the intermediate states to solve the problem and refining an abstract plan. Based on the theoretical attributes of holists and serialists that mentioned above; this research assumes that serialists were good at seeking alternative solutions to solve the problem than holists. In other words, serialists' strategies of interacting with hierarchical structures were more efficient than holists. Individuals were therefore examined with the

psychological test-the Tower of Hanoi. The significant difference between holists and serialists and their performance with the Tower of Hanoi was only found when solving 4-discs problem as serialists completed this task quicker than holists. This outcome might have occurred as a result of the problem of 3-discs being too simple, and the 5-discs being too difficult to complete on the initial attempt. In addition, the initial moves of solving 3-discs and 5-discs problems are the same; moving the first disc from the left peg to the right peg; whilst the 4-discs problem requires moving the first disc to the middle peg. The hypothesis was partially accepted in this investigation. Therefore, holistic users might benefit from a shallow hierarchically structured mobile phone interface; whilst serialists might have better adaptability with phone interfaces that were developed by hierarchical structure.

7.8 Summary and Conclusions

This chapter represents the process of connecting holistic-serialistic styles with individuals' problem solving abilities. According to examination of individuals with two psychological tests - Luchins's jar problem and the Tower of Hanoi - the effects of holistic-serialistic attributes on solving problems were identified. First of all, the rigidity of holists' mental set was stronger than serialists and meant holists were more likely to apply one strategy to complete the similar tasks. Secondary, serialists' attributes impacted their interaction with the hierarchical structure. This investigation was therefore achieving the aim of this chapter, to confirm that the established categories in chapter 5 are comprehensible.

CHAPTER 8 IDENTIFYING PHONE USERS' COGNITIVE STYLE BASED ON THEIR OPERATIONAL BEHAVIOUR

Overview

This chapter attempts to examine the validity of the categories that were developed in chapter 5. Individuals' operational behaviour with a touch screen mobile phone interface was examined and divided into categories that were consistent with the theoretical attributes of holistic-serialistic style. In general, individuals more or less have both holistic and serialistic attributes when interacting with the touch screen phone interface. Eventually, the individuals' tend towards one of the styles. This investigation provides confirmation of how holistic-serialistic styles reflect on mobile phone users' operational behaviour.

8.1 Introduction

This chapter aims to evaluate the findings of chapters 4 to 7. According to a series of investigations in this research, individuals' operational behaviour with phone interfaces was identified in terms of differences in cognitive style. The categories used in identifying phone users' cognitive style were developed based on the results of chapters 4 and 5. Four theoretical attributes of holistic-serialistic styles were linked with the individuals' operational behaviour when using touch screen mobile phone interfaces in chapter 5. Additionally UX was an important effect that impacted the users' performance in this research; chapter 6 was aimed to further understanding of the necessary elements that the users cared about the most that influence the users' interaction with mobile phones. Furthermore, based on the attributes of holistic-serialistic styles and the users' performance in seeking icons and targets with touch screen mobile phones in chapter 5, it seemed that holistic-serialistic styles also impact individuals' problem solving abilities. Chapter 7 then evaluated the links between the conditions. Holists were found to possess a stronger rigidity of mental set than serialists as they preferred to apply one strategy to complete similar tasks even though a better solution was obvious. In addition, serialists performed better than holists whilst interacting with

hierarchical structures in general tasks. The phenomena suggest the necessity of a consistent phone interface with similar handsets and to establish shallow hierarchical structure for holistic users.

The aim of this study is therefore to attempt to examine the categories that were developed in chapter 5 and to understand if holists-serialists' operational behaviour with a touch screen mobile phone is actually consistent with the categories. The users' cognitive style was then identified by their interaction with a phone interface. Meanwhile, the results were compared with their answer of SPQ in order to establish confirmation of their cognitive style.

8.2 Study design

This is a qualitative investigation to identify if a phone user's cognitive style tends towards holistic or serialistic style by structured observation in terms of the categories that were developed in chapter 5. Therefore the observation schedules follow by Table 5-27. The SPQ was also applied in this investigation for further comparison with the results of this investigation. A brief interview with a filter question was conducted before the investigation to understand the routes that the participants followed in order to make a call, to send text message and to seek a photo with their own mobile phones.

8.2.1 Method

Structured observation was the main approach in this investigation. Participants were given three tasks to complete using a touch screen mobile handset. As mentioned in chapter 3.5.1.2, it is essential to set a detailed observation schedule before collecting data. The categories that were developed in chapter 5 were thus applied as observation schedules to analyse the users' operational behaviour with a touch screen mobile phone. However, the interface of the instrument in this investigation is slightly different to the phone interfaces in chapter 5. Only one phone interface was used in this investigation and the observation schedules of c and d in chapter 5 were revised:

- a) how cognitive style differences affect the way in which an individual browses icons.
- b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface.
- c) how cognitive style differences affect the way an individual seeks the target photo *within a long list of unknown files*.
- d) how cognitive style differences affect whether or not the individual follows the same route to complete the task *with their mobile phone and the instrument in this investigation*.

In addition, this section intends to understand users' interaction with the phone interface further. Therefore, participants were required to apply 'think aloud' protocol to express the operation process and their using experience during the investigation. Due to the possibility of the 'think aloud' protocol affecting the users' completion time of tasks, this investigation was focused on qualitative data from the users.

8.2.2 Task design

According to the reports in previous chapters, the tasks of examining mobile phone users' operational behaviour should involve more unknown items. The aim of this research is to identify a user's cognitive style via common, often used functions, so the three tasks were designed as follows:

- a) make a phone call to someone who has been included on the contact list.
- b) send a text message to someone who has been included on the contact list.
- c) search for a target photo.

One of the elements in identifying individuals' cognitive style is the route that they utilise to complete tasks. According to the application of HTA in chapter 5.6.1, it presents a clear framework for each task and the routes that the users took in achieving the goals. This investigation also applies HTA to provide further analysis of the users' operational behaviour in chapter 8.4.2.

8.2.3 Instruments

This investigation was conducted with the study in chapter 6. The Vodafone 541 was used to observe the users' operational behaviour with the three tasks. The platform of Vodafone 541 touch screen mobile phone is exclusive to the Vodafone telecom company and was not operated by the main systems in the phone market. Interacting with the phone should be a new experience for most people. Figure 8-1 shows the desktop of this phone, Figure 8-2, 3 and 4 show the three pages of the main menu. The second page of the menu was shown to users when first access menu from the desktop. The green, blue and red squares at the bottom of the menu and the blue lights can be used to review the other pages of the menu.



Figure 8-1 Desktop of Vodafone 541



Figure 8-2 Second page of menu
(shows to users first)



Figure 8-3 First page of menu



Figure 8-4 Third page of menu

8.3 Collect data

This investigation collects data from the users by the questionnaire of SPQ and the observation of the users' operational behaviour when completing three tasks with Vodafone 541. Participants' interaction with the phone was filmed; the camera only focused on participants' hands and the mobile phone, and recorded their verbal commentary without showing their face. A brief interview took place before tasks were given to participants. The answer to the filter question about the route they use to make a call, send a message and seek a photo was applied to compare with the participant's selection of routes of completing the three tasks with Vodafone 541. They were also required to apply the approach of 'think aloud' to express the operation process. The collected data was analysed following the observation schedules as mentioned in chapter 8.2.2.

8.3.1 Study procedure

Participants were required to complete the SPQ to identify whether their cognitive style tends toward holistic or serialistic style in terms of the measurement that was established by Ford (1985) (see chapter 2.4.2.3). The filter question asked how the users make a call, send text messages and seek a photo with their own phones. Before conducting the data collection process, the observer of this research demonstrated to the participant how to apply the approach of 'think aloud' by trialling a touch screen camera. Participants were also required to practice the 'think aloud' protocol by trialling the camera. The practice was intended to help the participants get used to expressing their experience while completing tasks with the Vodafone 541 mobile phone. Before completing the tasks for this study, participants were asked to adopt a comfortable position to operate the phone. Three tasks were then given to participants to complete with the phone. The participants' performance was filmed for further observation by a camera that was only focusing on the individual's hands and the phone. The observer was not allowed to intervene in the participant's operation.

8.3.2 Participants

Participants who took part in the investigation in chapter 6 were also invited to participate in this investigation. Twelve of them were students from a British university. Half of them currently use a touch screen mobile phone while the other half owned numeric keypad mobile phones. They were separated into holistic-

serialistic style and gender with an equal number, aging 18-30, with a mean value of 25 ($SD=3.7$).

8.4 Data coding and analysis

8.4.1 Data coding

The users' verbal commentary and the timeline of each operation were transformed to a Microsoft Excel spreadsheet. Their performance in completing three tasks was analysed in terms of the categories that were developed in chapter 5. The observation schedules of this investigation are as follows:

- a) how cognitive style differences affect the way in which an individual browses icons.
- b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface.
- c) how cognitive style differences affect the way an individual seeks the target photo within a long list of unknown files.
- d) how cognitive style differences affect whether or not the individual follows the same route to complete the task with their mobile phone and the instrument in this investigation.

According to the observation, participants' performances were divided into the categories that were developed in chapter 5. Their cognitive style was then identified if their operational behaviour was consistent with more holistic or serialistic attributes in the categories.

8.4.2 Data analysis

The data analysis consists of two stages. Firstly, the participants' performance of route selection to achieve the goals was analysed with HTA at stage one. The observation of the users' operational behaviour took place in stage two.

8.4.3 Part 1-Hierarchical Task analysis (HTA)

This section discusses the routes that the participants applied to complete three tasks with Vodafone 541 followed by the instructions of HTA (see chapter 5.3.3) and presents participants' preferences of the routes utilised in achieving the goals.

8.4.3.1 Task 1-Calling

This task can be completed via two graphic icons on the desktop (Figure 8-5). This function was not listed on the main menu. Most participants completed this task via the icon of 'Contacts', selected the contact that was on the list and made a call (Table 8-1). The operation process tends toward a linear style. However, participants apply different strategies to seek the icon; the details were discussed in stage 2.

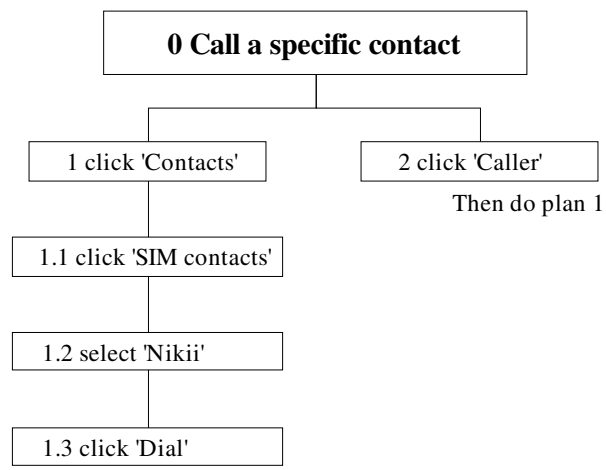


Figure 8-5 HTA of Task 1 with Vodafone 541

Table 8-1 Cognitive style-routes selection-Task 1

Routes	Holists	Serialists	Total
	N=6	N=6	N=12
0 ► 1 ► 1.1 ► 1.2 ► 1.3	100%	83.3%	91.7%
0 ► 2 ► 1 ► 1.1 ► 1.2 ► 1.3	0%	16.7%	8.3%

8.4.3.2 Task 2-Messaging

The task of sending text message with Vodafone 541 can be completed via four routes (see Figure 8-6). Three routes can be started via the icons on the desktop; one icon of 'Messaging' was listed on the menu. Holists have the tendency of sending text message by using the graphic icon of the envelope on the desktop, in contrast with serialists; they achieved the goal via both of the icons on the desktop and the main menu (see Table 8-2.)

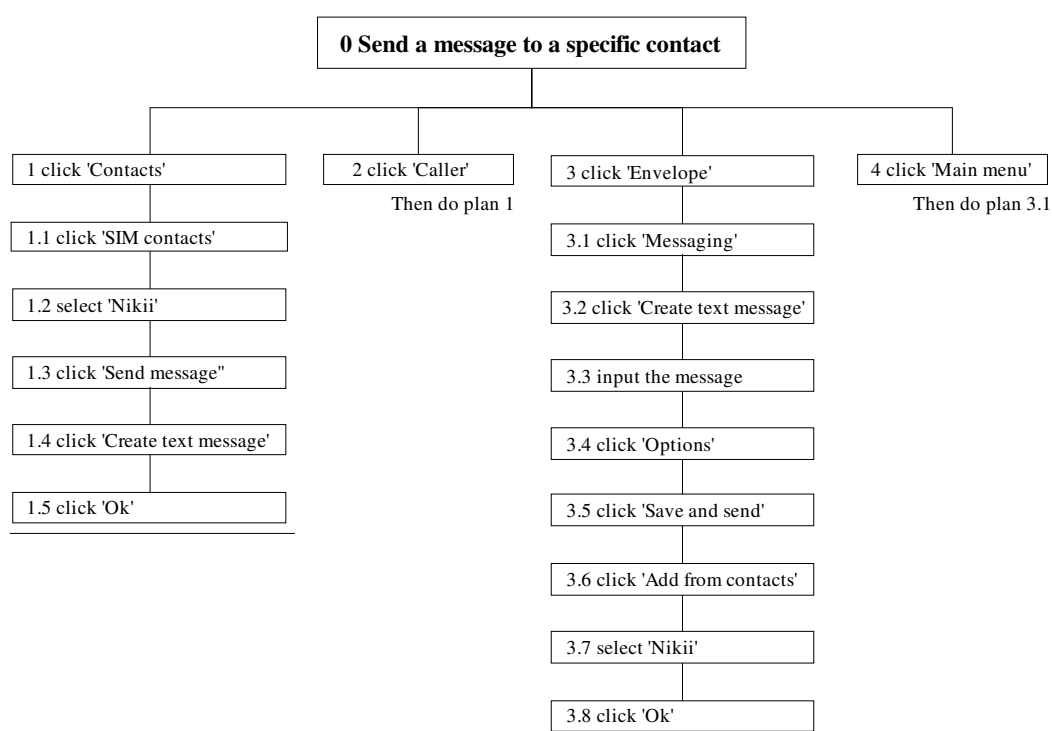


Figure 8-6 HTA of Task 2 with Vodafone 541

Table 8-2 Cognitive style-routes selection-Task 2

Routes	Holists	Serialists	Total
	N=6	N=6	N=12
0 ▶ 1 ▶ 1.1 ▶ 1.2 ▶ 1.3 ▶ 1.4 ▶ 1.5	16.7%	16.7%	16.7%
0 ▶ 2 ▶ 1 ▶ 1.1 ▶ 1.2 ▶ 1.3 ▶ 1.4 ▶ 1.5	0%	0%	0%
0 ▶ 3 ▶ 3.1 ▶ 3.2 ▶ 3.3 ▶ 3.4 ▶ 3.5 ▶ 3.6 ▶ 3.7 ▶ 3.8	83.3%	50%	66.7%
0 ▶ 4 ▶ 3.1 ▶ 3.2 ▶ 3.3 ▶ 3.4 ▶ 3.5 ▶ 3.6 ▶ 3.7 ▶ 3.8	0%	33.3%	16.7%

8.4.3.3 Task 3-Seeking a target photo

It is possible to access the photo album with Vodafone541 via two different routes (Figure 8-7.) The majority of participants sought the icon that related 'photo' on the menu, and then applied the icon of image viewer to find the target photo (Table 8-3). The image viewer presents the photos as a long list. Each file was shown by the title and a thumbnail photo. The photos were arranged alphabetically according to the files' title. The initial alphabet of the target photo is 's', therefore, it is necessary to operate the scroll bar to find the photo.

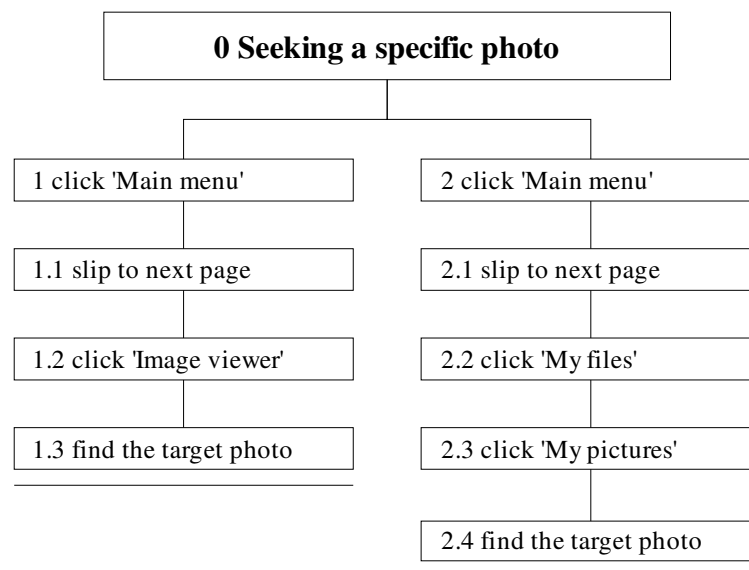


Figure 8-7 HTA of Task 2 with Vodafone 541

Table 8-3 Cognitive style-routes selection-Task 1

Routes	Holists	Serialists	Total
	N=6	N=6	N=12
0 ► 1 ► 1.1 ► 1.2 ► 1.3	100%	66.7%	83.3%
0 ► 2 ► 2.1 ► 2.2 ► 2.3 ► 2.4	0%	33.3%	16.7%

8.4.4 Part 2-Observation

Observation is an important part of evaluating the holistic-serialistic operational behaviour categories. Following the observation schedule as mentioned earlier, participants' interaction with Vodafone 541 and verbal commentary were recorded. Based on the observation schedule, the hypotheses were set to evaluate whether if individuals' interaction with the phone is consistent with the holistic-serialistic operational behaviour categories or not.

a) how cognitive style differences affect the way in which an individual browses icons:

Holists: reviewing icons randomly between the left side bar and bottom bar on the desktop;

Serialists: reviewing icons one by one from the left side bar or the bottom bar.

b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface:

Holists: tend to select the most known icon. For instance, Task 1, due to the graphic icons of contacts and caller being similar, holists might select either on their first attempt. However, they will eventually complete the task via the icon of contacts. To complete Task 2, majority of them might access the graphic icon of envelope to send a message instead the icon on the menu.

Serialists: tend to select the icon of 'contacts' on their first attempt at sending a text message due to it being the first icon on the bottom bar. Also, they might also tend to access the main menu to achieve the goal instead using the envelope icon on the desk top.

c) *how cognitive style differences affect the way an individual seeks the target photo within a long list of unknown files;*

Holists: reviewing the list quickly, checking photos randomly, and moved the scroll bar up and down repeatedly.

Serialists: reviewing the thumbnail photo icon one by one, checking fewer photos than holists before finding the target photo. They may have a problem with operating scroll bar.

d) *how cognitive style differences affect whether or not the individual follows the same route to complete the task with their mobile phone and the instrument in this study.*

Holists: should apply the categories to complete Task 1 & 2 that are the same as when they made a call or sent a text message with their mobile phone.

Serialists: might apply different categories to complete Task 1 & 2 that differ from their preferences when performing the tasks with their phones.

In order to observe the twelve participants' performance and their commentary of interacting with Vodafone 541, the response to the observation schedules were illustrated as follows. Participants' illustrations of their typical thought processes whilst completing the tasks were quoted followed by the analysis of the observation. Holistic participants were named as No. 1 to 6; serialistic participants were named as No. 7 to 12.

a) how cognitive style differences affect the way in which an individual browses icons

Holists: Over half of participants checked icons from the side bar on the desktop and curiously the other icons on the bottom bar at the same time. They performed irresolutely and tended to press the icons on the side bar or on the bottom bar. Two participants expressed their experience of making a call with the phone as follows.

Participant No.1

'Making a call, hum...I do not see the phone icon on the side bar or on the bottom. There is an icon with two arrows on the left side... And there is a phone with arrows, maybe this one? Ok, keypad for inputting phone number. Ok, maybe the first one of the bottom bar.'

Participant No. 4

'Ok, I want to make a call to Nikii. There is an icon with a red spot, and an icon looked like keypad. Ok, I press the icon of the keypad. Oh, no, it is the menu. And, how can I make a call from the menu? Call register? Calls? No, where is the contacts. I do not know how to make a call with this phone. It is funny. Ok, I am looking at the desktop, there is a phone with arrows, maybe this one? Oh, it is the keypad actually. But I do not know the phone number. So, there is must be a contact list at somewhere. How about this one? The left icon of the bottom bar. Yes, this is the contact list.'

Besides, according to participants No.2 and 3's commentary, they reviewed icons on the menu randomly when seeking the icon to access photo album.

Participant No.2

'Well, I want to find the photo. Here are call register, calendar, profiles...why it shows a speaker? (the participant was reviewing the second page of menu) And, settings, Bluetooth, calculator. (the participant was reviewing the first page of menu) And, radio, camera, here is the image viewer (the participant was reviewing the third page of menu)'

Participant No. 3

'I want to see the photo. Hum, there should be a photo album something. Hum, how to see the menu? (clicked the red spot on the side bar, then clicked the right icon on the bottom bar) Ok, here is the menu. Hum, notes, messaging, Internet, nope, anymore? (accessed to the third page) Here is a dice, and...maybe image viewer?'

Serialists: 66.7% participants started reviewing icons on the side bar whilst others reviewed the icons on the bottom bar during their initial attempt at using the phone. They showed their understanding of each icon one by one as well as some interest in unknown icons and maybe clicked the icon in order to comprehend its function.

Participant No. 9

'I want to make a call. The icons, on the left side, the first shows two arrows, should be call log or something, the second looks like a sun, let me take a look. (accesses the function) It shows the terms about using the function. Ok. And the next one looks like playing something. The fourth, it looks like a folder, let me check what it is. (accesses the function) Oh, it is camera, but the icon does not look like camera. Ok, go back to the desktop, the red stop, probably not. Ok, the one on the bottom looks like a phone book, yes, it is the contact list.'

Participant No. 11

'To make a call, I am looking for a phone icon. On the left, arrows, yellow stuff, and...hum, maybe the left one on the bottom? (accesses the function) Yes, it is the contact list.'

b) how cognitive style differences affect the way an individual selects an icon in order to complete a task when there is more than one option on the interface;

Holists: 33.3% holists intended to send text message (Task 2) via the function of 'Contacts.' However, only 16.7% of holists completed this task via 'Contacts'. Most of them preferred to send text message via the envelope icon on the desktop.

Participant No. 5

'I want to send a message to Nikii. Here is an envelope, okay, I am going to edit a message.'

Participant No.6

'Send a message to Nikii. Here is an envelope, so I should be able to send a message from here.'

Serialists: the majority of them completed Task 2 via the envelope icon on the desktop or main menu. Only 16.7 % of serialists sent text message via contact list.

Participant No. 7

'Ok, send a message. Contacts, select Nikii, and...hum, options, send messages...it is easy.'

Participant No. 10

'Here is an envelope, but I am not sure it is for sending email or message. So, I am going to the menu. Ok, here is the 'Messaging'. I prefer to see the text title.'

c) how cognitive style differences affect the way an individual seeks the target photo within a long list of unknown files

Holists: exhibited panic when presented with a long list, tended to move the scroll bar down and up quickly. They also tended to move the scroll bar down but not to the end, and to move it up to the middle several times. All of holists accessed the photo album via the icon of 'Image viewer' on main menu.

Participant No.1

'Well, I do not see the photo. The photos are so tiny (drags the handle of the scroll bar down and up for three times.) Where is the photo? Hum...I do not know how to do. The photo, maybe this one (clicks two photos randomly that are not the target and moves the handle bar twice). Hum...it is difficult. (Searches the photo one by one from the top of the list) Ok, I think it is the one.'

Participant No.6

'The photo, hum...(moves the handle of the scroll bar down) I'm skimming the list. And I do not see anything similar. (moves the handle of the scroll bar to the middle and down to the end of the list). Where is the photo? Where is it? Hum, this one looks like the target. (clickes three photos randomly that are not the target photo). Hum, maybe I should review the photos one by one. (starts to review photos with full screen mode) Here is the photo.'

Serialists: performed carefully, double checked the photo and extra information from the task sheet. Around half of the serialists were confused about how to move the scroll bar. They tapped the scroll bar instead dragging the handle to review the list. All functions of Vodafone 541 were located across three pages; the second page was shown to users when accessing the main menu from desktop. The icons of 'Image reviewer' and 'My files' were located on the third and the first page of the menu, respectively. Around 33.3% serialists therefore accessed the first page of main menu and sought the target photo via 'My files'.

Participant No. 9

'The photo, it looks like something in a clear background. Not here. Hum, how to move the list? (taps the top and the bottom of the scroll bar for several times) I see. It is not sensitive. Not here. Do you know what is the file name? No? Ok. (double checks the photo from the task sheet) Is this one? A dragon.'

Participant No. 12

'Hum, the photos looked small. I cannot see it clearly. Hum... (taps the handle of the scroll bar) Anything else? I do not know how to see more photos, if there is any? (taps the arrow on the top of the scroll bar and the arrow on the bottom of the scroll bar) Ok, now I can see more photos. (browses the thumbnail photos slowly). I think this is the one? (checks the photo on the task sheet before tapping the photo).'

d) how cognitive style differences affect whether or not the individual follows the same route to complete the task with their mobile phone and the instrument in this study

Holists: the majority of holists used the same categories to make calls and to send text messages on their mobile phone and Vodafone 541. They preferred to use the icons on the desktop to complete the two tasks, and use the same strategy to achieve the goal as they used with their own mobile phones.

Participant No.3:

With own phone: 'Well, I used to make a call via the shortcut on the desktop, quick. And, reply message when I got the message immediately. So I normally do not go to the menu. If I want to send a message to someone, I go to contact list, select the person and send a message. If I want to review photos, I would go to the album from the menu'

With Vodafone 541: This participant completed Task 1 & 2 via the icon of 'Contacts' on the desktop and sought the target photo in the category of 'Image viewer'. The participant was confused by the title of 'Image viewer' and suggested that it be changed to 'Photos' instead.

Participant No. 5

With own phone: 'I use a poor phone, old model (with numeric keypad). So I have to go to the menu to do something. But I can use the button to see who called me before; who are my friends, so it is easy just ring them from there. If the person was not on the list, then I have to go to the menu, to check the contacts. Send a message, just go to message, and create a new one. To review photos, go to gallery.'

With Vodafone 541: This participant accessed main menu on their first attempt; however, the function of 'Contacts' was only listed on the desktop. It was therefore necessary to return to desktop to complete the task. In terms of the experience of using the icon from the desktop, the participant quickly selected the graphic icon of 'envelope' to send a message. The participant reviewed all icons on the desktop when seeking the icon to view photos for

Task 3 at the initial time then accessed main menu, the icon of ‘Image viewer’ was thus found to achieve the target photo.

Serialists: they were more likely to complete tasks via the icons with clear meanings. They tended to access the main menu to complete a task. They also tended to apply different routes to make calls and to send text message in terms of their relationship and their frequency of contact with the recipient.

Participant No. 8

With own phone: ‘I used to go to menu, to call someone and to send messages. It all depends on if I contact the person often or not. If I call my mother, I remember the phone number at home, so I dial the number. If I spoke to the person recently, I might check the history. For example, my girl friend, I checked our messages and text her.’

With Vodafone 541: This participant accessed the menu to find the icon for making a call but the relevant icons were listed on the desktop only. Therefore, the icon ‘Call Register’ was selected. The participant then returned to the desktop to complete Task 1 by clicking the graphic icon ‘Contacts’.

Participant No. 11

With own phone: ‘I have some shortcuts on the desktop of my phone. I use them sometimes, or go to the menu. It is clearly to see the functions on the menu. It does not matter. If I remembered I just contacted the person recently, then I might find our previous texts, and reply. Or to find the person from missed call or recent called something like that. If I have to phone someone who I am not close with, then I have to go to contacts. I do not have many pictures in my phone, of course I would review pictures on photos or images or something like that.’

With Vodafone 541: This participant accessed the graphic icon ‘Call History’ that was illustrated by two arrows on the desktop. The participant then reviewed icons on the desktop slowly and accessed the graphic icon

‘Contacts’ to make a call. The target photo was found via the category of ‘My files’ due to page 1 of menu being reviewed before page 3.

8.5 Discussion

This chapter attempts to identify phone users’ cognitive style in terms of their operational behaviour consistent with the categories that were developed in chapter 5. Participants’ interaction with Vodafone 541 was transformed into text and then divided into the categories. This study also found that most participants’ performance includes both holistic and serialistic styles. Overall, 83% ($N=6$) of holists’ operational behaviour matches more holistic attributes than serialistic attributes in the categories, whilst 67% ($N=6$) of serialists’ performance matches more serialistic attributes than holistic attributes in the categories. The other participants’ operational behaviour matched with an equal number of holistic and serialistic attributes. Therefore, the categories can be treated as valid in identifying individuals’ cognitive style in terms of their interaction with the interface of touch screen mobile phones. The outcomes were then achieved the objective 3 and 4 of this research as the developed categories link theoretical attributes of holistic-serialistic styles with phone users’ operational behaviour by correct and clear descriptions. Therefore, the categories allow the researchers, designers and system developers to understand phone users’ operation with a phone via an alternative aspect. With regard to the concept of installing applications to smartphones and the relationship between cognitive style and learning style; identify phone users’ cognitive style will be also benefit for developing educational applications for phone users.

However, participants’ performance does not only tend towards holistic or serialistic styles, but also sometimes includes both styles. The results of this investigation can only be used in interpreting the users’ operational behaviour with such phone interfaces and tasks. More importantly, the categories point out the users’ differences according to their interaction behaviour, and help to collect the data from the users’ usage with a phone, aiding in the adjustment of the layout of the phone interface by the system.

In contrast to previous studies that seek the impact of cognitive style on individuals' selection of items and categories (e.g. Ford and Chen, 2002; Kim and Lee, 2007; Magoulas, Chen and Dimakopoulos 2004), this investigation provides confirmation of the link between theoretical attributes of holistic-serialistic style and the individuals' operational behaviour with touch screen mobile phone interfaces. The descriptions of the users' interaction with phone interfaces bridge the gap in understanding users in a practical way.

8.6 Summary and Conclusions

This chapter integrates the findings of previous chapters and examines the validity of the categories that were developed in chapter 5. In general, the participants' performance was more or less including both holistic and serialistic styles. However, the individual's cognitive style still reflected a strong effect on their operational behaviour. More specifically, this investigation introduces an alternative concern to the process of customising mobile phone interfaces.

CHAPTER 9 CONCLUSION

Overview

This chapter integrates the results from previous chapters and develops design guidelines for holist and serialist users. More importantly, this research suggests placing users as the core in design process; interface designers and system developers were also suggested to highlight UX as an important factor in improving interfaces for mobile handsets. This chapter not only proposes design guidelines for further interface design, but also discusses it in terms of the general design guidelines that are applied in the mobile phone industry. The design guidelines that were established in this research supply users' practical operational behaviour with phone interfaces to designers in order to further understanding of how the users react differently according to their individual differences.

9.1 Introduction

This PhD thesis follows a process of understanding users, categorising users, and then developing these principles to identify the users' type in terms of their operational behaviour. As can be seen in public media such as newspapers and manufactory report, the industry seems to tend towards investigating phone users' need for functions, communication quality and so forth, rather than their operational behaviour with mobile handsets. Following the interface design process, the functions were designed in terms of a specific purpose and the usability evaluation was then conducted. This research attempts to understand the users through their interaction process and operational behaviour with mobile phones rather than their needs according to a sociological perspective.

According to the investigation in chapters 4 and 5, the users' performance with phone interfaces highlighted significant differences in cognitive styles and UX. Through observation of the task of seeking a target photo within multiple layers and unknown folders, the categorisation of user types according to cognitive style was established. More specifically, based on the findings in chapter 4 and 5, the effects of UX and the links between cognitive style and individuals' problem solving ability were then investigated. The impact of UX on phone users' operational behaviour was discussed in chapter 6 by a novel methodology – ToE.

The necessary elements that the users cared about the most were distilled. In chapter 7, the connection between cognitive style and individuals' operational behaviour was examined. The outcomes provided confirmation of the phenomena as holists had a stronger rigidity of mental set than serialists and serialists interacted better with hierarchical structure than holists. The phenomena, elements, findings and confirmations were integrated to examine phone users in chapter 8. The investigation attempts to evaluate the application of the categories that were developed in chapter 5. The results show that although individuals' operational behaviour with the phone interfaces seemed to include both holistic and serialistic styles, eventually, their operational behaviour tended to exhibit their cognitive style in terms of the SPQ.

This chapter therefore integrates all of the findings to establish design guidelines that consider users' requirements from phone interfaces according to their operational behaviour. More importantly, the design guidelines provide an alternative perspective to interface designers and system developers concerning the users' individual differences.

Overall, this research achieves the aims of understanding phone users more deeply by applying both quantitative and qualitative methodologies, finding the effects of individual differences in users' operational behaviour, establishing a method by which to identify the user's type in terms of the differences of their operational behaviour and to suggest alternative design guidelines. More importantly, this research contributes the concept of recognising phone users' type by their operational behaviour and then providing suitable interfaces; in this case, the cognitive holistic and serialistic styles were applied.

9.2 Research summary

This research aims to understand phone users more deeply by studying their operational behaviour. Three individual differences of gender, cognitive style and UX were involved in examining individuals' interaction with phone interfaces. More specifically, the effects of cognitive style and UX were found to have a significant effect on the individuals' operational behaviour with phone interfaces. Cognitive styles have been applied in diverse studies concerned with users'

selection of categories and items in mobile phone interfaces as mentioned in chapter 2.4.2.4 (e.g. Masuda and Nisbett, 2001; Unsworth, 2005; Kim, Lee and You, 2007). However, there is a lack of reflection on its theoretical attributes in users' practical operational behaviour. UX has been widely discussed in the HCI community in recent decades as it is one of the most important elements of product design. It certainly had an effect on the users' interaction with phone interfaces in this research. This research was therefore motivated by the studies in the area of human-machine interface design, cognitive style and UX. In terms of the background study and literature review, the research focuses on *'understanding mobile phone users before conducting design'*. Two aspects were addressed in achieving the aim of understanding phone users more deeply: how individual differences affect one's operational behaviour with phone interfaces, and which elements the users care about most in a mobile phone.

This research was thus seeking the factors that impact individuals' interaction with a phone interface. Cognitive style and UX were then addressed in terms of their significance in quantitative analysis. Qualitative approaches were then applied to develop the links between theoretical attributes of holistic-serialistic styles and individuals' operational behaviour with phone interfaces. Furthermore, the necessary elements of the users' requirements of phone interfaces that affect the users' performance were investigated from the perspective of UX. More importantly, holistic and serialistic styles were also used to examine individuals' problem solving ability and their rigidity of mental set as well as their interaction with hierarchical structure in terms of their operational behaviour with phone interfaces. Finally, this research attempts to apply the categories that are consistent with the theoretical holistic-serialistic styles and the users' operational behaviour to identify a phone users' cognitive style and establish the application of the linkage and categories.

9.3 Research findings, contribution and discussion

This thesis applies both quantitative and qualitative methodologies for a deeper understanding of individuals' interaction with phone interfaces. In terms of the significance of quantitative findings, qualitative approaches were applied to explain the differences between individuals' operational behaviour. Based on the

differences in users' operational behaviour with phone interfaces, users might have difficulty in operating functions naturally and seeking functions, files, photos in a short time. To improve the process of completing tasks, this research suggests the solution is to identify a user's type and provide a suitable interface. The categories of identifying phone users' cognitive styles based on their operational behaviour were then established to fit the theoretical characteristics of holistic and serialistic styles. By doing so, this research expects that users' cognitive style can be identified by phone systems, and then, the systems could provide a suitable interface to the users in order to make the phone 'easy to use'. The design guidelines that fit holistic and serialistic styles were therefore established.

According to the investigation in chapter 6 to understand the necessary elements of phone interface design; one of the criteria is that the operation process should be easy to perform. The concept of providing a suitable interface to the user was an attempt to achieve this goal. Previous studies that relate cognitive style and interface design suggest that users might have the equal benefit of being able to operate the interface, and then obtain information from the interface that tailors it to the users' cognitive style (Chen, Magoulas and Dimakopoulos, 2005). In this research, the users had a higher level of satisfaction with the interface if they could complete a complicated task with the interface in a short time. However, relevant studies of users' operational behaviour and interface design are rare; this research thus provides an alternative perspective concerning phone interface design in terms of the users' operational behaviour with the interfaces.

9.3.1 Research findings

The findings of this research were discussed in terms of the cognitive style and UX aspects in following sections.

9.3.1.1 Cognitive style

The impact of cognitive style to phone users' operational behaviour

This research initially examined the relationship between phone users' cognitive styles and their performance and then applied two psychological tests to evaluate the findings. The attributes of holistic and serialistic styles were not only affecting users' strategies in seeking information to achieve the goal with phone interfaces, but also affected individuals' problem solving ability. Two psychological tests

were used to examine users' rigidity of mental set and their interaction with a hierarchically structured menu. The results were compared with the theoretical attributes of holistic and serialistic styles (Ford, 1985) as follows:

a) Theoretical holistic attributes:

Focus on several aspects of the subject at the same time.

Holists' operational behaviour:

Tended to skim icons quickly, neglected the target sometimes.

Theoretical serialistic attributes:

Step by step approach.

Serialists' operational behaviour:

Reviewed icons carefully instead quick skimming.

b) Theoretical holistic attributes:

Establish relationships between objects by using complex links, using top down approach.

Holists' operational behaviour:

Tended to be functionality-oriented and preferred to select known icons on the desktop to complete the tasks. If the necessary icon was not found on the desktop, holists tended to click available icons randomly and double checked the icons even though they have just accessed them.

Theoretical serialistic attributes:

Serialists concentrate on the chunks of information that are sequentially ordered and better defined.

Serialists' operational behaviour:

More goal-oriented and preferred to complete the tasks within routes that they were familiar with. They preferred to access the main menu to seek the icon that could be used to achieve the goal.

c) Theoretical holistic attributes:

More likely to use analogies to make the connection between different aspects of the subjects.

Holists' operational behaviour:

Checked unknown folders randomly without order, and repeatedly checked the folders which they have already accessed.

Theoretical serialistic attributes:

Use a bottom-up approach

Serialists' operational behaviour:

Checked unknown items and folders one by one.

d) Theoretical holistic attributes:

Relate concepts to prior experience.

Holists' operational behaviour:

Tended to complete the three tasks via the same categories and routes across all six interfaces.

Theoretical serialistic attributes:

Relate characteristics within a concept.

Serialists' operational behaviour:

Showed a greater tendency to apply different categories when completing the tasks across different mobile phone interfaces.

The findings were therefore transformed into design guidelines for designing interfaces for holists and serialists:

For holists

- ***Establish a hierarchical structure menu that is shallow with fewer folders and wide with icons; such as the structure of the interface of iPhone***

According to the evidence of this research, holists completed tasks faster than serialists with the interfaces that display all function icons on the desktop, such as iPhone and LG rather than the interfaces that require

users to access a main menu to execute functions, such as HTC, Nokia, and Samsung. Therefore, it is necessary to shorten the menu and display all icons on the desktop for holists.

- ***Highlight the most often used functions, the differences between icons and apply universal symbols, such as the design underneath the interface of iPhone and LG-KM900***

Based on one of the theoretical descriptions regarding holists' exploratory behaviour (Ford, et al., 2002), they tend to seek information by serendipity. This research also observed that holists preferred to quick skim function icons on phone interfaces rather than check items one by one. It is thus important to highlight the most often used functions and to emphasise the differences between icons for increasing the possibility of finding the target in a short time.

- ***Investigate users' preferences of categories when the interface requires users seeking information within multiple folders***

According to the findings in this research, holists panicked whilst seeking the target photo within several folders. As a result of not being given enough information on the photo and the folders, it was difficult to establish the relationship between folders. This research suggests investigating users' preferences of categories before designing multiple folders on an interface for a specific purpose, such as storing files, photos, categories, applications and so forth.

- ***The process of completing tasks should be the same with most of similar devices, in the way that operations on iPhone and iPod are the same***

Holists were more likely to complete a task by one strategy across different interfaces in this research. The phenomenon was also examined using a psychological test - Luchin's jar problem. The outcome shows that holists have a stronger tendency towards rigid mental set than serialists. This research hence emphasises the importance of applying similar processes of completing tasks and similar methods to operate a phone when designing an interface on the mobile phone for target consumers.

For serialists:

- *A process to narrow down the users' focus on the desktop, such as pressing a button to access the menu; e.g. the interface of HTC-G1, Nokia-N97 and Samsung-OMNIA II*

Due to serialists tending to complete tasks quicker than holists within the phone interfaces that require users to access the main menu for whole functions, this research suggests designing the interface with a process to narrow the users' focus. It might save serialistic users' time spent checking items one by one on the desktop.

- *Present organised icons, such as listing functions followed by alphabets or a linear style; e.g. the menu of HTC-G1;*

In this research it was discovered that serialistic users sorted through icons one by one following the layout on the desktop. In the meantime, they read the text title of each icon. Therefore, their performance benefited from organised icons.

- *Clarify the meaning of icons along with text title; e.g. HTC-G1.*

Compared with holists' operational behaviour with phone interfaces, serialists were more likely to understand the meaning of each icon. More specifically, they read the text title of each icon and tended to ignore the icons that did not have text titles. Although this is a basic design guideline of designing phone interfaces, it is also crucial to consider the font size of the text title, the distance between the text and graphic symbol and the ratio of the text title and graphic symbol. More importantly, the connection of the text and graphic symbol should be obvious.

9.3.1.2 User experience

In terms of the findings of chapters 4 and 5, UX was a factor that impacted the users' performance with phone interfaces. In addition, the post-interview in chapter 4 exposed the difficulty in organising the participants' requirements of mobile phones. In chapter 6, a novel methodology - Taxonomy of Experience (ToE) - was conducted to obtain the important elements of mobile phone design that affect the users' operational behaviour. Whilst researchers attempt to

transform UX into quantitative data, ToE provides a systemic platform to sort UX and to categorise and distil the necessary elements of UX. In this research, the users' trial experience with a touch screen mobile phone was transformed into eight categories (see chapter 6.4). The outcomes show that the most important element is 'understanding'. This includes the understanding of visual design, the feedback from the phone, the operation process and so phones are developed that can be aware of users' intentions. Moreover, familiarity with computers and the other phone models was also emphasised by the users. The other elements include the freedom of operation; if the platform allows operation of functions without going back to the main menu; the specific position to complete the specific tasks and the information the physical handset might provide about how to operate the phone. In addition, the users would like to share information with people if the size of the phone is small and easy to use. They also felt intimacy with a small size mobile phone as it is a part of the user. When the phone was easy to use and presented the operation process clearly, the users felt more comfortable using the phone and found more enjoyment in the entertainment functions.

Overall, this research thus provides the design guidelines and necessary elements that were generated from individual differences-cognitive style and UX. More importantly, they were generated from the users' operational behaviour. For the purpose of pointing out the differences between the design guidelines of this research and the phone industry, the general interface design guidelines of the platform Symbian, Android and iOS were reviewed as follows.

Reviewing phone interface design of industry

According to Gartner (2010), Symbian, Android and iOS were the top three operating systems sold to end users in 3Q 2010 (see Figure 9-1). This section reviews the design principles of these systems compares them with the design guidelines that were developed in this PhD thesis.

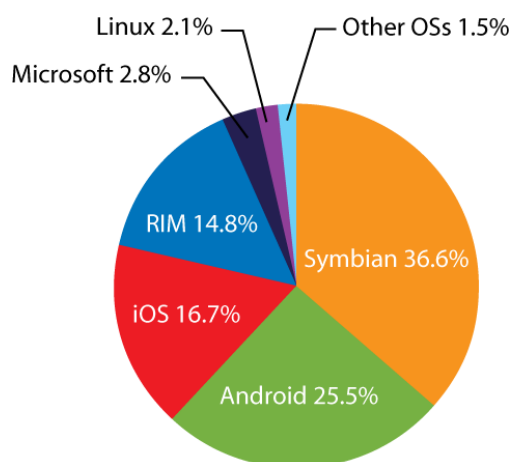


Figure 9-1 Worldwide smartphone sales to end users by operating system in 3Q10
(Gartner, 2010)

Symbian

The core of Symbian's design guidelines for designers and developers is graphic design. Most concerns about designing applications on Symbian's platform were delivered by visualised pages with handsets. The guidelines also express the importance of designing mobile applications with an attractive visual appearance. The design guidelines provide suggestions about how to create a good impression for an application, the limitations and restrictions of devices, the context of use, the purpose of an application and so on. In addition, the basic design issues include the application of colours, contrast, fonts and text, animation, icon design and sounds when designing an interface or an application for Symbian's platform. In spite of the graphic design principles, the design guidelines are also concerned with clarity and support navigation with visual clues.

Android

The user interface design guidelines of the Android platform were established based on the concept 'View'. The guidelines include the importance of defining an activity's user interface with a hierarchical structure, the design of layout, widgets, events, menu, styles and themes, and the adaptation with external sources. Except for the appearance of designing an interface, activity and task design were included in the guidelines. It discusses the relationship between the different functions, how to establish the connection between functions, the logic of the system, and the restrictions and capabilities of the platform. Overall, the design guidelines tend to emphasise the standard of graphic design.

iOS

iOS is the platform of iPhone and a series Apple products. Compared with the design guidelines of Symbian and Android, the principles of designing applications for iOS are not only focused on the appearance of the interface, but also emphasise the importance of consistency between applications and iOS, allowing users manipulate applications directly without separate controllers, response to users' actions, applying metaphors to objects, and letting users control actions.

Comparison

The design guidelines mentioned above provide the general concept of conducting design for phone interfaces. However, depending on individual differences of gender (e.g. Passig and Levin, 2001), cognitive style (e.g. Kim, Lee and You, 2007) UX (e.g. Väänänen-Vainio-Mattila et al., 2008), culture (e.g. Norenzayan, 2001; Khattab and Love, 2008), age (e.g. Ziefle and Bay, 2008) and so forth, the design guidelines should tell the story behind the scene. There is a lack of how to address the elements of individual difference, why it is necessary to address those elements, what the users' reaction and performance will be and what consequences might occur as a result of an inappropriate design.

Interaction design is a wide field that involves conception, cognition, communication, user expectation, experiences and so forth (Sharp, et al., 2007). More specifically, understanding users is one of the important elements when designing interfaces and users' interaction with a mobile device (Jones and Marsden, 2005). This research thus aims to understand phone users from the root of their performance and to find the effects that impact a user's subsequent interaction with phone interfaces. Cognitive style was adopted in order to understand how the users seek icons, target items and how they interact with problems, and provides the solutions to design the context for the users in terms of their operational behaviour. In addition, from a UX perspective, the users provide the important elements that affect their usage with a phone. While those elements might be addressed by the phone industry, the reason for addressing those elements might not be illustrated as clearly as in this research.

9.3.2 Research contribution

This PhD research not only achieved the objectives that were mentioned in chapter 1.3; but also extended the investigation to a deeper understanding of the users' operational behaviour with phone interfaces from a psychological perspective.

Objective 1 & 2:

This research utilises both quantitative and qualitative methodologies to understand the effects of individual differences to mobile phone users' operational behaviour. Whilst previous studies tend to present the differences only by quantitative results (e.g. Kim and Lee, 2007; Mullany, 2001; Magoulas, Chen and Dimakopoulos 2004,) this PhD thesis addresses how the differences impact the individuals' operational behaviour and what theoretical attributes support the behaviour. The approach of applying both methodologies provides the explanation as to how the attributes of cognitive style differences reflect on the users' operational behaviour, and the important elements of designing mobile phones which should be addressed to allow phone interface design from UX perspective.

Objective 3 & 4:

The links between theoretical descriptions of cognitive styles and phone users' practical operational behaviour were developed. It then sets out the design guidelines for holistic and serialistic users. Due to the cognitive holistic and serialistic style affecting the individuals' information seeking ability, applying the pair of styles to examine phone users' operational behaviour highlights a fundamental concern in categorising phone users. In terms of the sequence of designing easy to use phone interfaces, to shorten the completion time of tasks, and to improve the users' satisfaction of the phone interfaces, the contribution of this research is to finally attempt to achieve the goal of satisfying the users.

Moreover, a novel methodology ToE was applied to allow for a deeper understanding of how UX affects the users' interaction with a mobile phone. It contributes detailed descriptions and important, necessary elements concerned with mobile phone design. More specifically, to compare with the design guidelines in the phone industry, the application of ToE highlights what the

element affect the users' interaction with a touch screen mobile phone and how to improve the design of mobile phones.

In addition, this doctoral thesis develops the relationship between cognitive style and individuals' problem solving ability. The phenomena were found with the users' interaction with phone interfaces initially. Two psychological tests were then applied to examine the relationship between the conditions. Their inclusion was meant to confirm holist's tendency towards stronger rigidity of mental set, and serialists tendency to perform better than holists with hierarchical structure. Besides, the connection was established by both quantitative and qualitative methodologies; it fits the objective of this research, to understand phone users with mixed methods.

Finally, this PhD research links the knowledge of interface design and psychology. This was meant to provide an alternative angle to derive design from users' differences in their operational behaviour, instead of the functionality of handsets. The research process suggests understanding how the users interact with phone interfaces, what the factors are that affect the users' performance and why the operational behaviour was actually matching theoretical attributes of individual differences before conducting design.

9.4 Limitations

This doctoral research work is limited by a number of factors. Four aspects of the factors are discussed in this section: the instruments, the participants, the tasks and the application.

First of all, this research utilised several tools to assess participants' cognitive style (SPQ), performance (completion time, the numbers of icons clicked), satisfaction with interfaces (QUIS), user experience (ToE) and the structure of each task (HTA). Those tools have been applied to numerous studies in education and HCI fields. However, the validity of them might be in question. Although this research adopts a triangulation method to ensure independent the research findings for improving the validity of this research (Lincoln and Guba, 1985,) this

research relies on the qualitative approach-observation as research biases are difficult to avoid. Based on the quantitative results that indicate the correlation between participants' performance and phone interfaces, individuals' operational behaviour was thus analysed via the recorded video clips. This might be a factor which impacts the results due a lack of extra information obtained from users when collecting data. Furthermore, this research adopts handsets and emulators that looked the same as real handsets in the computer environment to examine phone users' performance. While, according to Love (2005) and Marsden (2005) it is important to make the prototype look real, the bias might still occur as a result of the different operation methods.

Secondly, the majority of participants are students in a British university, aged 18 to 35 years, and have had more than four years using experience with mobile phones. The bias might occur when applying the established design guidelines of this study to the other age groups. Due to interaction design being involved with diverse aspects such as HCI, cognitive ergonomics, information systems, human factors, social sciences and so forth (e.g. Sharp, Rogers and Preece, 2007); it might necessary to revise the developed design guidelines for further application to different groups of users.

Thirdly, tasks in this research include simple and complex tasks, and those tasks were familiar to participants. However, sending text message, calling a contact were too basic and involved fewer steps. This research thus suggests applying tasks that involve the variables of multiple folders with fewer clues for achieving the goal to aid in identifying users' cognitive style.

Fourth, although cognitive style is one of the stable individual differences (Benyon, Crerar and Wilkinson, 2001,) the familiarity of the interfaces might affect the users' performance at the same time. In recent years, phone interface design in the market tends to follow iPhone. The differences between similar interfaces might result in different operational behaviour for identifying an individual's cognitive style in terms of the categories that were established in this research.

9.5 Future research direction

This research contributes the categories for identifying mobile phone users' cognitive style in terms of their operational behaviour, the elements that users cared about the most with a touch screen mobile phone based on user experience and the design guidelines that were established based on users' individual differences in cognitive styles and using experience. The future research direction suggests improving interface design by crossing fields, quantifying the qualitative results, and considering interface design from users with a different angle.

a) Improving interface design by crossing fields

This research identifies four attributes of theoretical holistic and serialistic styles that match users' operational behaviour when using touch screen mobile phones. The concept of linking cognitive styles and interaction with an interface for designing interfaces can be applied to a wider range of studies. According to the findings of this research, the holistic and serialistic cognitive styles were also found to significantly affect individuals' problem solving abilities. Nevertheless, users' interaction with an interface involves diverse factors such as ergonomics, psychology, cognitive science, computer science, social sciences and so forth (Sharp, Rogers and Preece, 2007). It is therefore necessary to improve interface design by conducting research that crosses fields.

b) Quantifying qualitative results for systems

This research establishes the categories for identifying users' cognitive style based on their operational behaviour with phone interfaces. The further work can focus on transforming the qualitative results to a quantitative measurement for systems to identify users' cognitive style by the differences in their operational behaviour. As a result, a system will be capable of categorising users and providing a suitable interface to improve the users' usage of a phone.

c) Identifying users' cognitive style for educational apps

The concept of installing apps on mobile phones has grown rapid in recent years due to the launch of iPhone. Cognitive style is one of the factors that affect an individual's learning strategy (e.g. Riding and Douglas, 1993; Ford, 1995; Chen, 2000). The concept of identifying a user's cognitive style and providing a suitable

interface can be applied to designing educational apps to improve learning efficiency for educational purposes.

d) Alternative concerns of interface design

This research establishes the design guidelines and provides important design elements from the perspectives of individual differences, cognitive style and UX. The substantial design guidelines not only provide suggestions for interface design, but also highlight the importance of understanding users through their operational behaviour. This PhD thesis suggests developing a bridge between users, interface designers and system developers with a deeper, more complete understanding and raises concerns about designing an interface for target users. Meanwhile, the interface should be adjustable to make it a suitable for different groups of users.

9.6 Conclusion

This research provides a different angle with which to anticipate the development of customising interfaces for improving user experience with handsets. The role of a mobile phone is not only communication, but also includes various services and applications from personal assistant to healthcare, learning, the internet and entertainment (Love, 2005). Moreover, the concept of ‘relationships with objects’ for future generation mobile handsets and services was presented by Nokia in 2009. The aim of the concept is to collect and to transfer an individual’s psychological information via sensors and integrate all data to the ecosystem for developing personal digital profile. Such ideas reveal the importance of ‘the user’. Therefore, customisable interfaces for handsets will be an essential concern when designing interfaces for handsets in the future. This research demonstrates the process of understanding users from a psychological perspective and suggests guidelines to place users as the core of design. More importantly, this research links design and psychology to provide a better understanding of users for future design events and to address the importance of understanding users before conducting design.

Reference

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Appendices

- Appendix A Technographic questionnaire
- Appendix B Study preference questionnaire (SPQ)
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- Appendix D Informed consent form of pilot study
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Appendix A

Technographic questionnaire

1. Gender: male female
2. Age:_____
3. Education (the higher status currently possessing)
 - PhD Master Bachelor degree Diploma Certificate
 - High school or below
4. What is your major?
 - Arts Law Health Sciences and Social Care
 - Social Sciences Business Engineering and Design
 - Information Systems, Computing and Mathematics
 - Sport and Education Others_____
5. How long have you been using mobile phones?
 - <1 year 1-3 years 3-5 years 5+ years
6. How often do you purchase a mobile phone?
 - <1 year 1-2 years 2-3 years 3+ years
7. What is the main reason you purchase mobile phone? (please tick one)
 - current phone broken fancy for new products
 - current phone is difficult to use (interface hardware)
 - contract had expired Others (please specify) _____
8. How many text messages (SMS messages) do you send per day?
 - 0-10 11-20 21-30 30+
9. How many mobile phone calls do you make per day?
 - 0-10 11-20 21-30 30+
10. How long for a phone call on average?
 - Under 1 min 1-5 mins 6-10 mins 11-30 mins 31-60 mins
 - more than 1 hour
11. Do you call people more often than people call you?
 - Yes No fifty-fifty
12. What is the main purpose to make phone calls? (please tick one)
 - Contact with classmates Contact with friends Contact with family
 - Business purpose Others (please specify)_____
13. Where do you usually make phone calls? (please tick one)
 - Home Public places (outdoor) Public places (indoor)
 - Bus, tube, train Others (please specify) _____

Appendix B

Study preference questionnaire (SPQ)

- | | | |
|--|-----------|--|
| 1. When reading a book for my studies, I generally tend to concentrate on certain parts, and skip over others quite markedly, going back later if necessary to fill any 'gaps' or 'missing links'. | 1 2 3 4 5 | I tend to follow the author's presentation closely, rather than skipping about a lot. |
| 2. When I'm studying for an essay, I try to gather as much information as possible at the start. | 1 2 3 4 5 | I prefer to have more of a 'steady flow' throughout my preparation for the essay. |
| 3. I generally prefer to have a number of books 'on the go' at the same time. | 1 2 3 4 5 | When I'm studying, I generally prefer to deal reasonably thoroughly with one book before moving on to another. |
| 4. When I'm studying a new subject, I tend to want to keep the whole picture of the subject in my mind all the time and find it hard to concentrate on very detailed aspects unless I can constantly relate them clearly to the broad overall picture. | 1 2 3 4 5 | Once I've analysed the subject into its component parts, I like to focus on each of these parts in detail, systematically building up the overall picture bit by bit. |
| 5. I tend to spend quite a lot of time browsing in the library. | 1 2 3 4 5 | When I'm in the library, I tend to be looking for specific books, etc, rather than browsing. |
| 6. When reading a book for my studies, I prefer to spend quite a long time skimming over and dipping into it to get a clear picture of what it's about and how it will be relevant. | 1 2 3 4 5 | I prefer to get quite soon into a fairly detailed reading of it once I know that its going to be useful, in knowledge that its precise relevance and contribution will become clear from a detailed reading. |
| 7. Generally I prefer to be learning about a number of different aspects of a subject at the same time. | 1 2 3 4 5 | Generally I prefer to concentrate on one (or very few) aspect(s) of a subject at a time when I'm learning about it. |
| 8. I tend to want to keep the overall picture uppermost in my mind the whole time, and only work on more detailed aspect if I can see precisely how they will fit in to this picture. | 1 2 3 4 5 | Once I've done a basic analysis of what the subject involves, I'm happy to put to the back of my mind temporarily the broad overall picture while I do some work on more detailed aspects. |
| 9. Summaries would be very useful in the initial stages of my work on an essay. | 1 2 3 4 5 | Summaries of a wide range of books would not really be much use to me when I'm doing an essay – I really need the full texts more or less straight away. |

10. I like to approach a new subject in a broad way – often looking at widely spaced aspects of the subject and seeing how they may all fit together, before going back to ‘fill in’ any strictly logical steps that I may have skipped. **1 2 3 4 5** I like the logical links between different aspects of a new subject to be very close so that when I’m learning about a second aspect I can see very clearly how it relates to the first aspect that I have already learned about, and so on.
11. I think I tend to use rather more information sources than most people on the course. **1 2 3 4 5** When I’m doing an essay, I think that I tend to use rather fewer information sources than most people on the course.
12. I like to deal fairly thoroughly with the particular aspect I’m working on before going on to study others. **1 2 3 4 5** I find it too restrictive to wait until I have thoroughly ‘mastered’ one aspect of a new subject I am learning about before going on to study other aspects.
13. Generally I prefer to read the summary before reading the full text – even though it will all be found in greater detail in the main text. **1 2 3 4 5** Where an article includes a separate summary of what it is about, I generally prefer to get straight into the main text – since it contains all that is in the summary anyway.
14. When I’m studying for an essay, I like to start by ‘soaking in’ a wide range of information in order to get the ‘feel’ of the subject. **1 2 3 4 5** I prefer to analyse the topic fairly clearly on, and search for information which is more clearly focused on particular aspects of the topic.
15. I prefer to skip about and ‘dip in’ quite a lot. **1 2 3 4 5** When I’m reading a book for my studies, I prefer to work through it fairly logically from beginning to end.
16. I prefer to spend quite a bit of time reading the summary of conclusions before going on to a detailed reading of the main text. **1 2 3 4 5** Where a book or journal article has a separate summary of conclusions, I prefer to get straight into the main text, where each conclusion is presented along with the evidence on which it is based.
17. When I’m learning about a new subject, I like to keep coming back to particular aspects on different occasions, to get further details as I require them. **1 2 3 4 5** I prefer to deal with particular aspects of a new subject as thoroughly as I can at one time, so that I need not keep returning to them on different occasions to get further details.
18. For students who learn in the way I do, the best form of training in library use would be to follow a well structured course, building up from the basics and going on to more complex skills that will be essential for them to know. **1 2 3 4 5** For students who learn in the way I do, the best form of training in library use would be to learn them (whether simple or complex) as they encounter the need for them during their studies (a sort of ‘on demand’ teaching).

Appendix C

Questionnaire for User Interaction Satisfaction (QUIS)

Overall reaction to the software											
1	terrible	1	2	3	4	5	6	7	8	9	wonderful
2	difficult	1	2	3	4	5	6	7	8	9	easy
3	frustrating	1	2	3	4	5	6	7	8	9	satisfying
4	inadequate power	1	2	3	4	5	6	7	8	9	adequate power
5	dull	1	2	3	4	5	6	7	8	9	stimulating
6	rigid	1	2	3	4	5	6	7	8	9	flexible
Screen											
7	Reading characters on the screen										
	hard	1	2	3	4	5	6	7	8	9	easy
8	Highlighting simplifies task										
	not at all	1	2	3	4	5	6	7	8	9	very much
9	Organization of information										
	confusing	1	2	3	4	5	6	7	8	9	very clear
10	Sequence of screens										
	confusing	1	2	3	4	5	6	7	8	9	very clear
Terminology and system information											
11	Use of terms throughout system										
	inconsistent	1	2	3	4	5	6	7	8	9	consistent
12	Terminology related to task										
	never	1	2	3	4	5	6	7	8	9	always
13	Position of messages on screen										
	inconsistent	1	2	3	4	5	6	7	8	9	consistent
14	Prompts for input										
	confusing	1	2	3	4	5	6	7	8	9	very clear
15	This phone informs about its progress										
	never	1	2	3	4	5	6	7	8	9	always
16	Error messages										
	unhelpful	1	2	3	4	5	6	7	8	9	helpful
Learning											
17	Learning to operate the system										
	difficult	1	2	3	4	5	6	7	8	9	easy
18	Exploring new features by trial and error										
	difficult	1	2	3	4	5	6	7	8	9	easy
19	Performing tasks is straightforward										
	never	1	2	3	4	5	6	7	8	9	always
System capabilities											
20	System reliability										
	unreliable	1	2	3	4	5	6	7	8	9	Reliable
21	Correcting your mistakes										
	difficult	1	2	3	4	5	6	7	8	9	easy
22	Designed for all levels of users										
	never	1	2	3	4	5	6	7	8	9	always

Appendix D

Informed consent form of pilot study

This is a pilot study of understanding mobile phone users' interaction with phone interfaces. Your gender, cognitive style and experience of using mobile phones will be investigated to establish a linkage with your operational behaviour with a mobile phone.

As part of this investigation you will be asked to do three tasks as follows. The purpose of each task is to present your opinion and thoughts, there is no absolute correct answer.

1. Complete a short questionnaire that has been designed to obtain information about your background and mobile phone usage.
2. Complete the Study Preference Questionnaire (SPQ).

To help with the data collection and analysis, I would like to video record you for the next two tasks.

3. You will be asked to complete three tasks with a mobile phone.
4. A brief interview will discuss the obstacles that occurred during using the instrument in this experiment.

All the data collected for this study will be present as anonymous in future publications or presentations. If you are interested in the finding of this study, please leave your e-mail address in the end of this form and I will send you information on the result after publication.

You can withdraw from the study at any time. If you have questions relating to the study please do not hesitate to ask me during this investigation.

Finally, sincere thanks for your agreeing to take part in my research project.

I have read the above statement and I am aware of my rights and responsibilities.

Participant Name: _____ Date: _____

e-mail (if you need further finding of this study) _____

Appendix E

Informed consent form of understanding Individual differences and interaction with mobile phones

The aim of this study is to understand users' concepts about 'how to use a mobile phone' by concept maps and to categorize users by an alternative method instead of demographical categorization.

As part of this investigation you will be asked to do five tasks as follows. The purpose of each task is to present your opinion and thoughts, there is no absolute correct answer.

1. Complete a short questionnaire that has been designed to obtain information about your background and mobile phone usage.
2. Complete the Study Preference Questionnaire (SPQ).
3. Put the title of five functions that you used often on small cards and sort out them as a concept map. I will assist you to finish the map step by step.

To help with the data collection and analysis, I would like to video record you for the next two tasks.

4. You will be asked to trial three mobile phones with two tasks.
5. A brief interview will ask you two questions for understanding which style of interfaces do you prefer and your experience when trialling the mobile phones in this experiment.

All the data collected for this study will be present as anonymous in future publications or presentations. If you are interested in the finding of this study, please leave your e-mail address in the end of this form and I will send you information on the result after publication.

You can withdraw from the study at any time. If you have questions relating to the study please do not hesitate to ask me during this investigation.

Finally, sincere thanks for your agreeing to take part in my research project.

I have read the above statement and I am aware of my rights and responsibilities.

Participant Name: _____ Date: _____

e-mail (if you need further finding of this study) _____

Appendix F

Informed consent form of understanding individual differences and operational behaviour with touch screen mobile phones

The aim of this study is to explore the relationship between human natural ability (cognitive style) and operation behaviour of mobile phone interfaces.

As part of this investigation you will be asked to do four tasks as follows. The purpose of each task is to present your opinion and thoughts, no absolute correct

Complete a questionnaire that has been designed to obtain information about your background and mobile phone usage.

Complete Study Performance Questionnaire (SPQ).

To help with the data collection and analysis, I would like to video record you for next stage.

You will be required to operate some tasks on smartphone simulators on PC and present your opinion orally; in addition to complete a Questionnaire User Interaction Satisfaction after each trial.

All the data collected for this study will be presented as anonymous in future publications or presentations. If you are interested in the finding of this study, please leave your e-mail address in the end of this form and I will send you information on the result after publication.

You can withdraw from the study at any time. If you have questions relating to the study please do not hesitate to ask me during this investigation.

Finally, sincere thanks for your agreeing to take part in my research project.

I have read the above statement and I am aware of my rights and responsibilities.

Participant Name _____ Date: _____

e-mail (if you need further finding of this study) _____

Appendix G Analysis process of ToE-SEEing

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	Step 1: Data gathering	Step 2: ToE Meta-Themes / Sub-themes / Themes	Step 3: Meanings (all)	Step 4: Essential elements	Step 5: Superordinate elements	Step 6: Superordinate elements	Step 7: Weighing	Step 8: Summary descriptions	Step 9: Summary descriptions	Summary					
1															
2															
3															
4															
5															
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Appendix H

Informed consent form of understanding the relationship between individuals' cognitive style and problem solving ability-Online survey

Summary of Study

The aim of this study is to establish the relationship between individuals' cognitive styles and their problem solving abilities. You will be required to complete a questionnaire, a set of Tower of Hanoi problems and a set of Water Jar problems. The session should take no longer than 25 minutes to complete.

You are free to leave this study at any time during the session without negative consequences if you feel unable or unwilling to continue. Your withdrawal would not result in any penalty, academic or otherwise. This study will not ask for your name to link with the research materials.

If you have any questions regarding this survey, please do not hesitate to contact me at mepgwcw@brunel.ac.uk before entering the survey page.

Thanks for participating in this study.

Informed consent form

Brunel University requires all persons who participate in surveys to give their written consent to do so. Please read the following and click the 'Agree' button if you agree with the content of this investigation.

I freely and voluntarily consent to be a participant in the research project entitled 'Testing individual differences of cognitive styles and problem solving ability for executing mobile phone functions' to be conducted at Brunel University, with Wen-Chia Wang as principal investigator and Dr. Mark Young as supervisor. The broad goal of this research program is to establish the linkage between individuals' cognitive style differences and problem solving abilities. Specifically, I have been told that I will be asked to complete a questionnaire, a set of Tower of Hanoi problems and a set of Water Jar problems. The session should take no longer than 25 minutes to complete.

I have been told that my responses will be kept strictly confidential. I also understand that if at any time during the session I feel unable or unwilling to continue, I am free to leave without negative consequences. That is, my participation in this study is completely voluntary, and I may withdraw from this study at any time. My withdrawal would not result in any penalty, academic or otherwise. My name will not be linked with the research materials, as the researchers are interested in patterns in the data in general and not any individual's answers in particular. I have been given the opportunity to ask questions regarding the procedure, and my questions have been answered to my satisfaction. I have been informed that if I have any general questions about this project, or ethical issues relating to the project, I should feel free to contact Wen-Chia Wang at mepgwcw@brunel.ac.uk.

I have read and understood the above and I consent to participate in this study. My electronic agreement is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records (from the Print button below).

I am also interested in taking part in further studies in this area, my email address is (optional): _____

Appendix I Publications

- a) Wang, W-C, Young, M. and Giacomini, J., 2009. Understanding mobile phone users by concept map. In: *Proceedings of the 2nd SED Research Conference 2009*, Brunel University, London, June 22-24, 2009, pp.5-7.
- b) Wang, W-C, Young, M. and Love, S., 2010. The effect of cognitive style on user's behaviour when using touch screen mobile phones. Presented in *Workshop-Putting users' first: the importance of human-centred design in the development of mobile applications and services. Held in the European Conference on Cognitive Ergonomics*, Delft, the Netherlands, August 25-27, 2010.
- c) Wang, W-C, Young, M., Love, S. and Coxon, I., 2010. Understanding touch screen mobile phone users by Taxonomy of Experience (ToE). In: B. Poppinga, C. Magnusson, W. Heuten, D. McGookin, N. Henze, G.B. Claasen, M. Pielot, H. Efring and J. Peters (eds), *Proceedings of the 1st International Workshop. Held in Conjunction with NordiCHI*. Reykjavik, Iceland, October 17, 2010, pp.13-16.
- d) Wang, W-C, Young, M. and Love, S., 2011. Categorising mobile phone users and interfaces based on cognitive styles. Will present in *International Conference on Creative Design, Sustainable Development with Disaster Mitigation in 2011*. Held in Ming Chuan University, Taoyuan, Taiwan, March 11, 2011.

Understanding Mobile Phone Users by Cognitive Style and Concept Map

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Introduction

Keywords: easy to use, concept maps, cognitive style

Understanding users is an essential principle for designing an interface. However, designers, system programmers, and users have different definitions regarding 'easy to use'. This study attempts to understand users by their concepts about how to use a mobile phone by concept maps and to categorize users by their cognitive styles. The result will provide a clearer direction toward how to improve users' satisfaction by providing a suitable interface on mobile phones which are individually coherent with the user's concept of how to operate a mobile phone.

In the past 50 years, people have learned how to create and program computers; 'the next frontier is in actually making computers serve and adapt to human needs rather than forcing humans to adapt' [3]. Based on this concept, how to make computers (and relevant electronic products which need an interface) easy to use by fitting the user's needs individually has become an important issue. Cognitive style is defined as 'a person's typical mode of perceiving, thinking, remembering, and problem solving' [2]. It is 'stable, relatively enduring consistencies in the manner or form of cognition' [4]. This study anticipates obtaining users' cognition instead of demographical information to categorize users and explore the relationship between their cognitive styles and concepts by concept maps, carding sorting, and the Group Embedded Figures Test (GEFT).

Methodology

This study will execute interviews, concept maps, card sorting and GEFT to obtain participants' cognitions of how to use a mobile phone.

Concept maps-The aim of concept maps is to organize and represent knowledge by graphical tools [7]. It includes concepts and shows the relationship between two concepts by a connect line and words or phrases to specify their relationship. An important characteristic of concept maps is the cross-links; it helps to present the relationship or links between different segments or domains [7].

Card sorting-Card sorting is a low tech method to discover users' mental models by sorting a bunch of cards (with the description of concepts) into groups and to name those groups. It provides the investigator with information about the participant's insights and the information space and their inspiration of the names [6]. According to an analysis of mobile phones' functions from Nokia, Samsung, LG, and Sony Ericsson, the terms of functions vary; card sorting might help to understand users' categorization of the menu of a mobile phone.

Cognitive style-The definition of cognitive style has been quoted by [1] as 'consistent individual differences in preferred ways of organizing and processing information and experience' [5]. One of the dimensions of cognitive style is field independence /dependence (FI/FD). The instruments of the Group Embedded Figures Test (GEFT) can be conducted for FI/FD to examine the relationship between cognitive perceptual ability and learning ability individually [8].

Plan

1. Interview: to understand users' opinions of how to judge whether a mobile phone is easy to use or not. The results which relate to interface and operation behaviour might be helpful for further discussion and analysis.
2. Concept maps: based on the participant's oral description about how to use a mobile phone to draw a concept map and compare it with standard operation steps on current mobile phones to find out the differences.
3. Card sorting: for understanding user's categories of mobile phone functions. The terms of functions of Nokia, Samsung, LG and Sony Ericsson will be used on cards; the participant will only be given relevant functions that they mentioned for concept maps.
4. Cognitive style: the GEFT will be used to define whether the participant's cognitive style tends towards field independence or field dependence.

Discussion

The anticipation of the result of this study is to categorize mobile phone users by different aspects which can reflect their cognitive style and needs more precisely.

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The Effect of Cognitive Style on User's Behaviour When Using Touch Screen Mobile Phones

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Introduction

The impact of individual differences on consumer products has received much attention in recent years. Cognitive style is a stable and unique way to represent an individual's preference of organizing and processing information (Messick, 1976), therefore, it has been conducted in diverse studies such as web directories (Chen, Magoulas & Dimakopoulos 2005), information systems (Mullany, 2001), and interface design on mobile phones (Kim & Lee, 2007). The labels of cognitive style are varied; this study focuses on whether a holistic/serialistic style would affect the user's operation behaviour with a touch screen mobile phone.

Literature review

Green (1985) and Allinson and Hayes (1996) quote the definition of cognitive style from Messick as 'stable and relatively enduring consistencies in the manner or form of cognition' (Messick, 1969) and it is consistent with what Messick (1976) describes as 'individual differences in preferred ways of organizing and processing information and experience'. Green (1985) also indicates that cognitive styles are unique for each person to perceive information, to think, to remember and to solve problems. There are various types of cognitive styles, Riding and Rayner (1998) placed similar labels into two groups: wholist-analytic and verbal-imagery dimensions. The wholist-analytic dimension measures how an individual organises information while the verbal-imagery dimension measures whether an individual represents information by thinking verbally or in mental pictures. The group of wholist-analytic comprises labels of field-dependence/field-independence, leveller sharpener/impulsive reflective, convergent/divergent thinking, and holist-serialist thinking; whereas models in the verbal-imagery dimension include verbalisers/visualisers and verbal/imagery.

With regards to the impact of cognitive styles on users' performance with interfaces, John and Boucouvalas (1999) indicate that neither wholistic/analytic styles nor verbal/imagery styles affected the participants' performance with interfaces; even if the interface suits the participant's cognitive style. Uruchrutu, MacKinnon and Rist (2005) also pointed out that wholistic/analytic styles influence the way an individual interacts with different interface conditions, however, no simple effects were found regarding the relationship between cognitive styles and interface affect. A series of studies labelled users under holistic/analytic styles by cultural background. Kim, et al. (2007) found that cognitive style might affect the users' preference as Korean users (holistic style) prefer to complete tasks via thematically grouped menu whereas Dutch users (analytic style) prefer the functionally grouped menu. Moreover, Korean and

American users have obvious recognition differences with icons on mobile phone interfaces (Kim & Lee, 2005).

However, as mentioned before, the family of wholist-analytic styles include several dimensions (Riding and Rayner, 1998). Studies above focus on a broad concept of cognitive style. This study assumes that interacting with mobile phone interfaces involves information seeking and problem solving. The cognitive style of holist/serialist might be more appropriate to examine the impact of cognitive styles on users' operation behaviour with the mobile phone interfaces as it shows how an individual tends to respond to problem solving and it is more detailed than wholistic/analytic styles. Furthermore, when learners were under a free-learning situation, holistic learners tended to 'test a large predicate or relational hypothesis' with global strategies (Pask & Scott, 1972), they also have broad perspectives to learn, in order to find out interrelationships between several topics during the early stage of studying (Ford, et al., 2002). On the other hand, serialistic learners 'showed intention to search for specific data', they tend to use a step-by-step approach with logical linear progression from one hypothesis to another, in addition, their focus was narrow, and integrated information late in the learning process (Riding & Cheema, 1991). Besides, holistic people's behaviour of seeking information tended to be 'exploratory', 'serendipitous' and 'more idiosyncratic' than serialistic people (Ford, et al., 2002).

Hypothesis

This study is interested in whether users would perform better with the interface that corresponds with their cognitive style on the mobile phone. Thus, this investigation tested six mobile phone emulators on two groups (Group A & B) by the characteristics of holistic/serialistic cognitive style. Followed are the hypotheses:

Hypothesis 1: Holistic/serialistic users would complete tasks faster with the corresponding interfaces.

Hypothesis 2: Holistic/serialistic users would press fewer icons to complete tasks with the corresponding interfaces.

Methodology

Twenty-five students from Brunel University were recruited, of which fifteen were male and ten were female, aged between 18 to 30 years (Table 1). This study combines quantitative and qualitative methodologies. First of all, the experiment required participants to complete the Study Preference Questionnaire (SPQ) to understand their cognitive style. Followed by observing their operation behaviour on six touch screen mobile phones' emulators on a computer. The process was filmed so that it would be possible to calculate the time it took for participants to complete each task, and also the number of times they pressed icons. Participants were asked to perform only tasks that were possible to complete on all emulators. Therefore, the tasks were: sending a text message to a specific person who was on the contact list, checking a specific date, and looking for a specific photo.

Table 1. Descriptive statistics of participants' gender and cognitive style

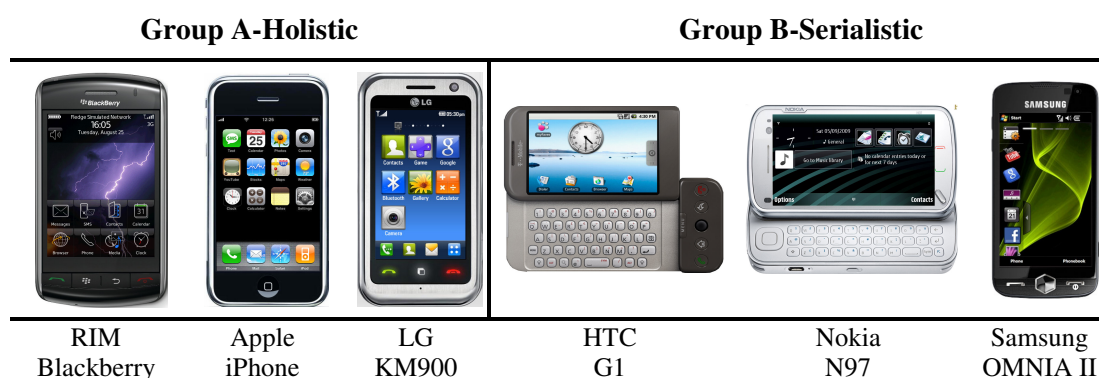
	Male	Female
Holistic	9	8
Serialistic	6	2

Study Preference Questionnaire-SPQ

The purpose of SPQ is to recognize if the user's cognitive style is holistic or serialistic (Ford, 1985). It assesses the learner's preferences of learning approaches such as 'global description-building predominantly before local procedure-building or vice versa' (Ford, 1985). The 18 items of the questionnaire reflect the way the students read and seek information. Each item shows two statements, participants were required to point out their tendency to either statement or no preference with both statements. If the participant's tendency for holistic statements are more than serialistic statements, then the participant has holistic cognitive style, or vice versa (Ford, 1985).

Emulators of touch screen mobile phones

The article of InfoWorld (2009) shows that nowadays six smartphone platforms have been launched in the mobile phone market: Apple's iPhone, Google's Android, RIM's BlackBerry, Nokia's Symbian, Palm, and Windows Mobile. The global smart phone market share by operation system (OS) in the second quarter of 2009 shows that Symbian occupied 50.3% market; followed by RIM, Apple, Microsoft, Android and others (Canalys.com, 2009). Therefore, this investigation adopted the interfaces of Nokia, Blackberry, iPhone, Samsung, HTC and LG as the tools to understand how users interact with the interfaces of touch screen mobile phones. Based on the characteristics of holistic/serialistic styles, this study allocated the interfaces into two groups: Group A (Holistic) and Group B (Serialistic) (Figure 2).

**Figure2. Emulators of six smartphones**

The investigation required participants to complete three tasks on six touch screen mobile phones' emulators on a computer. Emulators of HTC-G1, LG-KM900 and Samsung-OMNIA II are based on their individual official website; RIM-Blackberry and Nokia-N97 are based on a software development kit (SDK) on the computer. Apple-iPhone only provides SDK on MAC OS, this study therefore simulated the interface of iPhone by using the software of Powerpoint. All

necessary functions and interactions of operating specific tasks in this investigation are completely the same as on an actual iPhone.

Results

The collected data (Table 2) shows that holistic participants completed tasks in a shorter amount of time on emulators of Group A: iPhone ($M = 38.45$, $SE = 4.12$) and LG ($M = 66.83$, $SE = 7.44$), whilst serialistic participants seem to have completed the three tasks marginally quicker than holistic participants on emulators of Group A: Blackberry and all emulators of Group B. The trend also applies to the relationship between cognitive styles and the amount of times that the participants pressed icons to complete tasks. Holistic participants seemed to have clicked fewer icons to complete tasks than serialist participants only on the emulators of Group A: iPhone ($M = 12.35$, $SE = .89$) and LG ($M = 15.76$, $SE = 1.89$).

Table 2. T-test of cognitive style and total completing time/times of pressing icons to complete 3 tasks

		Cognitive style	N	Total completing time of three tasks			total times of pressing icons to complete 3 tasks		
				Mean	Std. Deviation	Std. Error Mean	Mean	Std. Deviation	Std. Error Mean
Group A	Blackberry	holistic	17	62.79	20.60	5.00	22.59	4.39	1.06
		serialist	8	60.25	19.24	6.80	20.88	4.49	1.59
	iPhone	holistic	17	38.45	16.98	4.12	12.35	3.67	.89
		serialist	8	43.95	18.04	6.38	14.13	6.42	2.27
	LG	holistic	17	66.83	30.69	7.44	15.76	7.80	1.89
		serialist	8	67.80	21.15	7.48	16.38	6.28	2.22
Group B	HTC	holistic	17	88.77	48.16	11.68	17.00	5.92	1.44
		serialist	8	67.38	33.66	11.90	16.75	7.25	2.56
	Nokia	holistic	17	107.21	47.46	11.51	35.18	11.77	2.85
		serialist	8	101.06	42.17	14.91	30.38	7.44	2.63
	Samsung	holistic	17	114.87	85.52	20.74	29.24	14.27	3.46
		serialist	8	89.00	21.34	7.55	25.50	8.52	3.01

The collected data was analysed using SPSS, all effects are reported at a .05 level of significance. The t-test showed there are no significant differences between participants' cognitive style and completing time of three tasks; also the number of times they pressed icons to complete tasks. The results seem consistent with the studies of John and Boucouvalas (1999) and Uruchrutu, MacKinnon and Rist (2005) as cognitive style of wholistic/analytic and verbal/imagery might not affect users' performance with interfaces. However, this investigation shows the time differences when holistic/serialistic participants operated the corresponding interfaces. Thus the next step examined participants' operation behaviour to explore individual differences in cognitive style.

According to the analysis of participants' operation behaviour of completing tasks, holistic participants tended to spend more time than serialistic participants on checking the same catalogues when they could not find the right path to complete the task (Figure 3), whereas serialistic participants seemed to prefer moving back

to the previous catalogue for the other options to complete the task when they became aware that the path was wrong. Furthermore, holistic participants spent an extra 16.8 seconds to complete tasks [averagely], whilst serialistic participants only spent an extra 11.7 seconds.

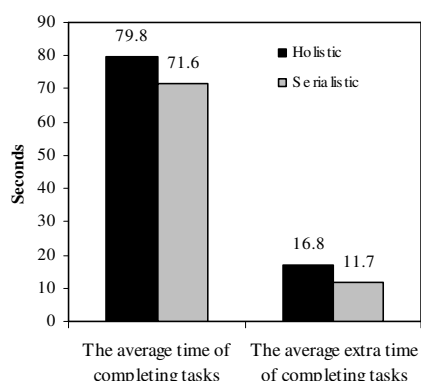


Figure 3 The average time/extra time to compete tasks

Table 3 shows the number of participants who spent extra time to check the same catalogues when they met difficulties to find out the right path to complete tasks. In general, holistic participants performed better than serialistic participants, however, 6 participants (35.3%) spent more than 20 seconds to check the same catalogues repeatedly compared to the serialistic participants (12.5%). Moreover, 47% of holistic participants who check the same catalogues also repeated the action with more than 1 task, whilst only 13% of serialistic participants checked catalogues repeatedly with more than 1 task. Although the statistical numbers do not show a significant difference between cognitive styles and users' performance with time, the observation results show a different phenomenon of their operation behaviour.

Table 3. The number of participants who spent extra time to check catalogues repeatedly

	0 sec.	1-10 sec.	10-20 sec.	20+ sec.
Holistic	5 (20%)	3 (12%)	3 (12%)	6 (24%)
Serialistic	1 (4%)	2 (8%)	4 (16%)	1 (4%)

Conclusions, limitations and future research

This study was carried out to establish the relationship between cognitive styles and their operation behaviour of mobile phone interfaces. A small sample of university students participated in the experiment, using six touch screen mobile phones' emulators on the PC as testing instruments. Although previous studies did not show significant differences with quantitative data, this study found differences between cognitive styles and users' interaction with mobile phone interfaces on emulators on a computer. The results show that participants might perform better without experiencing obstacles if the interface corresponds with their cognitive style of holistic/serialistic. It might also point out that cognitive style is a factor which influences participants' operation behaviour of solving problems on touch screen mobile phones with hierarchical menus.

The validity and reliability of SPQ was examined by previous studies, therefore, the result of this study should truly reflect the participants' individual differences and their operation behaviour with touch screen mobile phone interfaces on emulators. It would be desirable to validate the results by testing a larger sample size and using actual mobile phones. Further study will focus on whether users' experience might also be affected by their cognitive style and how to provide corresponding assistance to holistic and serialistic users to complete tasks without experiencing frustrations.

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Understanding Touch Screen Mobile Phone Users by Taxonomy of Experience (ToE)

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Abstract

The importance of user experience in the product design process has been discussed in recent decades. This paper introduces the methodology of Taxonomy of Experience (ToE) and its data analysis process of SEEing to obtain user experience with an unfamiliar interface on a touch screen mobile phone. To execute TOE, SEEing includes nine sequential stages to help researchers to deeply understand users' needs by transforming the user's verbal commentary into super-ordinary metaphors. This study presents the process of applying TOE-SEEing to understand users' experiences of trialing a touch screen mobile phone. The results can be used to establish extra design principles for touch screen mobile phones.

Introduction

User experience has one of the most important elements of product design and has often been discussed in the HCI community in recent decades. The general definition of user experience is beyond the usefulness and usability of a product [1, 2], and it might be affected by the 'user's internal state, the context, and perceptions of the product' [19]. Research into user experience endeavors to achieve users' pragmatic and hedonic level. It is, however, subjective, highly situated and dynamic in nature [19]. Therefore, efficient methodologies to obtain and to evaluate user experience accurately are essential for improving product design. Norman [3] indicates that an understanding of user experience should be able to evaluate the user's experience in a circumstance that is similar to the actual using situation to avoid the user imagining the experience. The data collection process should record the user's experience when it happens rather than rely on recalling the memory about the experience. Moreover, the user's experience should be understood through the user's subjective information about the experience [18]. Methodologies for evaluating experience have been established based on the user's attitudes and expectations [18], emotion [9], concept of the object [17], judgment of the product [16], and through comparing the user's reference to different interfaces [6]. These studies capture and analyze user experience by experimental pilots [18], emotion sampling [9], multiple card sorting [17], and repertory grids [16]. In addition, the approaches of diary [4], focus groups, surveys and competitive analysis are tools that are commonly used [14]. Whilst many researchers attempt to transform user experience to quantitative data, Coxon's [7] Taxonomy of Experience (ToE) and its analytic approach of SEEing, uncover an understanding of the user experience through qualitative analysis. The term 'SEEing' attempts to differentiate from the processes of thinking, but still associates with the thinking processes [7]. The nine steps of the

SEEing process aim to clarify the user's experience. It begins by transforming the user's verbal commentary and ends in a synthesis, super-ordinary metaphors. This study applied the ToE to capture the user experience of trialing an unfamiliar touch screen mobile phone. The outcome of the SEEing analysis provides an alternative consideration for the interface design of touch screen mobile phones.

Taxonomy of Experience (ToE)

The purpose of ToE is to understand the user's experience with a product via analysis of their verbal commentary to find the deep meanings hidden from the verbal commentary. It combines empirical [5] and academic [10, 11] perspectives. Previous studies that relate theory and practical concepts of user experience [15] provide a good foundation to establish this methodology [7]. The structure of the ToE is based on philosophy, methodology and design theory; thus the ToE provides a multi-layered method to understand user experience. In developing the initial concept to understand the experience of transportation vehicles, Coxon realised the importance of 'understanding the experience of those people already involved in designing and using the vehicle' [7, Ch.3, p.2]. Therefore, [7] discussed positivism, idealism, realism [13], and applied phenomenology as a methodology to 'understand individual lived experience' [7]. Whilst Coxon [7] reviewed the video that recorded his own trial experience of an electric vehicle, it helped to recall the deep aspects of the experience that he was not particularly conscious of while personally trialing the vehicle. The process of transcribing the sequence of the dialogue and other activities once again brought the experience more vividly into consciousness. Figure 1 is the framework for understanding an experience from four aspects. The experiential event impacts the user's cognition (thinking and acting), engages sensorial aspects, and impacts one's emotions and feelings. In the meantime, these elements are all taking place within an existential framework of temporality, spatiality, relationality and corporeality [7].

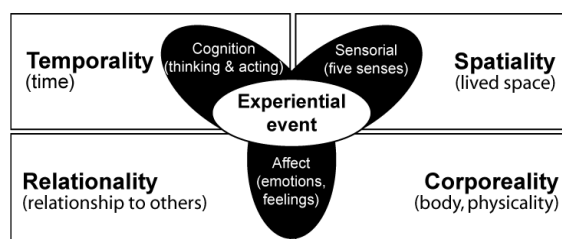


Figure 1. Framework of an experience

Coxon [7] thus develops the multi-layered analysis process of SEEing for understanding users deeply, which is also supported by [20]. The SEEing process suggests that when writing about 'lived experience descriptions', the descriptions should be able to a) describe the experience as it is lived without asking why; b) describe the experience from the inside, the feelings, mood, and emotions; c) focus on a particular example of the experience and to describe it; d) focus on an example that stands out, as it was the first time; e) aware how the body feels, smells, sounds and so forth; and f) avoid trying to beautify the illustration with flowery language or terms. Overall, the ToE-SEEing process brings an experience to a comprehensible and visible format rather than an abstract concept. It comprises nine steps, which can be seen as follow (details can be seen online [7]).

Step 1: Gathering data and establishing structures

It is important that the researcher ‘gets to know’ the experience, becoming familiar with the experience by understanding its ‘language’. This stage emphasises that the researcher has to immerse themselves in the experience completely [8, 12]. The data of people’s experience can be collected from observations, interviews, and contextual studies that are captured in creative ways. The information of images, sounds, samples or the other type of the information are collected that might be useful to the researcher to recall the user’s experience and to write the descriptions for further analysis at later stage.

Step 2: Descriptive narratives

This is the process of transforming the data collected in *Step 1* into a textual format for analysis. This stage also breaks the experience into fragments as small as a single word, or a phrase, and refers them into the SEEing process.

Step 3: Sorting fragments into themes

This step includes meta-themes and sub-themes. Meta-themes in the SEEing process include somatic, affective, cognitive and contextual factors; the sub-themes include senses, positive/negative affect, internal/externalised cognition, and many contextual categories. Each theme has a collection of fragments, and provides the researcher with the feeling of the story that they are telling.

Step 4: Developing meaning(s)

This step requires the researcher to look at each fragment of the information carefully and to find other and deeper ‘meanings’ behind the fragment. This process helps to ‘tease out’ the text into different meanings. It is not yet the stage for the researcher to judge and to interpret what they think the meanings of the fragment ‘should be’ or ‘could mean’. Instead, the aim of this process is to accept all ‘possible’ meanings that are contained within the fragment.

Step 5: Essential elements

This step helps to filter out the less important meanings. The researcher has to determine if the meanings in *Step 4* are incidental or vital to the essential nature of the experience. It is necessary to know the importance of the experience, whether if the element is essential to the experience, or the experience might be different without the element.

Step 6: Super-ordinary elements

This step distils the super-ordinary essence of the experience, i.e. the unexpected, novel and hidden aspects of the experience. Aside from the functional, form oriented, and everyday aspects; this stage isolates those elements of the experience that might not have been seen as an important part of the original design. However, those elements are still an important part of the experience. This process searches for the surprising elements, the unintended impacts of the experience.

Step 7: Weighting of super-ordinary elements

This is a weighting process to consider which super-ordinary elements are the more ‘powerful’ of the essential elements of the experience. The researcher evaluates the super-ordinary elements by his understanding of the language of the

experience, to give a subjective numerical scale using a Likert rating (1-7, 1 is low) to determine a relative level of intensity.

Step 8: Super-ordinary summary words

The sorted super-ordinary elements in descending order provide a ranking of the essential super-ordinary elements of the experience by intensity. This stage uses word metaphors to synthesise *'what is the collective meaning behind these elements'*? For example, the super-ordinary element of 'no risk means no fun', could essentially be a statement about 'freedom to enjoy danger'.

Step 9: Summary word descriptions

The previous step summarised the super-ordinary elements; this stage focuses on 'explaining' the summary. It concludes the work of *Step 6-8*. One or two narrative paragraphs helps to represent the understanding of the experience to someone who does not understand the meaning of the super-ordinary words.

Design guidelines for the interface design for mobile phones have been well established by mobile phone manufacturers and include design principles for elements such as content, layout, colour, font size, text and terminology. However, it is still necessary to understand the users' requirements from the user experience aspect. As the market for touch screen mobile phones continues to grow, understanding experienced users' thoughts and novices' expectations of the touch screen mobile device is essential to providing a better design. This study applies the ToE and its analysis process of SEEing to generate deep understandings of users' experience in order to provide extra design principles for mobile phone interfaces.

Experiment design

The aim of this study attempts to understand the extra criteria of designing mobile phone interfaces from the users. This is the first trial of applying ToE-SEEing to mobile phone user experience, so this study tends to simplify the variables to make sure the collected data is clear and precise. Therefore, the participants were required to trial the touch screen mobile phone in the laboratory. Twelve participants were recruited from a British University. Half of them currently use a touch screen mobile phone, whereas the other half currently use a 12 keypad mobile phone. A Vodafone 541 mobile phone (Figure 2) is used for this study because participants from the other series of experiments would not have used this model beforehand. Operating this phone should be a whole new experience for most participants.



Figure 2. Vodafone 541

This model is the previous generation of touch screen mobile phone. The hardware and software are not advanced to compete with new generation phones, such as the iPhone. The aim of choosing this model was to push the participants to talk more about the using experience. Before starting the data collection, the observer demonstrated to the participant how to apply the approach of ‘think aloud’ by trialing a touch screen camera. Participants then were required to practice a ‘think aloud’ protocol by trialing the camera. The practice was intended to help the participants to get used to expressing their experience while trialing the Vodafone 541 mobile phone. Participants had five minutes to free trial the phone as they wished. Their interaction behaviour with the mobile phone was filmed for the ToE-SEEing analysis (the camera only focused on their hands and the mobile phone, and recorded their verbal commentary without showing their face).

Result

All collected data was transferred into *Step 3* of ToE-SEEing. As mentioned earlier, *Step 3* includes two layers of themes (meta-themes and sub-themes). Firstly, each participant’s verbal description of the experience was coded into different themes. The meta-themes include the body-somatic experience (sensorial experiences, sound, touch-feel, sight, smell, taste, comfort-ergonomics, and appearance-aesthetics); the heart-affective experience (positive-negative emotions); the head-cognitive experience (conation-reflective thought-external-doing, conscious cognition-reflective thought-internal-thinking.); as well as a range of contextual factors (environmental, regulatory, social factors), and existential factors (time, space, corporeality body, and the relationship to others). Most of the participants’ usage experiences with the touch screen Vodafone 541 mobile phone strongly relate to the sub-themes of sight and cognitive experiences. The following section presents the super-ordinary elements and the summary of participants’ user experience with trialing the Vodafone 541.

Understanding-from the head

It is important to see that the ‘graphic icon and its title are consistent, and represent the function clearly’. Clear feedback is given confirming whether or not the operation was successful.

It is essential to show instructions for unique features of the phone, maybe to demonstrate how to operate the feature, or to make it easy to get ‘help’ information.

Sensitivity of the touch screen is crucial, and should fit the user’s pace when operating the phone.

The user would like to dominate, to trust the phone, and to fully understand the operation process before using the phone.

Experienced and familiar-from daily life and history

The way to operate the scroll bar on Vodafone 541 should be the same as using the scroll bar on a computer.

From previous experience of using a mobile phone with a 12 keypad, it would be good to see that the icon becomes highlighted when browsing the icon on the menu.

It will help to reduce mistakes if the phone can highlight what the mistake was, to detect the failed task automatically, and then provide help and instructions to complete the task correctly before the user has to ask for help.

Freedom-from the operation

The phone should provide links between different functions, rather than having to go to the menu to execute another function.

The size of the phone provides the freedom for the user to carry it all the time, and allowing the user to hold the phone in the hand easily without worrying that the phone might slip from the grasp.

The three super-ordinary elements above had the highest score from participants. The other super-ordinary elements were 'specific', 'share', 'intimacy', 'comfortable', 'enjoyment', 'flexible', and 'logic'.

The ToE-SEEing helps to transform and to categorise the raw meaning of an experience to find the meanings behind the user's commentary, to sort the importance of those elements, and to summarise super-ordinary elements of the experience. It provides an overview of the user's experience and describes whether it is the user's previous experience or the experience that was produced when trialing the object. The categories in *Step 3* help to clarify the key themes of users' experience, and to establish a good foundation for further analysis. In this case, the summarised super-ordinary elements not only reflect the user's expectation of Vodafone 541, but also highlight the components that the user cares about most. There is no doubt of simply following design guidelines to design a product, furthermore, this study suggests that it is helpful to include user experience as part of the design guidelines before executing 'design'.

Conclusion

This paper presents the process of executing the methodology of ToE-SEEing to understand user experience with a touch screen mobile phone. The validity of ToE has been examined with extensive observation data from video clips and interviews during the development process [7]. This method might be questioned due to its explicit subjectivity; nevertheless, as mentioned earlier, the nature of an experiential encounter is subjective, situated, complex and dynamic. Therefore, the ToE-SEEing process is a useful tool for distilling the true meaning that lies behind the verbal description of such a complex event. This short paper emphasises the importance of understanding user experience before design begins. The result provides alternative considerations to achieve the goal of making things 'easy to use'.

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Categorising Mobile Phone Users and Interfaces Based on Cognitive Styles

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Abstract

This study establishes the categories necessary for identifying mobile phone users' cognitive style based on their operational behaviour with phone interfaces. Two stages of data collection and analysis were conducted in order to better understand the user's contact with mobile phones. The quantitative results of stage one indicated the direction for setting the observation schedules in stage two which went on to find the differences in users' operational behaviour. Three theoretical attributes of the cognitive styles-holistic and serialistic were linked to users' actual behaviour when interacting with touch screen mobile phone interfaces. The findings could be applied to design mobile phone interfaces in the future.

Introduction

The importance of recognising and utilising different cognitive styles has been applied to various fields including learning processes and strategies (Fiding & Rayner, 1998), learning and teaching styles (Ford & Chen, 2002), interface designs of mobile phones (Kim & Lee, 2007), information systems (Mullany, 2001) and categories of searching information on the internet (Magoulas, Chen & Dimakopoulos 2004). In addition, previous studies have found a correlation between more effective studying instruction which has been matched with individual learning styles (e.g. Riding & Douglas, 1993; Ford, 1995).

Most of these studies highlighted the connection between cognitive styles and a user's preferences for icons and categories of the interfaces through quantitative approaches. This has led a lack of detailed description of how cognitive style differences affect user' operational behaviour when interacting with human-machine interfaces. This study attempts to establish the detailed description with regard to how cognitive styles impact the users' interaction with mobile phone interfaces. The behaviour based on cognitive style differences that has been identified in this study can be applied to better customisation of mobile phone systems in the future.

Cognitive style

According to Green (1985, p.3), Messick (1969) defined cognitive style as 'stable and relatively enduring consistencies in the manner or form of cognition'. Allinson and Hayes (1996, p.119) quote the definition of cognitive style from Messick (1976, p.5) as being coherent with 'individual differences in preferred ways of organising and processing information and experience'. Despite the definition of cognitive style varying between researchers, they all share the idea that an individual's cognitive style is one of the essential elements to the way the individual organises information (Riding & Rayner, 1998; Benyon et al., 2001).

In spite of the different titles, researchers generally agree that cognitive styles have similar attributes, which Riding and Rayner (1998) divided into two groups: the *wholist/analytic* dimension and the *verbal/imagery* dimension (Table 1 below).

Table 1 The catalogue of cognitive styles (adapted from Riding & Rayner, 1998, P.14)

Wholist/Analytic	Verbal/Imagery
field dependence/field independence	verbalisers/visualisers
leveller-sharpener/impulsive-reflective	verbal/imagery
convergent/divergent thinking	
holistic/serialistic thinking	

According to the literature, the styles of wholist/analytic and field dependence/field independence were more often applied in studies which related to users' interaction with interfaces. These studies were more likely to focus on issues such as users' categorisation of function icons, task headings (Kim, Lee & You, 2007) or how to organise the subject categories (Chen, Magoulas & Dimakopoulos, 2005). The aim of this study is to generally examine the impact of a user's cognitive style on mobile phone operational behaviour and, more specifically, how individuals interact with a mobile phone menu that has a hierarchical structure.

Holists and serialists' learning strategies were first identified by Pask and Scott in 1972 (p.218). They indicated that holistic learners tend 'to learn, remember and recapitulate as a whole', based on 'high order relations'. In contrast, serialistic learners prefer to learn, remember and recapitulate a chunk of information in 'string-like cognitive structures' and to find the connection between data through 'low order relations'. In addition, serialists tended to be 'intolerant of irrelevant information' when dealing with lengthy and sequent data unless they had an 'unusually large memory capacity'.

Ford (1985) mentions that holists and serialists have different ways of interacting with a hierarchical structure. Whilst holists tend to establish relationships with such structures through the use of complex, top-down links, serialists concentrate on the chunks of information that are more clearly defined and sequentially ordered, preferring to use simple links and a step by step approach from the bottom-up. Moreover, holists are likely to use analogies to make the connection between different aspects of the subject; serialists are more likely to emphasise the relationship between previous knowledge and the current subject and to make logical links between them. The contrasting cognitive styles of holists and serialists were therefore chosen for this study to investigate the relationship between individual differences and operational behaviour.

Experimental design

This study attempts to analyse mobile phone users' operational behaviour in two stages. Quantitative approaches were applied at stage one to clarify the relationship between individuals' cognitive styles and their performance with the tasks. The completion time and the number of clicking icons were used as performance measures. The hypothesis of this stage is that holists/serialists would perform better with mobile phone interfaces which are consistent with their cognitive style. Based on the outcomes of stage one, stage two analyses data obtained from observing participants' operational behaviour when they completed the tasks with the different interfaces.

Instruments

Study Preference Questionnaire (SPQ)

The 18-item self-report questionnaire was developed by Ford in 1985 to assess learner's preferences of learning approaches such as 'global description-building predominantly before local procedure-building or vice versa' (Ford, 1985, p.68). This implies that a learner prefers to develop a whole scope of a topic before establishing details to process the procedure or vice versa. The 18 questionnaire items reflect the way students read and seek information. Each question has two statements-holistic and serialistic; participants were required to rate the degree of their tendency of either statement. If the participant's tendency for holistic statements is higher than serialistic statements, then the participant was identified with holistic cognitive style, or vice versa (Ford, 1985). Although the reliability of the SPQ has not yet been convincingly proved, it has been applied to many educational studies (e.g. Kwok & Jones, 1985; Eills, Ford & Wood, 1993) and information systems studies (e.g. Clarke, 1993; Magoulas, Chen & Dimakopoulos, 2004; Ghinea & Chen, 2008).

Emulator

Six popular touch screen mobile phone interfaces were allocated into two groups based on the characteristics of holistic and serialistic styles (Figure 1). The interfaces of Group A display the most often used functions or all available functions on the desktop, delivering a global concept to users about the phones' functionality and providing broad relations on the same page and allowing users to span various functions at once. In contrast, the interfaces of Group B (Figure 2) show fewer icons on the desktop. The three interfaces here require users to access the menu for all functions and the operation process tends towards a more linear style which narrows the users' focus. In addition, the menu of the interfaces in the Group B phones list functions alphabetically or group icons by functions to narrow the relationships between icons. All of the interfaces were running on a desktop environment as prototypes. This allowed participants to complete the tasks by simply clicking a mouse and avoided the variable of actually operating the handsets.



Figure 1 Holistic interfaces of smartphones



Figure 2 Serialistic interfaces of smartphones

Tasks design

According to Kim, Lee and You (2007), sending an SMS or saving a contact might be a too basic task to examine the differences of cognitive style in task handing and interaction flow. Based on the number of steps to complete a task such as sending an SMS, this study therefore set the task of sending message as being of medium difficulty level (Task 1). An easier task was checking specific date on the calendar (Task 2) as it required fewer steps to complete; whilst seeking a specific photo (Task 3) was the most difficult task in this experiment as it required more steps to retrieve the target photo.

Procedure

Data was collected from 40 current touch screen mobile phone users in the laboratory. They were first required to answer the SPQ. The participants were then presented with six interfaces of touch screen mobile phones on the computer one by one in order to examine their performance on three tasks. Their completion time of the tasks and the number of icon clicks in achieving the task goal were recorded. In the meantime, their interaction behaviour with the mobile phone was filmed for further analysis during stage two (the camera only focused on their hands and the mobile phone and recorded their verbal commentary without showing their face).

Results

A total of forty participants were recruited, 22 males and 18 females aged 18 to 35. The participants were divided into 6 brand groups according to the mobile phone that they currently have, with 6-7 participants in each brand group of Blaceberry, iPhone, LG, HTC, Nokia and Samsung.

Stage1

All of the collected data were analysed with SPSS 15.0 for Windows. The dependent variables evaluated the individuals' task completion time and the number of icon clicks to complete the tasks across six interfaces. All effects were reported at a .05 level of significance. Overall, serialists and males performed slightly fast than holists and females at completing three tasks across the six interfaces (Figure3). However, when comparing the number of icon clicks in achieving the task goals, serialists and female clicked fewer icons than holists or males (Figure4).

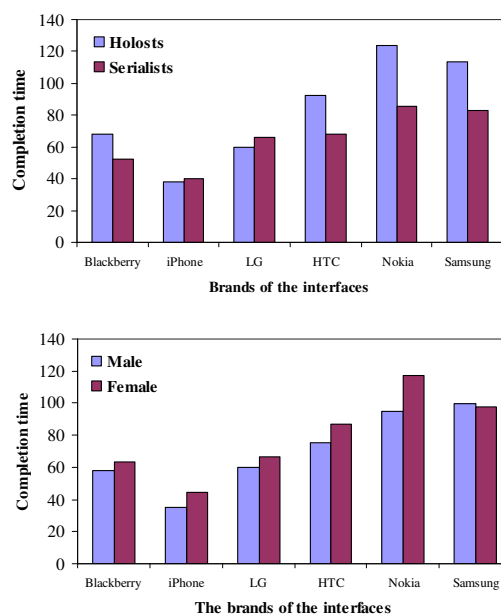


Figure 3 Performances of completion time with six interfaces by the differences of cognitive styles and gender.

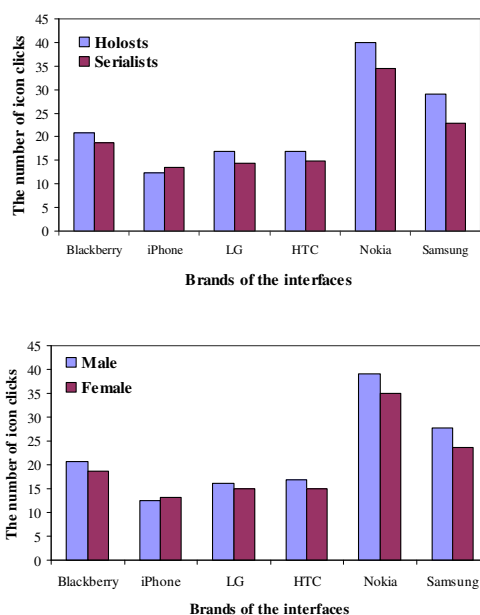


Figure 4 Performances of the number of icon clicks with six interfaces by the differences of cognitive styles and gender.

Completion time of tasks

The descriptive statistics show that holists only performed better than serialists at Task 1 (sending text messages) & 2 (checking the date) with the iPhone and LG interfaces in Group A (holistic interfaces). The completion time of the serialists' interaction with Task 3 (seeking a target photo) was significantly shorter than the holists with the interfaces of the Blackberry ($M=28.69$, $SE=2.71$; $M=38.18$, $SE=3.26$; $t=2.24$, $df=38$, $p=.031$, two-tailed, $d=.51$), Nokia ($M=51.53$, $SE=5.36$; $M=66.92$, $SE=4.25$; $t=2.25$, $df=38$, $p=.030$, two-tailed, $d=.72$) and Samsung ($M=33.55$, $SE=3.81$; $M=61.20$, $SE=10.81$; $t=2.41$, $df=23.66$, $p=.024$, two-tailed, $d=1.77$). According to Cohen (1988), the effect

size estimate indicates that the differences between user's cognitive style and the seeking of a specific photo on the mobile phone showed a larger effect with the Samsung than with the Blackberry and Nokia interfaces.

The number of icon click in the completion of tasks

Overall, serialists clicked fewer icons in order to complete tasks whilst interacting with six interfaces. The exception to this was with the iPhone (Group A interface-holistic interface). Nevertheless, this difference was only significant in task 1 (sending text messages). Holists using the Nokia interface ($M = 4.65$, $SE = .24$) pressed the icons fewer times when sending a text message than serialists ($M = 5.85$, $SE = .43$). The mean difference between conditions was 1.20 and the 95% confidence interval for the estimated population mean difference is between 0.20 and 2.19. According to Cohen (1988), the effect size was large ($d = .80$). An independent t-test shows that the difference between conditions was significant ($t = -2.451$, $df = 30.28$, two-tailed, $p = .02$).

The results of stage 1 show that the users appear to be able to complete tasks quicker with the interfaces which better match their cognitive style. The participants' operational behaviour was affected by cognitive styles whilst completing Task 3 with Blackberry, Nokia and Samsung's interfaces which involved the folders with unclear information as the titles. In the meantime, Task 1 with the Nokia interface also showed a similar phenomenon due to the pages requiring multiple icons for the achievement of the same goal. The findings were then applied to stage two as observation schedules.

Stage 2

The video clips of the participants' interaction with the six interfaces were reviewed. Based on the results of stage 1 and the assigned attributes of the holists and serialists, the observation schedules were based on the following:

- a) how an individual selects an icon in order to complete a task when there is more than one option on the interface;
- b) how an individual seeks the target photo within unknown folders of Task 3;
- c) whether or not the individual follows the same route to complete the task across different interfaces.

The route that the individual applied followed in achieving the goals listed based on the hierarchical structure of the menu with each interface and the time of moving to next icon was also recorded. After reviewing forty participants' interaction with three tasks across six mobile phone interfaces, the responses of the observation schedules were listed as follows:

- a) Holists: tended to be functional-oriented and preferred to select known icons on the desktop to complete the tasks. If the necessary icon was not found on the desktop, holists tended to click available icons randomly and double checked the icons even though they have just accessed the icons.

Serialists: were more goal-oriented and preferred to complete the tasks within routes where they certain of the consequence. They preferred to access the main menu to seek the icon that could be used to achieve the goal.

- b) Holists: checked unknown folders randomly without order, and repeated checking the folders which they have accessed.

Serialists: checked unknown folders one by one.

- c) Holists: tended to complete the three tasks via the same categories and routes across all six interfaces.

Serialists: showed a greater tendency to apply different categories when completing the tasks across different mobile phone interfaces.

The participants' operational behaviour thus can be linked to the attributes of holistic and serialistic styles as followed Table 2 & 3 below.

Table 2 Linkage between holists' attributes and operational behaviour

Holists	
Theoretical attributes	Operational behaviour
Establish relationships between objects by using complex links, using top down approach.	Preferred to select known icons on the desktop to complete the tasks. If no known icons were available to achieve the goal, the tendency was to select any available icon rather than accessing the menu to check for all functional icons. As a result, there was sometimes initial difficulty completing the task and instead time was spent seeking the known icons for the completion of the tasks.
Likely to use analogies to make the connection between different aspects of the subjects.	When there is no clue for finding the target within unknown folders, holists preferred to double check the folders in a random manner. It seemed that they do not remember which folders had been reviewed and there was difficulty establishing the order within unknown folders.
Relate concepts to prior experience.	Tended to complete the task following the same categories and routes across all six interfaces.

Table 3 Linkage between serialists' attributes and operational behaviour

Serialists	
Theoretical attributes	Operational behaviour
Serialists concentrate on the chunks of information that are sequentially ordered and better defined.	Serialists were more goal-oriented and preferred to complete the tasks following routes where they certain of the consequences.
Use a bottom-up approach	Serialists preferred to apply the icons via the main menu. In the meantime, they tended to clarify the function of each icon before moving on to next step.
Relates characteristics within a concept.	Tended to complete the tasks based on their comprehension of the interface in the context. They performed more flexibly of achieving the goal via different categories and routes.

Discussion

This study integrated both quantitative and qualitative approaches and intended to better understand how the attributes of cognitive styles reflect users' operational behaviour when interacting with mobile phones. Based on the differences between holists and serialists, this study analysed forty touch screen mobile phone users' operational behaviour with six selected touch screen mobile phone interfaces. The quantitative results of stage one provided the direction to observe and analyse the users' operational behaviour with the mobile phone interfaces at stage two. The findings show that there is a correlation between the users' cognitive styles and how they handled multiple, unknown options.

It is interesting to note that holists clicked more icons in completing the tasks possibly due to their tendency to look for the required icons, whereas serialists clicked more icons because of confusion about how to operate other elements related to the interface, such as moving the page by slipping the screen and browsing the information with the scroll bar.

The observation results of stage two in this study also imply that having a holistic or serialistic style might affect individuals' approach to tasks. According to Roy, Srull and Wickens (1991), people sometimes apply one strategy or hypothesis to similar tasks even when better alternative solutions were apparent. Therefore, future work will address the relationship between cognitive styles and problem solving ability.

In addition, this study presents the importance of conducting both quantitative and qualitative approaches to understand users. Whereas the quantitative results point out the significance between cognitive style and the participants' performance, qualitative approach of observation provides the detailed description of the effects.

Conclusion

This study establishes a link between cognitive style and mobile phone users' operational behaviour. The findings provide a clearer picture of how to categorise holistic and serialistic users based on their interaction with mobile phone interfaces. According to Ford et al. (2002, p.734), holists performed more engagement in exploratory activity and

'more valuing of serendipitous information encounters' when seeking information. The phenomenon was also observed in this study as holists tended to seek the target goals randomly within unknown folders. The outcomes will be examined further in future studies. The categories of the users' operational behaviour can be applied to mobile phone systems to better customise user interfaces based on cognitive style differences.

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