# Supporting Collaborative Work using Interactive Tabletop

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This thesis submitted in partial fulfillment
of the requirement for the degree of

*Doctor of Philosophy*

February 2016

To Dad, Mum and my family.

# Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other University. This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where specifically indicated in the text.

Kanida Sinmai
February 2016

# Acknowledgements

Over four years at Newcastle University I have many people to thank for their support, motivation and guidance through it all.

First and foremost I would like to thank my supervisor, Professor Peter Andras for providing assistance in numerous ways. For supervision and continuous guidance enabled me to complete my work. Thank you for his expertise, patience, and kindness. Also I would like to thank Dr Phillip Lord for his helps and support me to finish the thesis.

Thank you Professor Aad van Moorsel for his help, support and kindness. My gratitude is also extended to the School of Computing Science for giving me the opportunity to undertake the memorable learning experience. I would like to thank all people and staff in the School for helping me in many ways.

Of my friends at University, I would like to thank particularly to Dr John Colquhoun, Sarah Crabbe and Dr Jennifer Warrender who always support me in many ways and also help me with proof reading and give me a great deal of potential information. Thank you for their friendship, inspiration and never giving up on me.

I would like to thank Supandee Maneelok who always supports and cheer me up.

To my parents, my brothers, sister, sisters-in-law and all of my family for undying and unconditional support. Also my three little nieces who always make me smile.

The Royal Thai government, for the full funding during my PhD.

To the numerous people I have crossed paths with during my time at Newcastle, I would like to say thank you to everyone who has steered me towards its completion, I am eternally grateful.

# Abstract

Collaborative working is a key of success for organisations. People work together around tables at work, home, school, and coffee shops. With the explosion of the internet and computer systems, there are a variety of tools to support collaboration in groups, such as groupware, and tools that support online meetings. However, in the case of co-located meetings and face-to-face situations, facial expressions, body language, and the verbal communications have significant influence on the group decision making process. Often people have a natural preference for traditional pen-and-paper-based decision support solutions in such situations. Thus, it is a challenge to implement tools that rely advanced technological interfaces, such as interactive multi-touch tabletops, to support collaborative work.

This thesis proposes a novel tabletop application to support group work and investigates the effectiveness and usability of the proposed system. The requirements for the developed system are based on a review of previous literature and also on requirements elicited from potential users. The innovative aspect of our system is that it allows the use of personal devices that allow some level of privacy for the participants in the group work. We expect that the personal devices may contribute to the effectiveness of the use of tabletops to support collaborative work.

We chose for the purpose of evaluation experiment the collaborative development of mind maps by groups, which has been investigated earlier as a representative form of collaborative work. Two controlled laboratory experiments were designed to examine the usability features and associated emotional attitudes for the tabletop mind map application in comparison with the conventional pen-and-paper approach in the context of collaborative work. The evaluation clearly indicates that the combination of the tabletop and personal devices support and encourage multiple people working collaboratively. The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the pen-and-paper conditions. The work reported here contributes significantly to our understanding of the usability and effectiveness of interactive tabletop applications in the context of supporting of collaborative work.

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# Abbreviations

| | |
|---|---|
| ADB | Android Debug Bridge |
| CCV | Community Core Vision |
| CDSS | Clinical Decision Support System |
| CM | Concept Mapping |
| Cmate | Concept Mapping at an Adaptive Tabletop for educaiton |
| CSCW | Computer Supported Collaborative Work |
| CUI | Command Line User Interface |
| FTIR | Frustrated Total Internal Reflection (FTIR) |
| GP | General Practitioner |
| GUI | Graphic User Interface |
| HD | High Definition |
| IDE | Integrated Development Environment |
| JDK | Java Development Kit |
| JPEG | Joint Photographic Experts Group |
| LCD | Liquid Crystal Display |
| MERL | Mitsubishi Electric Research Laboratories |
| MDE | Multi-Display Environment |
| MM | Mind Mapping |
| MVVM | Model View View-Model |
| NUI | Natural User Interface |
| PNG | Portable Network Graphic |
| SDK | Software Development Kit |
| SQL | Structured Query Language |
| SMS | Short Message Service |
| TMM | Tabletop Mind Map |
| WCF | Windows Communication Foundation |
| WIMP | Windows Icons Menus and Pointers |
| WPF | Windows Presentation Foundation |
| XAML | Extensible Application Markup Language |
| XML | Extensible Markup Language |

# Chapter 1

# Introduction

## 1.1 Context and Motivation

"Coming together is a beginning, Keeping together is progress. Working together is success" said Henry Ford, a well-known American industrialist [Brinkley, 2003]. The ability to work together is a backbone of any strong and successful relationship.

Collaboration is an ambitious weapon for success. People constantly collaborate to meet mutually beneficial goals. Collaboration can occur in any situation, for example studying, working, meeting, and brainstorming. Collaboration benefits participants in many ways. People have opportunities to exchange their different experiences. Furthermore, they are able to achieve a wealth of knowledge. Most importantly, they can develop a shared vision, and also find a new solution. A common group activity is collaboration around a table, for example, a meeting table, a coffee table, a common room table, a dinner table, and a game table. With the explosion of the Internet and computer systems, there are a variety of tools to support collaboration in groups, such as groupware, and tools that support online meetings. However, in the case of co-located meetings and face-to-face situations, facial expressions, body language, and verbal communications have significant influence on the group decision making process [Hilliges et al., 2007]. People may have a natural preference for using traditional pen-and-paper-based decision support solutions.

Increasing recent research on technologies that can support collaboration. One of these technologies is the interactive tabletop. It is becoming increasingly difficult to ignore the benefits of interactive tabletops. The tabletop systems provide a large workspace where people can collaborate in a face-to-face setting simultaneously. Recent developments in related research into tabletops found that interactive tabletops are enjoyable to use and support group awareness [Baraldi et al., 2008; Chi et al., 2011; Lee et al., 2009; North et al., 2009;

Pantidi et al., 2009]. Tabletop applications have been widely developed for studying and comparing the usability of the interactive surfaces [Hilliges et al., 2007; Seifert et al., 2012; Shen et al., 2003]. Although many research studies have investigated around interactive tabletops in the context of collaboration, tabletop mind map applications still need to be explored [Buisine et al., 2007].

Collaborative decision making is a particularly interesting area of research. It requires the sharing of information and also discussion amongst group members. There are a great deal of decision making tools to find a new solution. With face-to-face meeting situations, mind mapping is a well-known powerful decision making technique for generating new solutions and ideas.

Mind Mapping is the striking combination of imagery, colour, and visual-spatial arrangement. This valuable method is a graphical diagram for presenting thoughts or ideas relating to the central topic [Faste and Lin, 2012]. The mind mapping approach was introduced by Buzan in the mid-1970s [Buzan, 2008]. The mind map can be applied to every discipline to enhance human performance and to unlock the potential of the brain [Buzan, 2008]. It was initially used for learning and note-taking. Recently, the mind map has been widely used in other areas such as planning, presenting, problem solving, decision making and so forth [Willis and Miertschin, 2006].

The advantages of mind mapping compared with ordinary note taking include, for example, time is saved by just noting down relevant keywords [Chik et al., 2007], increasing productivity by 30% and improved understanding of complex issues [Frey, 2011]. Frey [2011] also reveals that mind mapping empowers creativity, boosts up memory, and manages information overload. Mind mapping also promotes group collaboration. Shih et al. [2009]'s work showed that mind map structure imposes an important framing effect on group dynamics and thought organization during the brainstorming process. Consequently, mind maps are a great tool to support collaborative decision making and argument building.

The first application of mind maps on tabletop devices to support collaborative decision making was reported by Buisine et al. [2007]. The research aimed to compare the usability and usefulness of this approach to traditional paper-and-pen conditions. The results showed no difference in production of ideas, but the tabletop condition significantly improved gestural and verbal interactions, as well as the perceived efficiency and pleasure of group tasks.

However, until relatively recently, little had been written on the mind mapping issue. It is a challenge to implement such tools that rely on more advanced technological interfaces, such as interactive multitouch tabletops. We believe that not only do multitouch tables enhance the productivity of mind mapping tools, but incorporating the use of personal devices further extends the possibilities for greater collaboration.

It is well established that emotional attitudes are important factors that influence the effectiveness of collaborative work [Ashforth and Humphrey, 1995]. It has been shown that positive emotions (e.g. happiness, enjoyability) are significantly more influential factors for collaborative working than for individual work [González-Ibáñez et al., 2011]. Positive emotions also indicate self-fulfillment of participants in the context of collaborative work [Fredrickson and Losada, 2005]. In contrast, negative emotions such as anxiety, sadness, and anger, may be associated with reduced accuracy on tasks and executive functioning by biasing cognitive processing, or may lead to reduction of the production of ideas [Fredrickson, 2001]. Therefore, it is important to consider the emotional attitudes of users in the context of evaluation of techniques aimed to support collaborative work.

Hence, this thesis proposes a tabletop mind map application to enhance collaborative work among group members. This work also explores the issue of design challenges for interactive tabletops. Furthermore, the usability of the system will be studied through observation and experimentations.

## 1.2 Research Aims and Objectives

This research focuses on tabletops that people can work together in a situation of synchronous co-located collaboration. The main aim of this research is to investigate the effectiveness and the usability of the tabletop mind map system in the context of support for collaborative work. The principal objectives of this research are as follows:

- To increase an understanding of the use of interactive tabletops in the context of collaborative work.
- To review the existing tabletop applications and identify challenges and weaknesses in this regard.
- To design and implement a framework for collaboration using tabletops.
- To evaluate the approach by conducting experiments.
- To propose design guidelines for tabletop application in the context of collaborative work.

## 1.3 The Challenges

The key challenges of this research which are as follows:

- Design challenge for interactive tabletops: people usually work collaboratively around a physical table. Moving to the digital table is a challenge to ensure users become familiar with this environment. This is because a benefit of the tabletop is to use the multitouch interaction technique to enable users to interact with the surface simultaneously by directly touching the screen instead of using the traditional input (i.e. mouse and keyboard). Consequently, from command line user interface (CLI) to natural user interface (NUI), in this thesis, touch interaction was considered.

- Development challenge: developing tabletop mind map application is complicated since the framework consists of two main applications: tabletop mind map application and Android mind map application. Both applications support multi-touch interaction. The former one was developed by C#, and Java for the latter one. What is more web-service was chose to be media of the two components.

## 1.4 Research Contributions

The research contributions can be divided into two sections presented below:

### 1.4.1 Main Research Contributions

This thesis makes a number of contributions in the area of supporting collaborative work using interactive tabletops. These are summarised below:

- The design of the table mind map system for collaborative work. The requirements for the developed system were based on a review of previous literature and also on requirements elicited from potential users. The design was guided by the work of Bachl et al. [2010] which presented the challenges for designing user experience and a given specific guidelines for co-located collaboration by Scott et al. [2003]. The design of the system aims to support simultaneous user actions, consider the appropriate arrangement of users, support individual differences and support transition between individual and collaborative work.

- The implementation of the tabletop mind map system. The proposed implementation consists of two main components: tabletop mind map application and Android mind map application. The tabletop mind map component is for supporting users work simultaneously in the same surface. To support privacy and may help the creativity and feeling well of participants, the Android hand-help component is developed.

- The evaluation of two controlled laboratory experiments. The first experiment compared the use of our mind map application with pen-and-paper condition. The second experiment combined our tabletop mind map application with personal devices and compared this combined application with the conventional approach. The results clearly indicate that the combination of a tabletop and personal devices support and encourage multiple people to work collaboratively. The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the pen-and-paper approach.

### 1.4.2 Publication

This work has been documented in part of this publication:

K. Sinmai and P. Andras, "Mapping of Surfaces: Supporting Collaborative Work Using Interactive Tabletop". In 20th International Conference on Collaboration and Technology (CRIWG 2014), September 7-10, Chile, 2014. [Sinmai and Andras, 2014]

This work presented the evaluation of the effectiveness and usability of the applications.

## 1.5 Thesis Outline

This thesis is organised as follows:

- Chapter 2 provides the background information of the research areas relevant to this work. These include the theoretical dimensions of interactive tabletop work and evaluation, collaborative work, mind mapping, and multi-display groupware. Furthermore, the next part of the review concerns design guidelines for the tabletop system. What is more, the final section of the review presents the combination between table and personal devices system related to collaborative work.

- Chapter 3 The methodology adopted for this research is presented. This includes a discussion of experimental design, data collection and analysis. This also explained how research questions are going to be answered.

- Chapter 4 presents the system requirements and design for the development of the applications. Next, a high level architecture of the system will be presented. Finally, the user interface and the interaction are discussed.
- Chapter 5 reports the results of experiment one and experiment two.
- Chapter 6 discusses the research finding for chapter 5 and 6. Also it explains how the research questions are answered. These also include limitation of the work.
- Chapter 7 draws conclusions from the research presented throughout the thesis. These also summarise the achievements, contributions, and problem of this thesis. Additionally, a number of directions for future work into this research are recommended.

# Chapter 2

# Background and Related Work

The purpose of this chapter is to provide the background information on commonly used concepts within the setting of this research study and to summarise briefly the related work. The chapter begins by giving some information into tabletop technology which is the main hardware used in the research. The basic issues in collaborative work and mind mapping technique are also presented. Finally, recent works into tabletop mind mapping are discussed.

## 2.1 Tabletop Technology

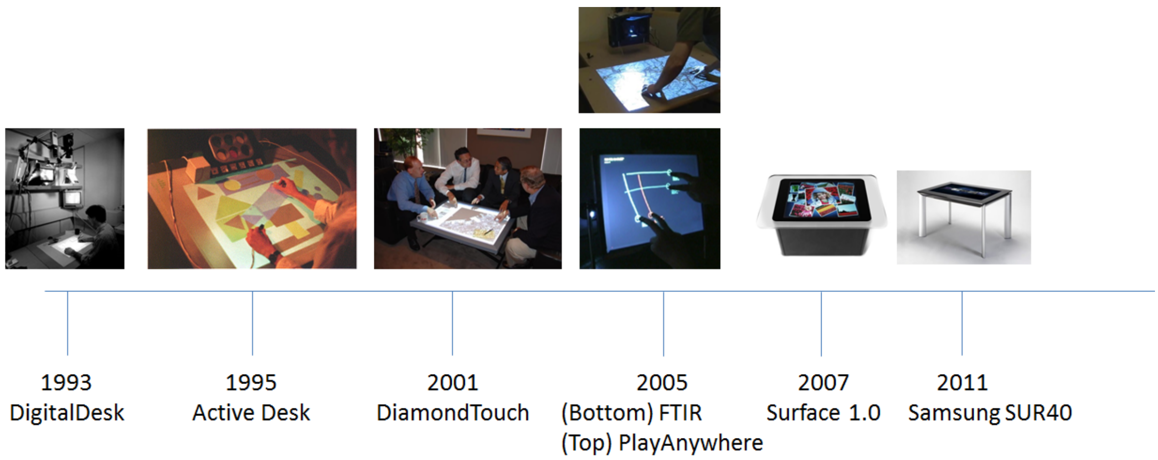



Figure 2.1 Tabletop Timeline

Over the past twenty years, interactive tabletop technologies have been studied in various domains, not only because it is a new form of computer, but also because of the advantages of this technology. Tabletops are multi-user horizontal devices designed for simultaneous use. They have the potential to support collaborative working and more specifically to aid people to collaborate more effectively.

The tabletop technology timeline is presented in Figure 2.1. The area of interactive tabletops and horizontal displays research was started by Pierre Wellner who proposed the DigitalDesk system in 1993 [Wellner, 1993]. The DigitalDesk is a real physical desk but it is enhanced to provide digital characteristics by using fingers which were tracked by a computer system. It could detect touches on a relatively large surface. Fitzmaurice et al. [1995] developed a large horizontal desktop surface called ActiveDesk, which allowed interaction devices other than fingers. Using a rear-projected digitizing board, it was also possible to interact with a stylus. Additionally, a graspable user interface was introduced, which is the physical representation of the graphical user interface. These two tabletops did not provide multi-user interaction.

The most common tabletop technology that is used in a number of tabletop studies is DiamondTouch [Fleck et al., 2009; Forlines et al., 2007; Pantidi et al., 2009; Piper and Hollan, 2009; Shen et al., 2003; Smeaton et al., 2007; Tse et al., 2007; Yamaguchi et al., 2007]. DiamondTouch was developed at the Mitsubishi Electric Research Laboratories (MERL) [Dietz and Leigh, 2001]. It was the first multi-user and multitouch technology for tabletop front-projected displays. It enables users to use the same touch-surface simultaneously without interfering with each other.

Han [2005] presented a multitouch technology that provided the most widely known optical technique, frustrated total internal reflection (FTIR). This technology is used for demonstrating in many studies [Echtler et al., 2009; Gross et al., 2008; Hansen and Hourcade, 2010; Hunter and Maes, 2008]. Later on in 2006, Perceptive Pixel developed a wall-sized multitouch display called "Multi-Touch Collaboration Wall". In 2012, Microsoft purchased Perceptive Pixel [BBC, 2012].

In 2005, PlayAnywhere was introduced by a Microsoft researcher which uses a front-projected, computer-vision based interaction tabletop system [Wilson, 2005]. Both the wide-angle projection and infrared-based tracking system are located above the tabletop. The infrared illumination is deployed to generate shadows.

Microsoft introduced an interactive table surface called Microsoft Surface which is capable of sensing multiple fingers and hands in May 2007 [Buxton, 2011]. The device is optimized to recognize 52 simultaneous multitouch points of contact. It can also identify various objects and their position on the surface. In 2011, Microsoft Surface 2.0 was developed which uses rear projection and projectors replaced by augmented LCD technology. It is now called the Samsung SUR40 [Pepitone, 2011]. The Microsoft Surface Table website is now no longer online, instead it is rebranded to Microsoft PixelSense [Microsoft, 2012].

Numerous computer manufacturers have released commercial devices and operating systems with multitouch capabilities. Moreover, there are a growing number of research groups and hobbyists developing their own multitouch low-cost solutions [Buxton, 2011; Han, 2005; Microsoft, 2012].

### 2.1.1 From CLI to NUI

In the very first user interfaces, users had to interact with computer by using a keyboard entering text into a command line. The command line interface (CLI) was the first user interface. Next, the graphical user interface (GUI), with which users interact regularly is based on the desktop metaphor using a mouse and a keyboard. A GUI provides graphical icons, and visual indicators such as label underneath the icons. It can be referred to as WIMP: windows, icons, menus, and pointers or direct manipulation interaction style. The terms of GUI and WIMP are usually used interchangeably. The GUI represents a lower barrier for users than a command line interface. Then, the natural user interface (NUI) seems to be in same position as the GUI was in the early 1980s [Wigdor and Wixon, 2011]. The GUI cannot completely replace the CUI likewise the NUI cannot completely replace the GUI. The NUI is not simply a natural veneer over a GUI. Instead, it has a set of strengths based on what it makes easier, how it makes those things easier and how it shapes the user's interaction with technology [Norman, 2010].

In terms of natural is understood to mean of the real world. Blake [2011] stated that developers should forget what natural means but they should make an interface that makes users act and feel like a natural. Wigdor and Wixon [2011], moreover, addressed that a NUI is not a **natural** user interface, but rather a **natural user** interface. The NUI may represent a revolution in computing, not because it replaces existing ways of interacting with computers, but because it enables computing to expand into new niches that could be of a very large size and importance.

According to Blake [2011], NUI is a user interface designed to reuse existing skills for interacting directly with content. There are three important characteristics about the natural user interface. Firstly, during the design process, the designer has to create NUI interactions that are appropriate for users. Secondly, NUI reuses existing skills, which focuses on how to create interfaces naturally. Users should interact with computers using intuitive actions such as touching, gesturing, and talking. Finally, NUI have direct interaction with contents.

Furthermore, the NUI is defined by three elements: enjoyable, leading to skilled practice and appropriate to context [Wigdor and Wixon, 2011]. The NUI should have all of these elements. Additionally, NUIs are concerned about objects, containers, gestures and manipulations. Objects and containers are types of interface elements. They are presented by the application using whatever output technology is appropriate, whether graphics, sound or voice, tactile, or future output technologies such as 3-D holograph. Gestures and manipulations are types of interface actions that the user performs. The user provides input to the application with whatever input technology is appropriate, including multitouch, motion tracking, stylus, voice, or future input technologies such as muscle sensors or brainwave sensors.

With regard to objects, each object presented in the interface should be represented by an individual, self-contained object. For instance, images that can move, rotate, scale and be thrown. There are three main attributes of the object metaphor. Firstly, permanent objects, if user leaves an object in a particular state at a particular position, leaves to work on another task and comes back later, that object should still be in the same state and position. Next physical attributes, these attributes determine how users interact with objects, how objects interact with each other, and how objects behave within the environment outside of this interaction. Lastly, fluid transitions, is an aesthetic, continuous animation that helps user to understand how and why an object is changing states. Containers are metaphors for the relationship between contents. This metaphor is based on user experience with real-world containers.

### Touch

The process of touching is immediately recognisable as the gift of life [Shneiderman, 1991]. People always interact by touching in daily life. Touch is a common intuitive interaction. Back to 1965, the first touch screen was introduced by E.A. Johnson of the Royal Radar Establishment, Malvern, UK [Buxton, 2011]. Since then touch screens have been progressively developed and enhanced from single touch to multitouch displays with more colours and faster response rates. Single touch is one point of contact on a surface at a time such as ATM, Palm and so forth, whilst multitouch is many points of contact that allows users using their fingers touch on screen simultaneously such as DiamondTouch, SUR40 and iPad [Dietz and Leigh, 2001; Microsoft, 2012; Morrissey and Campbell, 2010].

Multiple methods on how touch and gesture are incorporated into computing systems have also arisen. For instance, iPhone uses touch as the sole input method [Buxton, 2011; Morrissey and Campbell, 2010]. Windows 7 uses a triad of input methods: touch, stylus and keyboard/mouse [Buxton, 2011]. Also, different hardware interfaces are being developed. Wigdor and Morrison [2010] mentioned that some devices are based on camera system and others on capacitive technologies. For example, Apple's track pad uses multiple gestures including a four finger touch gesture, while the HP TouchSmart can recognize track only two points of contact, and larger devices such as Microsoft Surface and the Smart Table are able to simultaneously track over 50 contact points.

**Why Touch Screen?**

[Shneiderman, 1991] also stated that there are many advantages of touch screen over the previous pointing devices. Firstly, touching requires little thinking and is easy to learn in a form of direct manipulation. Secondly, touch screens are the fastest pointing device. Thirdly, touch screens have easier hand-eye coordination than mice and keyboards. Next, no extra workspace is needed as they use the same devices for input and display. Finally, the screens are durable in public access and in high volume usage. Touch screens, however, have some disadvantages. For example, user's hands may obscure the screen and they cost more than previous devices.

### 2.1.2 Design Guidelines for Tabletops

Numerous research suggests general guidelines for multitouch designing [Bachl et al., 2010; Kruger et al., 2003; Scott et al., 2003]. Scott et al. suggested design guidelines for tabletop technologies as follow:

1. Natural interpersonal interaction: This design is to support group activities at the heart of collaboration. Also it can be supported with an appropriate and friendly physical design for the table.

2. Transitions between activities: This can be in term of software tools, or hardware/ software tools as in switching between using a physical keyboard and a stylus.

3. Transitions between personal and group work: To divide the table space into personal and public territories.

4. Transitions between tabletop collaboration and external work: Work generated externally should be easy to incorporate in the tabletop environment and vice versa.

5. The use of physical objects: Physical objects include pen, paper and tangible objects augmented with digital data.

6. Accessing shared physical and digital objects: Shared access to physical and digital objects should be provided where it helps in maintaining group focus and facilitates awareness.

7. Flexible user arrangements: Consideration should be paid to the appropriate arrangement of users and the table shape and size.

8. Simultaneous user interactions: Supporting multiple users collaborating simultaneously.

A number of studies have followed these guidelines. For instance, WorkTop [Clifton et al., 2010] is a sketching tool designed to facilitate and augment collaborative brainstorming. This study meets most of these guidelines excepts number four. Also, WordPlay a tabletop interface, has been developed for supporting collaborative brainstorming and decision making [Hunter and Maes, 2008]. Furthermore, UbiTable was designed to support collaborative work for small group meetings and also supports these guidelines [Shen et al., 2003]. In this study people could walk up, share their content, and exchange data.

However, research suggested that a tabletop application should meet some of Scott's guideline for co-located collaborative work on a tabletop. Finger Talk supported collaborative work for small by using talk and fingertip interaction [Rogers et al., 2004]. They suggest that in the future tables may have to increase in size allow to for users sitting further away from each other. They also suggest the need of Scott et al.'s guidelines for natural interpersonal interaction and fluid transition between interaction and activities.

Furthermore, Bachl et al. [2010] presented eight challenges that need to be considered when designing the user experience of multitouch interfaces. These challenges can be classified into three categories: screen based, user-based and input-based challenges.

The screen-based challenge describes problem related to physical properties of touch screens. This group is related to the affordance of screens and the lack of tactile user feedback. Next challenges, the user-based explores the use of fingers for direct input as the origin of problems users are facing when interacting with multitouch interfaces. This category includes the challenge of the ergonomics, individual differences of users, and accessibility. Lastly, the input-based challenges present the difficulties in interpreting and supporting the input to enhance the user experience of multitouch interfaces. Challenges of within the group are related to gestures and patterns, supporting data input, and multi-user support.

### Challenges of design for multitouch interfaces

According to the affordance principle, Shen et al. [2003] states that “an affordance is a property of whatever the person interacts with, but to be in the category of affordances it has to be a property that interacts with a property of an agent in such a way that an activity can be supported”. Then NUI designers should forget all about web design or GUI design which is point and click interaction. NUI designers should think about a clean paper that users can fill in.

In addition, they should be concerned about sources of error. There are many sources of error that designers should be concerned with understand.

One challenge of designing multitouch is from users' experiences that related to ergonomics and individual differences of users and accessibility. One important thing to consider when designing multitouch interfaces is partial occlusion of the screen caused by fingers, hands and arms when users interact with the display [Ryall et al., 2004]. For a small multitouch display, the designers should focus how to touch correctly the targets, where touch targets are also small. This problem increases when designing multitouch applications that support different platforms. Individual differences between users are an important for designing user interfaces for multitouch applications. For instance, different finger sizes differ from a computer mouse that has a target zone of one pixel. The next challenge is multiple users support. Designing a system for multiple users, who interact simultaneously, is the ability to distinguish between individual users. Still there is no conclusive solution for multiple users support that works for different technologies.

## 2.2 Collaborative Work

As far as history goes, people tend to work together to achieve their goals. Groups of people work around a physical table such as a coffee table or a meeting table for sharing ideas, brainstorming, discussing, and making a decision. Many decision making problems have to be solved by discussion among a group of people. The "world of work" [Levin, 2005] requires more time and effort, awareness, knowledge, skills, ideas to gain benefit of group work. Therefore, in collaborative work, people have opportunities to exchange their different experiences. Furthermore, they are able to achieve a wealth of knowledge. Most importantly, they can develop a shared vision, and also find a new solution.

Collaboration has occurred when more than one person works on a single task. According to Iivari and Linger [1999] "collaborative work is constituted by the interdependence of multiple people who, in their individual activities, in changing the state of their individual field of work, also change the state of the field of work of others and who thus interact through changing the state of a common field of work". Furthermore, collaboration definition, is defined by Roschelle and Teasley [1995] that "Collaboration is a coordinated, synchronous activity that is the results of a continued attempt to construct and maintain a shared conception of a problem". Also, Denise [1999] identified that collaboration is not about agreement, but it is about creation. This is also presented in a book by Schrage [1990] stating "collaboration is the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own. Collaboration creates a shared meaning about a process, a product or an event. In this sense, there is nothing routine about it. Something is there that wasn't there before". Furthermore, Denise [1999] also stated that collaboration is unlike communication, coordination and cooperation. Collaboration is about using information, seeking divergent insight and spontaneity, not structural harmony. What is more collaboration thrives on differences and requires the sparks of dissent. The collaboration can be successful only when the goal is achieved and accomplished by a group not an individual.

Therefore, collaboration is a process to achieve a goal with can be done by a group of people.

### 2.2.1 Computer Supported Collaborative Work

Computer Supported Collaborative Work or CSCW emerged in 1984 from shared interests among product developers and researchers in diverse fields [Grudin, 1994a]. CSCW is a very strongly related area of research to group working. It is a research agenda that focuses using computer systems to support group work. CSCW is an umbrella bringing researchers together from several areas such as computer science, psychology, sociology, anthropology, ethnography, management and medical [Greenberg, 1991]. Computer supported collaborative work must overcome the difficulties of multidisciplinary interaction [Grudin, 1994a]. CSCW refers to people working together with formal and informal tasks in organisation with help from computer. CSCW is related to social dynamics which users need to learn how to work in interactive group situations. It starts as an effort by technologists to learn from economists, social psychologists, anthropologists, organizational theorists and so on. This field is also known as computer-supported collaboration, GroupWare, Workflow, and Group Decision Support Systems [Palmer and Fields, 1994]. Palmer and Fields also stated that a primary key to success in CSCW activities lies in user comfort with system operations.

The heart of this comfort is the user interface that it needs to become more intuitive.

As far as design challenges for CSCW developers are concerned, Grudin [1994b] listed eight design challenges that must be considered during the design and implementation process of a successful and suitable groupware system.

1. Disparities between effort required and benefit for individuals.
2. Limits of informed intuition: Managers and designers beware.
3. Critical mass of users for economical usage of groupware systems.
4. Avoiding other social and motivational pitfalls.
5. Support for exception handling.
6. Designing for low-frequency events.
7. Difficulty of evaluation.
8. The adoption process. Designer must consider what will be needed to promote successful adoption from the outset.

### CSCW Typologies

People work together in different modes. Activities can occur in the same place at the same time or different sites at the same time or different times and different places. Figure 2.2 illustrates the CSCW typologies. The matrix considers the two dimensions of time and place.

The time factor can be divided into two categories: same time and different time. The former category refers as synchronous or real time while the latter one refers as asynchronous where people collaborate asynchronously.

The location factor can also be divided into two categories: Same place and different place.

Additionally, Wilson [1991] identified four categories of CSCW technology that can be considered.

1. Communication mechanisms enabling people at different locations to see, hear and send messages to each other. For instance, video conferencing and email.
2. Shared work space facilities enabling people to view and work on the same electronic space at the same time. For example, remote screen sharing.

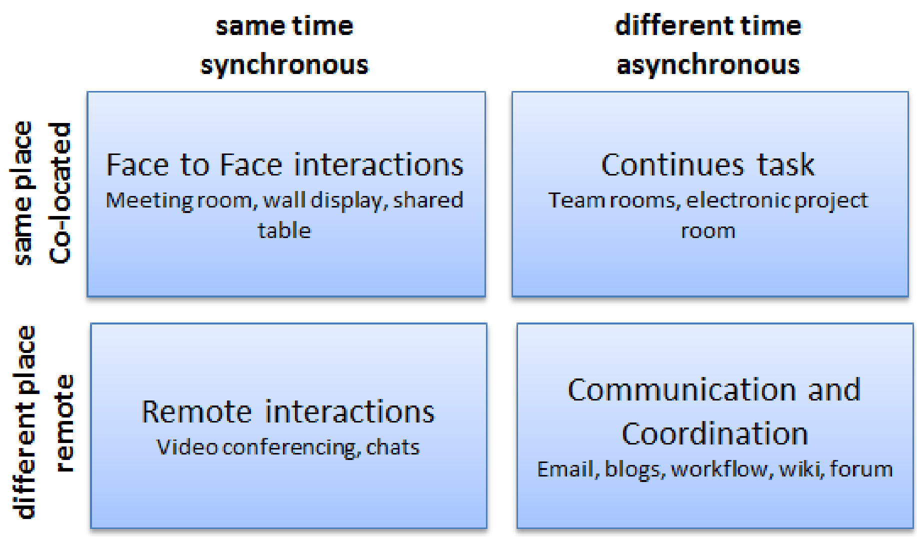



Figure 2.2 CSCW Typologies

3. Shared information facilities enabling people to view and work on a shared set of information, for example multiple user databases.

4. Group activity support facilities to augment group work processes, for example, the co-authoring of documents and idea generation.

Grudin and Poltrock [2013] also addressed the framework of the CSCW technology as presented in Table 2.1. These human behaviours can be roughly divided into three categories: communication, sharing information, and coordination. These behaviours can occurred at the same time or at different times.

### Groupware Usability

Gutwin and Greenberg [2000] defined groupware usability as the degree to which a groupware system supports the mechanics of collaboration for a particular set of users and particular set of tasks. They also suggested the usability analysis which should be focused on when studying group work. The groupware usability are:

- *Effectiveness* considers whether the activity was successfully completed, and the number and severity of errors made during that activity. A usable groupware system will not prevent the mechanics of collaboration from taking place, and will not cause group members to make undue errors in those activities.

Table 2.1 Collaboration framework with examples of CSCW technology

| | Synchronous | Asynchronous |
|---|---|---|
| Communication | Telephone<br>Video Conference<br>Instant messaging<br>Texting | Email<br>Voice Mail<br>Blogs<br>Social networking sites |
| Information Sharing | Whiteboards<br>Application Sharing<br>Meeting facilitation<br>Virtual worlds | Document repositories<br>Wikis<br>Web sites<br>Team workspaces |
| Coordination | Floor control<br>Session management<br>Location tracking | Workflow management<br>CASE Tools<br>Project management<br>Calendar scheduling |

- *Efficiency* considers the resources such as time or effort required to carry out the activity. A good groupware system will allow the activities of collaboration to proceed with less time and effort than will a system with usability problems. Note that any measures of efficiency must be carefully focused on task activities, since groups often engage in off-task activities that are not detrimental to the overall shared work.

- *Satisfaction* considers whether the group members are reasonably happy with the processes and outcomes of each of the activities of collaboration. Satisfaction will sometimes overlap with efficiency and effectiveness (that is, problems in the other areas are likely to reduce satisfaction).

### 2.2.2 Tools for Collaboration

There are a great many tools for supporting collaborative work such as pen and paper, a desktop PC, and a whiteboard. With the advent of digital technologies, not only pen and paper have been used in a meeting situation, but a computerised tool is also involved such as a desktop PC, a laptop, a tablet or even an electronic whiteboard. The computerised tool is seen as an ideal work facilitator. In the very early days of computing, a personal computer was too expensive for individual use. As time goes by, the power of computer technology has been increasing while the cost has decreased. Computers have implicitly supported the work of a single user by using off-the-shelf software such as word processors, spreadsheets and slide presentations.

However, work could not be done by a single person. To augment group work, groupware, a computer software has been designed. In the context of interactive tabletop research, the terms of collaboration is used to refer to co-located settings involving small groups of two to five users [Kharrufa, 2010].

Table 2.2 below shows collaborative tools that can be considered into seven categories. Tool features can be roughly divided into four groups: 1) portable: if the device is easy to move; 2) large screen: if the device has a big screen and it is possible to work with other people; 3) input devices: what input technique used for each device; 4) network connection: if the device can connect to network or internet.

Table 2.2 Collaborative technologies

| Tools | Portable | Large Screen | Input Devices | Network Connection |
|---|---|---|---|---|
| Pen and Paper | / | | pen | |
| Tablets | / | | touch | / |
| Laptops | / | | mouse, keyboard | / |
| Desktop PC | | | mouse, keyboard | / |
| Interactive whiteboards | | / | mouse, keyboard | / |
| Whiteboards | | / | pen | |
| Interactive Tabletops | / | / | touch, mouse, keyboard | / |

Pen and paper are the most traditional tools that can be used as they always support hand-writing and portability. However, nowadays, in the digital era some people prefer to use tablet rather than pen and paper. Tablets make use of touch with either a finger or a stylus and the output is provided on the same surface. The benefits of tablets are portability, mobility, support for video and audio, robust and improved communication [Scholtz et al., 2013].

Interactive whiteboards are technologies that support collaboration with vertical screen. They can directly connect to a desktop PC or can be controlled by a PC. This technology is popular in classroom environments [Scholtz et al., 2013]. However it has some limitations - they are expensive, time-consuming to learn, and need to be well maintained.

Whiteboards are non digital tools for collaboration. They are vertical boards that also support group work. However they are not portable devices and can not be able to connect to the internet.

Interactive tabletops are large screen technologies which has input and output on the same device as same as tablets. This technology is promised to support multi-user work simultaneously. Interactive tabletops are also considered a perfect technology for collaboration [Scholtz et al., 2013]. Users can use their fingers to interact with the screen instead of using a mouse or a physical keyboard.

### 2.2.3 Horizontal and Vertical Displays, which one is the best?

In the section, between horizontal and vertical displays, which one is the best for collaboration will be discussed. Few studies have focused on this matter. A horizontal display offers a great deal of possibilities for user arrangement, providing users with diverse perspective, and providing a flat surface for placing objects [Inkpen et al., 2005]. While a vertical display provides users the same perspective, is also more commonplace, require less space, and are less expensive than horizontal surfaces [Inkpen et al., 2005; Potvin et al., 2012].

Potvin et al. [2012] suggested that the vertical displays better support a co-located situation, while the horizontal surface encourage more discussion. This study used non-digital surfaces (i.e. a whiteboard and a physical table). They compared both surface orientations by using dyads preforming a collaborative design task while standing. The result shown that dyads can work effectively with both vertical and horizontal surfaces. That is perhaps participants were standing while performing the experiments.

Inkpen et al. [2005] found that participants interacting with the vertical display noted more ergonomic difficulties related to arm fatigue, difficulty writing and back stiffness. Furthermore, a vertical display may be better for shorter, more focussed tasks, while a horizontal display may be better for longer duration tasks that require more discussion.

Another study [Rogers and Lindley, 2004] found that in horizontal displays, groups switched more between roles, explored more ideas and had a greater awareness of what each other was doing. In vertical condition, groups found it more difficult to collaborate around display. Rogers and Lindley also listed the advantages of tabletop displays that encourage group members to work collaboratively in more cohesive ways. The main benefits include:

- Enabling the group to refer to the same representations, making it easier for all members to contribute to the problem-solving at hand.
- Supporting more fluid interaction through close coupling between the creation of a plan, document, etc. and the digital information that needs to be accessed.

- Providing a physical surface that affords easy role swapping, and, in so doing, more alternative to be put forward for discussion.

In conclusion, vertical displays are better at providing a shared surface for communal and audience-based viewing and annotating of information that is to be talked and referred to [Rogers and Lindley, 2004]. However, horizontal displays support the participants in collaborative activities that involve using and creating an assortment of representations [Inkpen et al., 2005; Rogers and Lindley, 2004].

### 2.2.4 Multi-Display Environment

Nowadays, display technologies become increasingly available at low prices and blend thus into our everyday lives. People have a lot more devices to provide additional displays. For example they extend a computer monitor with a television for entertainment at home. In the workspace, a laptop could extend with a digital projector for a presentation. Moreover, people connect their phone to a tablet or a desktop to share their personal data or play games. In terms of collaborative work, multiple displays configurations has gained a lot of attention.

A multi-display environment (MDE) is a system that integrates many devices such as tabletop, wall displays and personal devices (i.e. tablets and mobile phones) [Seyed et al., 2012]. This system offers the potential to support teamwork [Bachl et al., 2011; Nacenta et al., 2012; Seifert et al., 2012; Seyed et al., 2012]. Wallace et al. [2009] also confirmed that MDE offers advantages for preforming individual tasks. MDEs often include heterogeneous displays to take benefit of different capabilities such as their size, position, resolution or portability to support the task at hand [Seyed et al., 2012].

MobiSurf [Seifert et al., 2012] has been used to investigate how the combination of personal devices and a simple way of information exchange between the devices and an interactive surface change the way people solve collaborative tasks compared to an existing approach of using personal devices. This finding shows that users can facilitate switch between the devices.

## 2.3 Tabletop and Group Work

Tabletop research is located in the Computer Supported Cooperative Work (CSCW) domain which addresses how computers can mediate and support group collaboration, and social interaction. Collaborative working on tabletops can be challenging for communication between people. The studies examined in this section show that interactive tabletop supporting group brainstorming, decision making, game, education and health care.

It can be argued that there are several important directions for future research including: standardization of methods to evaluate collocated collaboration; comparative studies to determine the impact of existing system configurations on collaboration; and creation of a taxonomy of collaborative tasks to help determine which tasks and activities are suitable for tabletop collaboration.

What is the most appropriate type of tabletop system to build? Answering this fundamental question could benefit the larger CSCW community as more researchers begin exploring co-located collaboration. There is no standard configuration for tabletop systems. Decision about the size and resolution affect how many collaborators can gather around the table. Projection technology: top, bottom, self illuminating, which affect the view angle, brightness and robustness of the system but also influences interaction.

There are several projects on multitouch systems. These studies are about understanding, designing and developing multitouch applications and comparing them with traditional group working. The findings of the studies reveal that both surfaces can affect the nature of the collaboration and interaction during a workshop [Baraldi et al., 2008; Chi et al., 2011; Lee et al., 2009; North et al., 2009; Pantidi et al., 2009]. For instance, Pantidi et al. [2009] compared between four different surfaces: Post-It note, large sheets of paper, writeable wall, and tabletop computer. The last two surfaces are unfamiliar to the participants, they may have initial difficulties understanding them. However Post-It note can be easily used. In case of group size, this study also found the participants using the tabletop broke up into smaller groups (4 people) because larger sizes of group members made it difficult for all group members to use the surface.

There is numerous research involving supporting collaborative working for multitouch technology. These projects introduce the differences in real world and digital tabletop collaboration. The research projects found tabletop systems afford and encourage interaction amongst a group of people [Pinelle and Gutwin, 2008; Shen, 2007; Wang et al., 2009; Yamaguchi et al., 2007].

Moreover, increasing health care facilities are adopting electronic medical record systems. Piper and Hollan [2011] introduced an application for older patients using a shared touch screen computer. This research found that users can simply use the system by operating the horizontal touch screen, but a few participants mentioned that the size of the display screen could be made smaller.

Also, in Clinical Decision Support System (CDSS), most of the applications focus on providing diagnostic assistance to medical doctors and healthcare professionals. For example, the medical consultation which is a two-way interaction between clinician and patient involving interactive decision making [Gibson et al., 2006]. This study investigates into verbal prescribing in general practice consultations. The research found that GP decision making need to be incorporated in CDSS design. Another study explored the aims to facilitate the awareness of how GPs use their computers while in consultation with their patients [Gibson et al., 2005].

A focused partnership is a goal of collaborations in a small group that needs to complete a task, for instance two pathologists consulting about a cancer patient's biopsy. In traditional face-to-face meetings, participants work at a computer and make simultaneous contributions. Shared and private windows plus large-screen projectors enable simultaneous shared comments.

Hilliges et al. [2007] investigated the design guidelines and implications of using a tabletop interface in combination with a large wall display for face-to-face group brainstorming. They compared a digital brainstorming application composed of an interactive table and a wall display to the pen-and-paper condition. The result showed no difference in task performance between the two conditions but subjective evaluations were globally favourable to the digital condition.

WebSurface has evolved on a tabletop environment to address the problem of collaborative Web browsing [Tuddenham et al., 2009]. This study was tested by six pairs of collaborators, each pair of them tested three different Web browsing technologies: WebSurface, single laptop and dual laptops. This work suggested that the tabletop condition can help to address limitation of conventional tools, and presents beneficial affordances for information layout.

The co-located meeting tends to encourage more equitable work style than shoulder-to-shoulder working style [Morris et al., 2010]. Hansen and Hourcade [2010] compared multi-touch with multi-mouse (two mice) found that users were efficient when using multi-mouse but preferred multi-touch.

Other related work considered social factors in enticing users and groups to approach displays and begin interaction. For example, Marshall et al. [2011a] found that users move around a collaborative surface and they also gather dynamically. Marshall et al. [2011b] has suggested that spatial relationships can encourage more people engage in an interaction naturally.

Several studies have applied the interactive table with children. Cao et al. [2010]'s TellTable supported sketch-based storytelling on a Microsoft surface, aiming to encourage incorporating physical objects into stories via 'capture tools' that inserted photos directly on to the story surface. The application has been found to support creativity and collaboration.

## 2.4 Mind mapping: A Tool for Collaborative Work

Mind Mapping is a powerful thinking tool for brainstorming [Buzan, 2006]. This valuable method is a graphical diagram for presenting thoughts or ideas relating to the central idea [Faste and Lin, 2012]. The mind mapping approach was invented by Buzan [2008]. It can be applied to every discipline to enhance human performance and to unlock the potential of the brain [Buzan, 2008]. Mind map was initially used for learning and note-taking. Recently, mind maps have been widely used in other areas such as planning, presenting, problem solving, decision making and so forth [Willis and Miertschin, 2006].

Mind mapping has several advantages when compared with ordinary note taking. For example, time is saved by just noting down relevant keywords [Chik et al., 2007], there is increased productivity of 30% and improved understanding of complex issues [Frey, 2011]. Mind mapping empowers creativity, boosts memory, and helps manages information overload [Frey, 2011]. Mind mapping also promotes group collaboration. Shih et al. showed that the mind map structure imposes important framing effect on group dynamics and thought organization during the brainstorming process [Shih et al., 2009].

Mind Mapping is built from the centre which represents the main idea and branches out as dictated by the individual ideas and general form the central theme [Buzan, 2006]. Later, Shui and Le [2010] stated that a mind map is a tree-like diagram used to represent words, ideas, tasks, or other items and their relationships. An example of a mind map can be seen in Figure 2.3. The four main features of a mind map are:

1. Each mind map has a starting location, the centre node that contains the central theme.
2. The ideas of the mind map "radiate" from the central node as branches with sub-nodes connected to each other in parent-child relationships.
3. The final structure of the mind map becomes a hierarchy of linked nodes.

4. Each connector/branch has keywords or an image associated with it.


Figure 2.3 Component of a mind map: the central idea represents the core topic, branches radiate the sub-topic from the main node, nodes represent the ideas of topic, and lines show a hierarchy of the nodes. The conceptual hierarchical relationships of the concepts represented by the nodes.

Mind maps can be used in any situations where thinking and learning are involved. ThinkBuzan [2014] lists the example of the situations as follows:

- Learning: Mind maps can improve reading and assimilation of large volumes of books and helps aid understanding.
- Over viewing: Users can see an overview of the solution.
- Concentrating: Mind maps helps users focusing on the task.
- Memorising: As Mind maps use picture that would be easily stored in the brain and helps in quick recall.
- Organising: It can be a great help to organise the task.
- Presentation: Mind maps can help in effective communication and presentation. A Mind mapped presentation helps in giving concise and clear speech as the entire details are in a single Mind Map.

- Thinking: Mind Maps can help in considering minute details about the problem and can aid in better and consistent thinking.
- Planning: Mind Maps can help in effective planning. All the stages to the solution can be approached in a systematic way.
- Brain booming: It is a modern way of Brainstorming using mind maps in which every thought generated are properly analysed with its critical details.

Generally, a mind map can be created by using blank paper, coloured pens and pencils. Alternatively, with the advent of the digital realm, mind mapping has been converted from a hand drawn hard copy into an electronic form using a physical keyboard and a mouse for input. Tools for mind mapping are summarised in Table 2.3, which has traditional pen-and-paper, whiteboard, and computerised tools. The mind map is editable and reusable by using computerised tools. Blank paper is portable as same as laptop, tablets and mobile phones. However tabletops are better suited for working in co-located meeting.

Table 2.3 Mind maps hardware

| Tools | Interaction technique | Editable | Reusable | Large Screen | Portable |
|---|---|---|---|---|---|
| Pen and Paper | Pens or Pencils | | | | / |
| Whiteboard | pens | / | | / | |
| Desktop PC | keyboard, mouse | / | / | | |
| Laptop | keyboard, mouse | / | / | | / |
| Tables | touch | / | / | / | |
| Mobile Phone | touch | / | / | | / |
| Tabletop | keyboard, mouse, touch | / | / | / | |

Digital mind mapping applications have been provided both commercially and as freeware such as XMind [XMind, 2006], FreeMind [FreeMind, 2014] and iMindMap [ThinkBuzan, 2014].

### 2.4.1 Tabletop Mind Mapping

Table 2.4 Comparison table for work related to this research

| Works | Tool | users | sit / stand | input devices | multi-display |
|---|---|---|---|---|---|
| Buisine et al. [2007] | MM | 4 | sit around the table | a keyboard | No |
| Do-Lenh et al. [2009] | CM | 3 | sit/ side by side | a mouse / a keyboard | No |
| Oppl and Stary [2009] | CM | 2-3 | standing | Tokens | No |
| Martínez Maldonado et al. [2010] | CM | 2 | Sit side by side | Touch | No |

Table 2.4 presents related work. In the context of tabletop mind mapping, one of the most relevant pieces of research on this area is Tabletop Mind-Maps (TMM) [Buisine et al., 2007]. This project was developed to support collaborative decision making and aimed to compare the usability and usefulness of this approach to the traditional pen and paper conditions. A similar approach was presented by Do-Lenh et al. [2009]. The researchers evaluated the usage of a tabletop concept mapping tool in cooperative settings. They compared a concept mapping using two different interfaces: a desktop computer using one mouse/keyboard and tabletop to support tangible interaction. Furthermore, Oppl and Stary [2009] developed a hybrid tool for concept mapping using labelled physical tokens as concepts and digital unlabelled relationship between them. They found concept mapping at the table offers participants equal opportunities of participation to share their individual when compared with a networked system.

In an additional study by Martínez Maldonado et al. [2010], they presented Cmate (Concept Mapping at an Adaptive Tabletop for education) to support learners in the form of discussion based on comparing personal understanding as captured in personal concept maps. More recently, Buisine et al. [2012] designed an experiment to answer how interactive tabletop systems influence collaboration. This study explored two experiments comparing the use of a tabletop system to the traditional pen-and-paper in two different creative problem solving tools: a Brainpurge on sticky notes and a Mindmap.

In terms of Buisine et al work, they developed the first mind map application for tabletop devices. Therefore, they evolved the Tabletop Mind-Maps (TMM) application using MERL DiamondTouch Dietz and Leigh [2001] which was conducted with the DiamondSpin toolkit Shen et al. [2004]. The TMM mind maps are built top-down from the root label (i.e. the central idea). All users can create or move nodes but editing these nodes must be consensual:

this is why text input is allowed from a single source only. They compared the tabletop interface to conventional paper and pen environment. The results showed no difference in production of ideas, but the tabletop condition significantly improved gestural and verbal interactions, as well as the perceived efficiency and pleasure of group tasks. In Table 2.5 summarised the TMM features.

Table 2.5 Summary of the TMM approach described

| **Aspects** | **TMM approach** |
|---|---|
| Flow | Top-Down |
| Editable | Yes |
| Input devices | A wireless Keyboard |
| Multi Display | No |
| Tabletop | DiamondTouch |
| Toolkit | DiamondSpin |

## 2.5 Summary

The main contribution of this chapter was to introduce background information that related to the research. Previous research involved with this study was also discussed. The review was concerned into three major areas: tabletop technology, collaborative work and mind mapping.

The research in tabletop application seems especially suited to augmenting collaborative discussions by enabling users to visualize, modify, and expand on their own ideas in a fluid manner. Therefore this research will develop multitouch applications that support collaborative working for small group around a tabletop.

# Chapter 3

# Research Methodology

This chapter provides a clear indication of the methods that were used to evaluate the novel contributions of the tabletop mind map system. It describes the evaluation through two empirical studies, each consisting of research questions and hypotheses, experiment designs and variables, data collection methods, and data analysis approaches. Additionally, how the results of the empirical studies were analysed in order to find answers to the research questions is explained. The evaluation dimensions include performance, collaboration, usability and emotional attitudes. Table 3.1 gives an overview of the research methods for the studies.

Table 3.1 Research methods overview

| | | |
|---|---|---|
| Goal | To investigate the effectiveness and usability of the interactive tabletop application in the context of support for collaborative work. | |
| Main research question | Does the attractive interactive tabletop support collaboration in the context of collaborative work? | |
| How | Two empirical studies on comparative the tabletop mind map application with the pen-and-paper condition | |
| | Experiment One | Experiment Two |
| Apparatus | a TouchScape, Pen-and-Paper | a TouchScape + Tablets, Pen-and-Paper |
| Participants | 40 participants | 40 participants |
| Data Collection | Observation and Questionnaire | |
| Data Analysis | • Performance<br>• Collaboration<br>• Usability<br>• Emotional Attitudes | |

## 3.1 Goal

The main research goal of the experiments was to investigate the effectiveness and usability of the interactive tabletop application in the context of support for collaborative work. To achieve this goal, two empirical studies were conducted to find the answers to these research sub-questions.

### 3.1.1 Research Questions

**Q1:** Does the tabletop mind map application encourage users to create more ideas than paper-based conditions?

**Q2:** Does the tabletop application support users to complete the task faster than paper-based conditions?

**Q3:** Does the tabletop mind map application encourage more effective collaboration among group members than paper-based conditions?

**Q4:** Does the tabletop motivate users to work with others more than paper-based conditions?

**Q5:** Is the interactive tabletop easier to use than the pen-and-paper?

**Q6:** Is the interactive tabletop more pleasant to use than the pen-and-paper?

**Q7:** Do users collaborate with others on the interactive tabletop more efficiently than under pen-and-paper conditions?

**Q8:** Do users experience positive emotions using tabletop conditions more than pen-and-paper conditions?

### 3.1.2 Hypotheses

Eight hypotheses were designed to be tested in two experiments in order to answer these research questions.

**H1:** The interactive tabletop encourages users to create more ideas than paper-based conditions.

**H2:** The interactive tabletop helps users to complete the task faster than paper-based conditions.

**H3:** The interactive tabletop promotes group members to collaborate more effectively than pen-and-paper conditions.

**H4:** The the interactive tabletop increases individual engagement and motivation, which can also be a moderating factor of social learning.

**H5:** The interactive tabletop is easier to use than pen-and-paper conditions.

**H6:** The interactive tabletop is more pleasant to use than pen-and-paper conditions.

**H7:** The interactive tabletop supports collaborative work.

**H8:** Users experience positive emotions from using the tabletop.

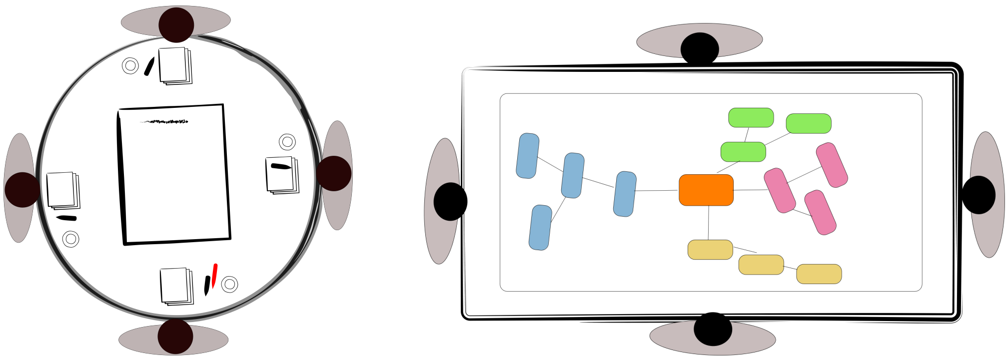
## 3.2 Experimental Method

### 3.2.1 Design

Two experiments were conducted to examine the usability features and associated emotional attitudes to answer the research questions proposed in section 3.1.1.

#### Experiment One

The aim of the experiment one was to investigate the effectiveness and the usability of the tabletop application in the context of collaborative work. Experiment one was conducted to compare the use of the tabletop mind map system and a conventional pen-and-paper condition. Experiment one setup is illustrated in Figure 3.1. The results of this experiment are reported in Chapter 5.

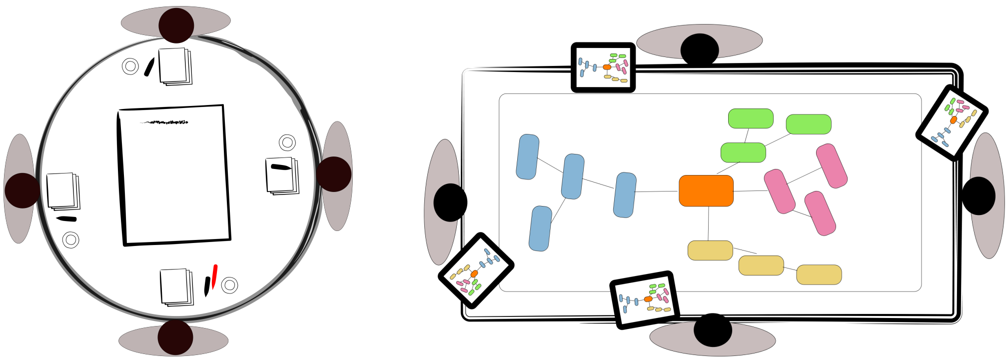


(a) Pen-and-paper Condition (b) Tabletop Condition

Figure 3.1 The setting of Experiment One

### Experiment Two

Building on the finding from experiment one, experiment two also aims to investigate the effectiveness and the usability of the tabletop application in the context of collaborative work, but the application was extended to incorporate personal devices. To support individual work and privacy, we integrated our tabletop mind map application with tablets that allow users to create their own work from the devices. Chapter 4 explains the implementation of the proposed system in detail. This experiment was created to examine the combination between tabletop and personal devices in comparison with the traditional pen-and-paper condition. The setting of experiment two is presented in Figure 3.2. The results of this experiment are presented in Chapter 6.



(a) Pen-and-paper Condition (b) Tabletop Condition

Figure 3.2 The setting of Experiment Two

A qualitative approach was used to explore users' satisfactions and attitudes. Also a quantitative approach was used to obtain statistics to find out the relationships between research variables [Newman, 1998]. This study used both approaches.

To collect data for the experiments, within-subjects was used in this study. Within-subjects design, also known as repeated measures, uses the same subjects with every condition of the study [Field and Hole, 2002].

A counterbalanced measured design was used in the experiments. First five groups performed pen-and-paper conditions first then the tabletop condition. The other five groups used the tabletop condition then pen-and-paper conditions (See Table 3.2 ).

Table 3.2 Groups and scenarios

| Group | Scenarios |
|---|---|
| 1 | Pen-and-Paper -> Tabletop |
| 2 | Pen-and-Paper -> Tabletop |
| 3 | Pen-and-Paper -> Tabletop |
| 4 | Pen-and-Paper -> Tabletop |
| 5 | Pen-and-Paper -> Tabletop |
| 6 | Tabletop -> Pen-and-Paper |
| 7 | Tabletop -> Pen-and-Paper |
| 8 | Tabletop -> Pen-and-Paper |
| 9 | Tabletop -> Pen-and-Paper |
| 10 | Tabletop -> Pen-and-Paper |

### 3.2.2 Apparatus

The experiments were run at Newcastle University. The main hardware of the tabletop mind map application was a TouchScape table. The tasks were performed on a TouchScape table with 47inch (1190mm) LCD screen diagonal with a display resolution of 1920x1080 full HD pixel. The TouchScape is 500 mm high and a table outer dimension is 1300 x 900 with weight of 132 pounds [Ridden, 2011]. The interactive surface is based on frustrated total internal reflection (FTIR) technology with a rear-projected screen, which is claimed can support thousands of interaction points every second [Jesús, 2011]. This table runs Windows 7 (32 bit), 3.4GHz quad-core Phenon processor and 4GB of memory. The input condition used virtual keyboards.

With regard to the traditional pen-and-paper conditions, a blank-A2 paper was provided. Groups could also ask for extra paper if they desired. Also, permanent coloured marker pens were provided. The participants were seated around a round table.

For experiment two, three Samsung Galaxy Note 10.1 and a Motorola Xoom were also used to integrate the tabletop. They have a 10.1 inches screen with a resolution of 1280x800 pixels.

### 3.2.3 Tasks

For the collaborative tasks, two case scenarios were provided: global warming and stress management. The participants were free to choose one of these topics.

**First Scenario-Stress management**

You are in a stressful office, you have four deadlines in the next four days, you have a number of scheduled meetings, you are still waiting for a report from a colleague for a piece of work required for one of your reports, some of the data that you got for another report is much more disorganised than you expected, your partner called to check whether you forgot his/her birthday that is coming next week, and you have got to do Christmas shopping buying your parents presents. Furthermore, you are going to present new products to a critical customer before Christmas, but you have never done this task before.

This task asked the participants to discuss:

1. *Discuss how you manage to finish everything on time.*
2. *How can you cope with stress? What can you/should you do in this situation to reduce your stress?*
3. *What is causing the stress, what are you worried about?*
4. *How is the stress affecting your behaviour and your life?*

**Second Scenario-Global warming**

One of the biggest problems facing the world today is global warming. The world is being heated by human activity and emissions from human industry and vehicles. This issue has been studied for decades, and has generated a lot of controversy, but is broadly held to be true. Models of global warming predict major polar ice melts, rising sea levels, severe weather, and serious deterioration of water resources, agriculture, and other essential human resources. Many governments are currently putting into place local policies to deal with global warming, and attempting to curb emissions. Alternative energy sources are also being widely deployed commercially to combat emissions and pollution.

This task asked the participants to discuss:

1. *Discuss the factors and impact of climate change related to the increasingly variable weather, increasingly frequent floods and strong winds, and other unusual weather. The possible switch to electric cars from petrol cars. Alternatively, a lot of people use public transport, carpooling, even riding their bikes to lower the amount of greenhouse gases in the air.*

2. *What causes climate change?*

3. *How do you feel about climate change?*

4. *Should anything be done to stop it? If so, what?*

### 3.2.4 Participants

A within-subjects design with repeated measured was used. Groups were formed by self-selection where users chose their own group members as we believe that close friends would work effectively in a limited time. As the performance tasks did not take a long time, there was little concern about boredom or loss of enthusiasm during the experiment.

The study used a group size of four. Each experiment involved 40 students from Newcastle university and Northumbria University (80 participants in total), divided into ten groups. In each experiment, students were allocated to the two different conditions (See Figure 3.3). Participants were not paid, but they were offered cookies and soft drinks at the end of the study.

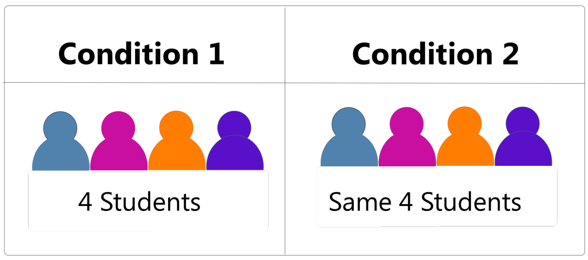



Figure 3.3 The within-subjects design

### 3.2.5 Procedure

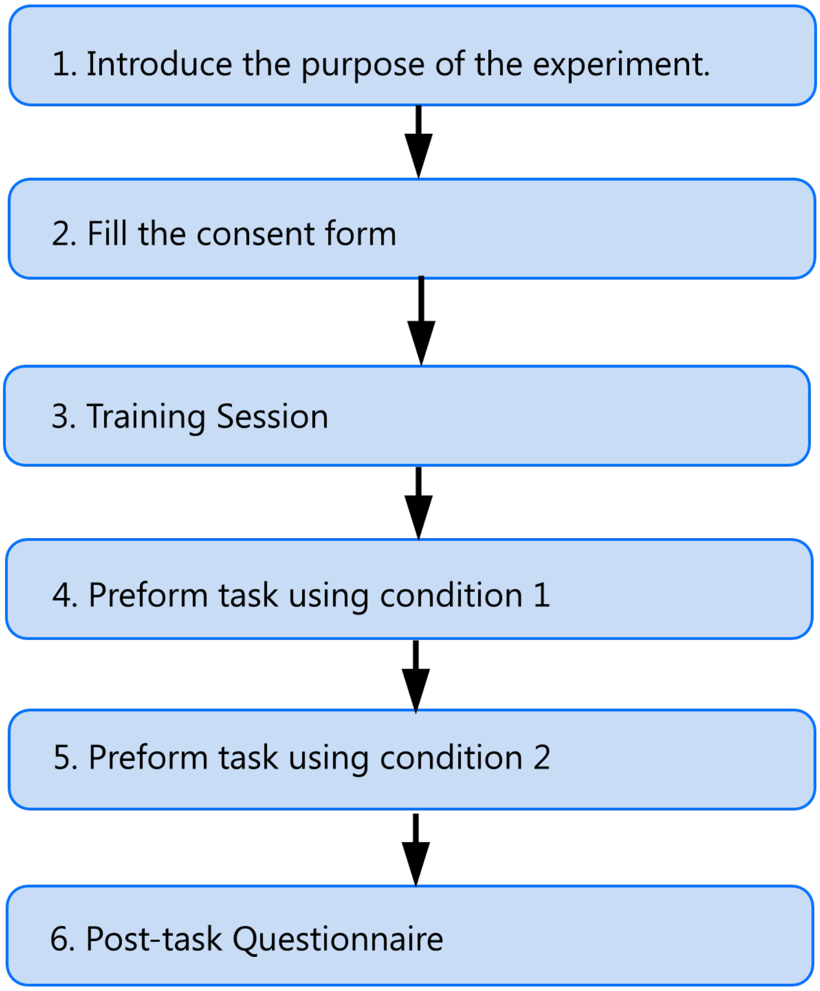



Figure 3.4 Experiment procedure

Figure 3.4 shows the experiment procedure. Once participants arrived, they were welcomed and seated to introduce the purpose of the study and filled in a consent form. They then chose an experiment task and were asked to perform this task twice under different conditions.

In the pen-and-paper approach, groups spent up to 20 minutes seated around a round table though were free to move chairs. To perform this task, each group was given A2-paper. Each participant was given a permanent marker pen, which was green, blue, black or red. Furthermore, each participant was given A4-paper and a pen in case they wished to make some notes. They would also have an extra A2-paper if they desired.

Before using the tabletop condition, the subjects were introduced to the use of the tabletop mind map application and also to drawing mind maps. The groups were shown the tabletop application and practised using it with a practice brief for 15 minutes. They then also spent up to 20 minutes in this condition. They were also given an A4-paper and a pen to take notes.

After the groups has finished both configurations, the participants individually completed a questionnaire containing both Likert-scale and free-form questions about their satisfaction and emotional attitudes. The study lasted approximately one hour.

### 3.2.6 Variables

There are two kinds of variables: independent and dependent variables [Field and Hole, 2002]. Independent variables are the causes of the outcomes while dependent variables are the outcome or the effect of the experiment.

The independent variables of these studies were the experiment conditions. The variables for experiment one were pen-and-paper and tabletop approaches. In experiment two, the pen-and-paper and the combination of tabletop and tablets conditions were independent variables. These variables would affect the dependent variables. These effects would influence the collaboration in groups, which is the main concern of the study.

Four main dependent variables were designed: performance, collaboration, usability and emotional attitudes.

#### Performance

- *Effectiveness:* This was measured by task completion rate. Dealing with the outcome of the total number of ideas which is a complex issue since there is "no right answer" [Buisine et al., 2012]. By meaning of ideas in this metric was the number of concepts or meaningful keywords that users place in ovals [Brinkmann, 2003; Buzan, 2006].

- *Efficiency:* This was measured by duration for successfully completed tasks. how long participants take to complete the task and the total amount of work done [Baeza-Yates and Pino, 1997].

#### Collaboration

- *Communication:* This metric considered collaborative activities. Collaborative activity may support group performance in complex tasks. Therefore, the participants' collaborative behaviour were collected: bringing group focus back to the agenda, asking clarifying questions, restating what other have said, moving group forward when agreement is reached, making suggestion to resolve disputes, acknowledging contributions by others, giving an idea (without writing or typing) and writing or typing an idea directly on paper or tabletop [Buisine et al., 2007; Morris and Winograd, 2004].

**Usability**

- User satisfaction: This was measured by a 5-point Likert rating given by the subjects. The questionnaire was adapted from a work of Buisine et al. [2007].

**Emotion Attitudes**

- Emotion attitudes: This was measured by a 10-point Likert rating given by the subjects. The questionnaire was adapted from a work of Buisine et al. [2012].

### 3.2.7 Data Collection Methods

A number of quantitative and qualitative data were gathered. The former research method was utilised to investigate things that can be observed. All groups were observed by the researcher, who took notes throughout. The later research was interested in opinion, experiences and feelings. To measure performance, a stopwatch was used to time the duration of each task. After finishing the task, the amount of work was counted and also the task was automatically saved as an XML file. Additionally, to measure usability, after using the system, all users completed a questionnaire containing both Likert-scale and free-form questions.

The questionnaire was divided into three sections. The first section was all about users' details such as gender, age, education level and how long they use a computer each day. Secondly, users' satisfaction was designed to use five Likert-scales: 1 is strongly disagree and 5 is strongly agree. Finally, emotional attitudes were designed to use 10 Likert-scales which 1 is strongly disagree and 10 is strongly agree (see Appendix A).

### 3.2.8 Data Analysis Approaches

The statistical test was used to generate the results presented in Chapters 5 and 6. Normality was initially tested to find if data is normally distributed and then which statistical test would be chosen to produce results. In this study, the data was not normally distributed then non-parametric tests were applied to analyse the variables and examine the difference between tabletop and pen-and-paper conditions. The Friedman test is the non-parametric equivalent of one-way repeated measure and so is used for testing differences between experimental conditions [Field and Hole, 2002]. Therefore, in this study the Friedman test was used for comparing samples using SPSS version 21.

#### Null Hypothesis

Each hypothesis in this study was presented as null hypotheses and tested statistically to find out whether it can be accepted or not. The p-value and confidence interval were considered.

*p-value*: The probability of observing a test statistic as extreme as the one actually observed, which makes the test result significant. The smaller the p-value, the more strongly the test rejects the null hypothesis. The most common level for the p-value used in statistical test is 0.05. Hence, when the test p-value is less than 0.05, the hypothesis is accepted.

*Confidence interval*: The range of values around the statistical test result that are believed to contain. A common interval used in statistical test is the 95% confidence interval.

## 3.3 Answering The Research Questions

To answer the research questions presented in Section 3.1.1, a set of investigations are designed to analyse the independent and dependent variables. A summary of the investigations is presented in Table 3.3.

Table 3.3 Summary of the investigation of answering the research questions

| Investigation Metrics | Investigation outline |
|---|---|
| Performance metric | Compare the means and medians of performance variables between the two conditions (i.e. effectiveness and efficiency) |
| Collaboration metric | Compare the means and medians of collaboration variables between the two conditions (i.e. communication) |
| Usability metric | Compare the means and medians of usability variables between the two conditions (i.e. satisfaction) |
| Emotion attitudes metric | Compare the means and medians of emotion attitudes variables between the two conditions |

### 3.3.1 Performance metric

Performance criteria was designed to analyse the effectiveness and the efficiency.
**Effectiveness**: Compare the means and medians of the number of ideas in both conditions.
**Efficiency**: Compare the means and medians of duration in both conditions.

The analysing of this metric will help to answer the following questions:

*Q1: Does the tabletop mind map application encourage users to create more ideas than paper-based conditions?*

The question aims to investigate if users can create more ideas when using the digital tools than using the conventional approach.

*Q2: Does the tabletop application support users to complete the task faster than paper-based conditions?*

This question examines if users can finish the task faster when using computerised tools than using pen and paper.

Q1 leads to hypothesis 1 (H1) that the attractiveness of the interactive tabletop encourages users to create more ideas than paper-based condition does. Also Q2 leads to hypothesis 2 (H2) that the attractiveness of the interactive tabletop helps users complete the task faster than the paper-based condition does.

### 3.3.2 Collaboration Metric

The level of communication between group members was used as a measure of collaboration.
**Communication**: compare the means and medians of communication in both conditions.

The research question answered by this metric is:

*Q3: Does the tabletop mind map application encourage more effective collaboration among group members than paper-based conditions?*

Q3 aims to investigate if users participate and communicate with others more when using the tabletop.

Q3 leads to hypothesis 3 (H3) that the attractiveness of the interactive tabletop promotes group members to collaborate more effectively than pen-and-paper conditions do.

### 3.3.3 Usability Metric

Users had an opportunity to clarify the impression in a questionnaire. The questionnaire consisted of 10 questions based on a 5-point Likert scale. Analysing this metric helps to answer the following questions:

*Q4: Does the tabletop motivate users to work with others more than paper-based conditions?*

This question aims to determine which condition users feel motivated when performing the tasks.

*Q5: Is the interactive tabletop easier to use than the pen-and-paper?*

This question aims to examine which condition users easy to use.

*Q6: Is the interactive tabletop more pleasant to use than the pen-and-paper?*

This question aims to investigate which condition users feel enjoy when performing the tasks.

*Q7: Do users collaborate with others on the interactive tabletop more efficiently than under pen-and-paper conditions?*

This question aims to examine which condition users collaborate with other more efficiently.

Q4 leads to hypothesis 4 (H4) that the attractiveness of the interactive tabletop increases individual engagement and motivation, which can also be a moderating factor of social learning. Also Q5 leads to hypothesis 5 (H5) that the interactive tabletop is easier to use than pen-and-paper conditions. Then Q6 leads to hypothesis 6 (H6) that the interactive tabletop is more pleasant to use than pen-and-paper. Finally Q7 also leads to hypothesis 7 (H7) that the interactive tabletop supports collaborative work.

### 3.3.4 Emotional Attitudes Metric

Users had an opportunity to clarify the impression in a questionnaire. The questionnaire consisted of 12 questions based on a 10-point Likert scale. Analysing this metric helps to answer the following question:

*Q8: Do users experience positive emotions using tabletop conditions more than under pen-and-paper conditions?*

The question aims to investigate which condition users experience positive emotions after they finish the tasks.

Q8 leads to hypothesis 8 (H8) that users experience positive emotions from using tabletop.

### 3.3.5 Mapping metric to research questions and hypotheses

Table 3.4 presents a summary of the relationship between question, hypothesis and dependent variable.

Table 3.4 Mapping metric to research questions and hypothesis

| Question No | Hypothesis No | Dependant variable |
|---|---|---|
| 1 | 1 | Performance |
| 2 | 2 | Performance |
| 3 | 3 | Collaboration |
| 4 | 4 | Usability |
| 5 | 5 | Usability |
| 6 | 6 | Usability |
| 7 | 7 | Usability |
| 8 | 8 | Emotion attitudes |

## 3.4 Summary

This chapter presented the research methods used in this study. An overview of the experimental design techniques were presented. Furthermore, data collection and analysis approaches were also described. Variables were also defined with their roles in the data analysis.

Two experimental were designed:

- *Experiment one:* Comparison between the tabletop and traditional pen and paper was studied.
- *Experiment two:* The combination of the tabletop and personal devices were used in this experiment to compare with the traditional pen and paper conditions.

Each experiment had forty subjects. The subjects were divided into ten groups of four participants. Dependent variables were analysed: performance, collaboration, usability and emotional attitudes.

# Chapter 4

# Tabletop Mind Map Application

This chapter presents the group meeting application that aimed to use for collaboration around the interactive table. The application allowed users to add annotations to the sharing document on the table. However, the application was changed and become the tabletop mind map applications to encourage students to work together on the table. The tabletop mind map application that was developed to enable users to work collaboratively in the context of collaborative work in a co-located setting. It starts by describing the system requirements. Then the overview of user interface design is discussed. Furthermore, the implementation stage is explained. This stage is one of the challenges as the application consists of two different components: the tabletop mind map application and Android mind map application.

## 4.1 Group Meeting Application

This application was aimed to replace large paper-based packs with the interactive table. It would be easier for group members to access high volumes of information conveniently. The group meeting application was designed to have some intuitive annotation tools that allowed users to make notes, comments on the sharing paper. The requirements can be summarised as follow:

- Allow multiple concurrent users input.
- Users shall be able to have their own visual keyboard.
- The system should be able to distinguish between individual users.
- Users shall be able to rotate and relocate items on the tabletop freely.

- Users shall be able to access every area of the tabletop surface.
- Users shall be able to resize items on the tabletop surface.

### 4.1.1 Main workspace

The application had three main menus as seen in Figure 4.1. The first menu was placed at the top right corner. The menu was for accessing meeting attachments. The second menu was placed at the top left corner for an administrator who can add any users who were involved in the meetings. The last menu was for connecting to an external device (Android tablet), and it was at the bottom left corner.

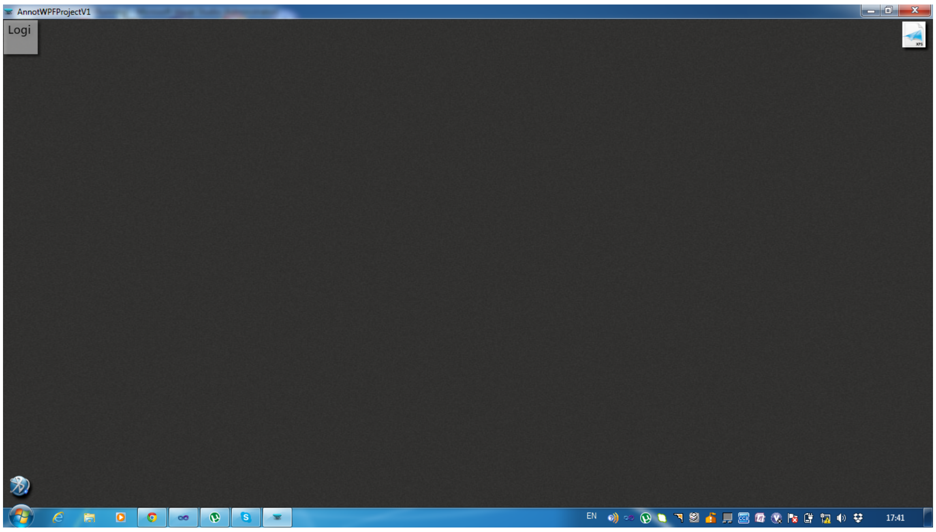



Figure 4.1 Group meeting application workspace

### 4.1.2 Accessing meeting attachments

The meeting attachments folder lists files that have been attached to the meeting spaces as seen in Figure 4.2. Tap the filename to open the file. The data will be shown and ready for users to make notes or add any comments. Figure 4.3 illustrates the document viewer including icons on the right-hand side which allowed users to highlight, comments. Users can place a finger anywhere on the screen to invoke a new way to select text and move cursor around. Then icons on the right side will active and ready to rock (Figure 4.4).

Additionally, users also were allowed to make notes on the documents. Analogous to the highlighting users had to select text and then tap the note button for making notes. Figure 4.5 shows the sticky note that was placed on the document. If users would like to hide it as well by selecting the checkbox on the left. Then it will minimise itself as shown in Figure 4.6.

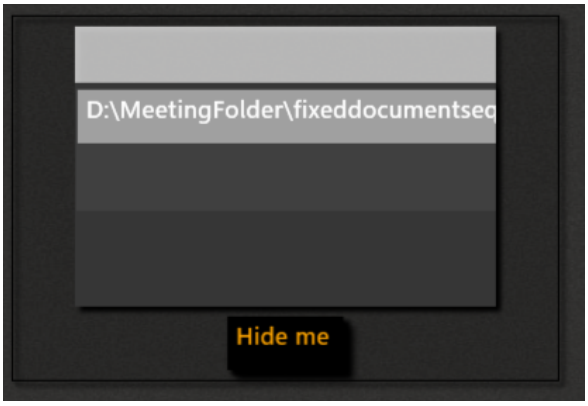



Figure 4.2 Meeting attachments folder

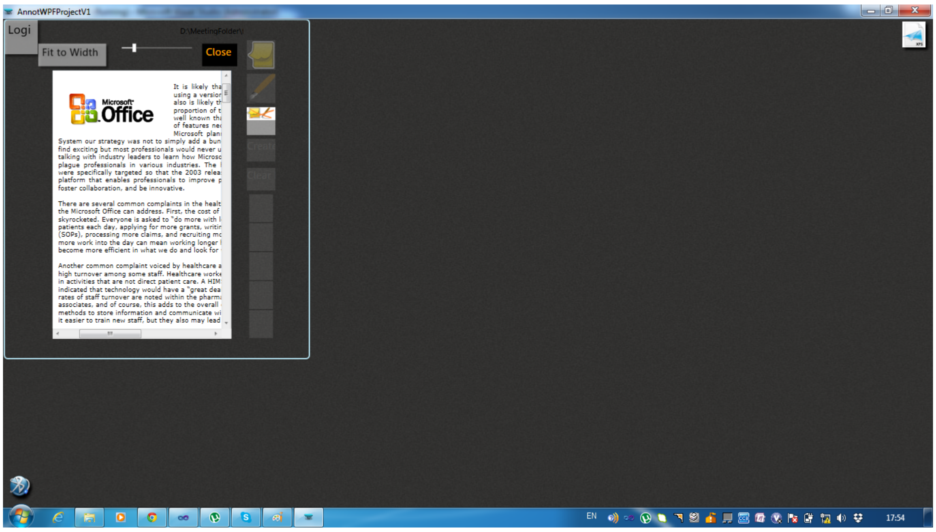



Figure 4.3 The document viewer

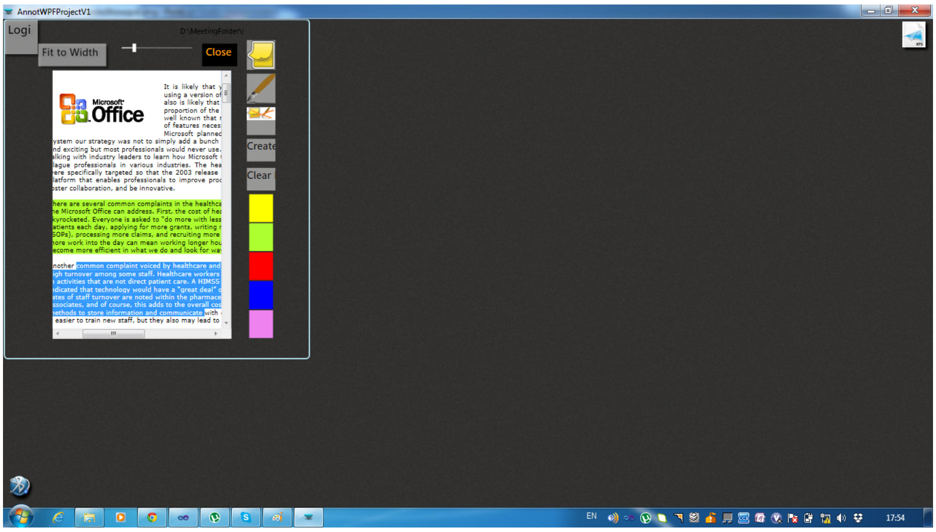



Figure 4.4 The document viewer with icons for adding annotations

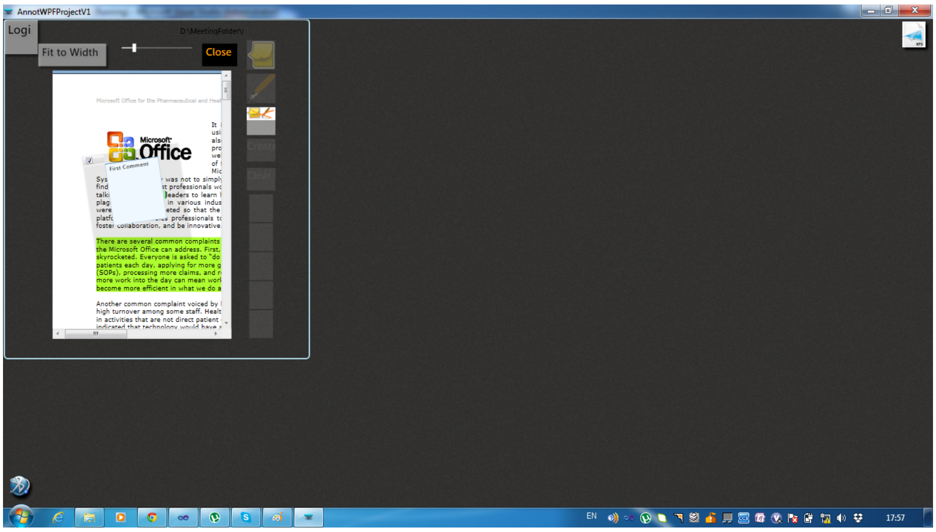



Figure 4.5 Show the notes

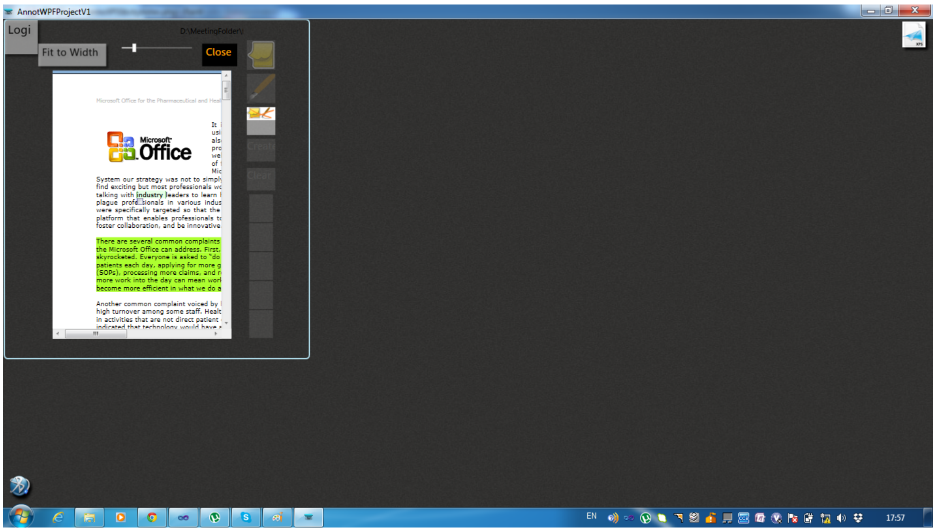


Figure 4.6 Hide the notes

## 4.2 Tabletop Mind Map Application

### 4.2.1 System Requirements

The requirements for the developed system were based on a review of previous literature and also on requirements elicited from potential users. The design was guided by the work of Bachl et al. [2010] and Scott et al. [2003]. Bachl et al. presented the challenges for designing user experience. Further, Scott et al suggested specific guidelines for co-located collaboration. How these were used will be explained in the following section.

#### Support Simultaneous User Actions

This is one of the most desired goals that several users are able to share the same surface and interact seamlessly together [Scott et al., 2003]. Scott et al. suggested that tabletop must provide multiple users input capabilities, such as input devices or touch screens that detect simultaneous, multiple touches. Therefore, systems designed for collaboration should enable simultaneous interaction and parallel work. Not only input devices were considered in this challenges, but also the ability to distinguish between individual users was desired [Bachl et al., 2010]. The solution for this matter is to provide user by using colour for input.

**Requirements derived:**

- R1: Allow multiple concurrent users input.
- R2: Users shall be able to have their own visual keyboard.

- R3: The system should be able to distinguish between individual users.

#### Consider the Appropriate Arrangement of Users

For collaborative work especially when users sit around a table, it can be difficult to see all items on the table perfectly. Likewise Scott et al. also stated that when users are sitting at various locations around a table, the displayed information may not be oriented appropriately for all users. Providing support users arrangement is a challenge and a salient issue for tabletop system [Scott et al., 2003]. One solution to solve this problem is to allow users to rotate elements themselves. Alternatively, the elements could be automatically oriented towards a user [Kruger et al., 2003; Scott et al., 2003].

Although tabletops have a great deal of potential for collaboration, these are still concerns at a perceptual level in this context [Schneider and Shen, 2010]. Users can be affected by the orientation of elements. Schneider et al. highlighted that this drawback can be reduced by using multiple representations across displays.

**Requirements derived**

- R4: Users shall be able to rotate and relocate items on the tabletop freely.
- R5: Users shall be able to access every area of the tabletop surface.
- R6: Users shall be able to use a personal device to view contents on the tabletop surface.

#### Support Individual Differences

One of the benefits of multi-touch user interfaces is the possibility to directly interact with the screen using ones fingers for input. However when objects on the screen are small, some users find it difficult to interact with them [Bachl et al., 2010]. For instance different finger sizes may make the detection of touch point difficult. So to support individual differences between users, scalable elements were included.

**Requirements derived**

- R7: Users shall be able to resize items on the tabletop surface.

#### Support transitions between individual and collaborative work

The challenge of private activity and collaboration is a key for tabletop design [Martínez Maldonado et al., 2010]. Users tend to work in parallel [Do-Lenh et al., 2009], so a personal space and public area should be considered. Each user may has a system menu at the table edge, this can prevent them from interrupting others. The personal space allow user to work without changing the entire activity. Scott et al. also highlighted that partitioning the input area is another way that designers have provided distinct workspace. Furthermore, providing the ability to integrate personal computer devices such as laptop computers for supporting personal and collaboration on the table needs to be explored.

**Requirements derived:**

- R8: Provide a personal space at the table edge for additional artefacts
- R9: Provide a public space for working together.
- R10: Allow personal devices to connect to the tabletop.
- R11: Users shall be able to create their own private or public items on personal devices.

### General requirements

Mind map applications were developed to support collaborative work running on a horizontal multi-touch surface. The system should enable users to create a mind map collaboratively. Beyond the requirements mentioned above, these general requirements should also be considered.

**Requirements derived:**

- R12: Allow users to create and modify items on the tabletop surface.
- R13: Users shall be able to create and modify items on tablets surface.

### 4.2.2 User Interface Design

Two different user interfaces were designed to enhance collaborative work using mind mapping technique. The tabletop user interface design needs to support concurrent users, while the tablets user interface design is for individual use.

#### Tabletop User Interface

The tabletop mind map system allows concurrent people to perform at the same time. The tabletop user interface is presented in Figure 4.7. Two different spaces were designed: workspace or public space and personal space. The public space is where people work together, while personal space is where user works on one's idea. Each user has a system menu at the table edge which consists of two menus: add a node and a photo, except user who sit at the bottom edge of the table, she/he has two addition menu: start and exit program. The user menu will be appeared when user move fingers over the personal area and be disappeared when the fingers has gone (See Figure 4.8). To delete items on the surface, two bins were provided at the top left corner and bottom right corner by moving the item over the bin.

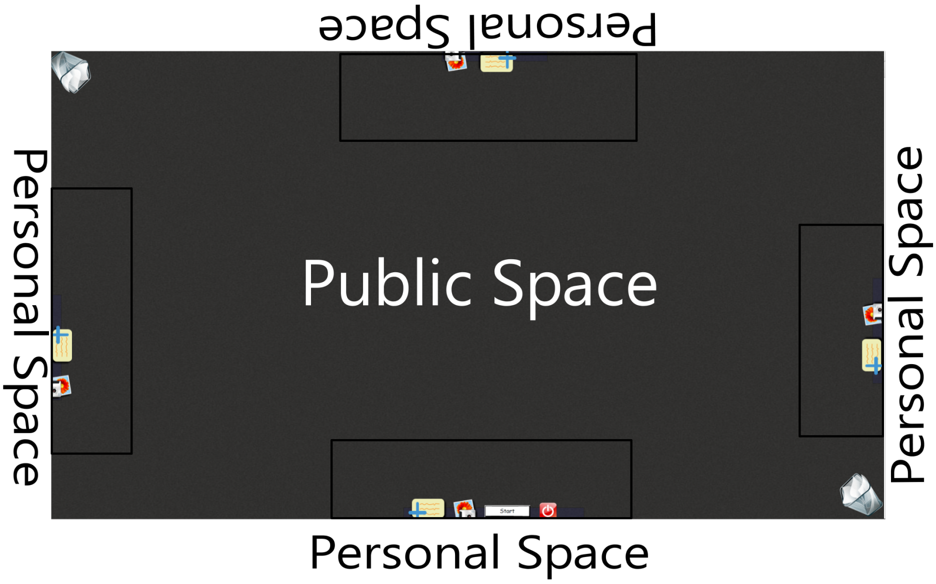



Figure 4.7 Tabletop mind map workspace (1)

The start of the application places the central idea at the centre of the tabletop display by tapping the start menu. Users can either create the node by tapping the "add a new node" menu in front of them or using the node's ElementMenu. The ElementMenu will always appear when the node is touched. There are four menus at the moment: add a new node,

Figure 4.8 Tabletop mind map workspace (2)

bold, font size, and background colour as seen in Figure 4.9. The node can be moved, rotated or scaled to support readability from every point of view around the table. Each node has a virtual keyboard. When a node is active the background colour is changed (See Figure 4.11). The node can be freely relocated, rotated, scaled, deleted and also change its parent.

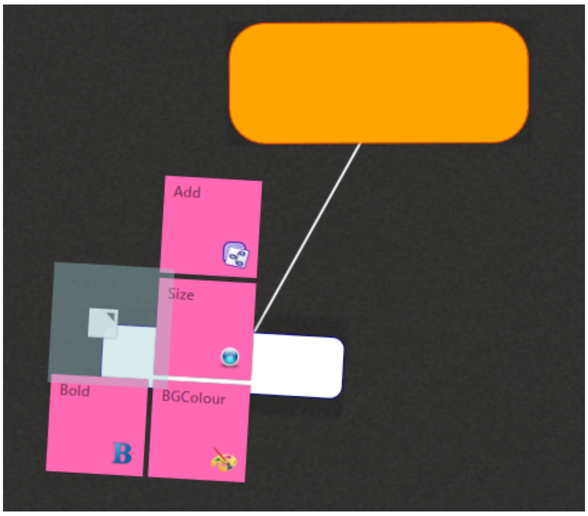



Figure 4.9 Element menu

To change a parent, user moved a node over the parent and then dragged over to the new node. If the node has child nodes, the child nodes will also follow their parent automatically (See example in Figure 4.10).

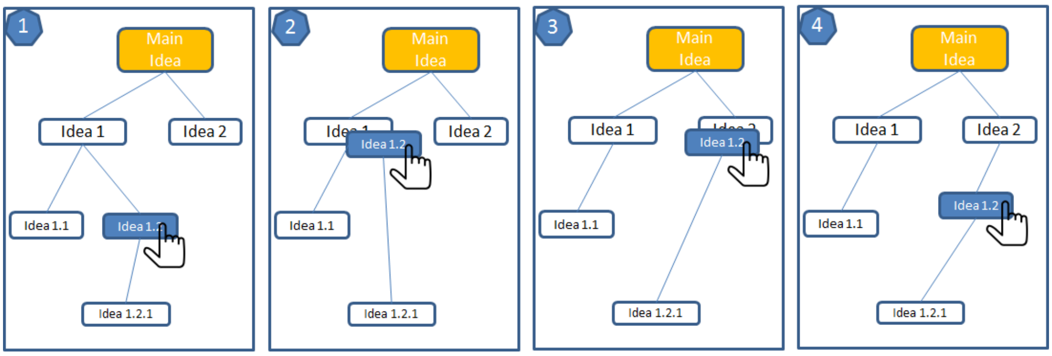



Figure 4.10 Example for changing a parent node

### Virtual Keyboards

To support multiple user work simultaneously, virtual keyboards were designed. A keyboard is invoked when a text box gains focus by double-tap interaction. The connection line associates the keyboard with the node as seen in Figure 4.11. Users may hide the keyboard by double-tapping on the same node. The size, orientation and location of each keyboard can be freely changed. This can support individual different between users as well.

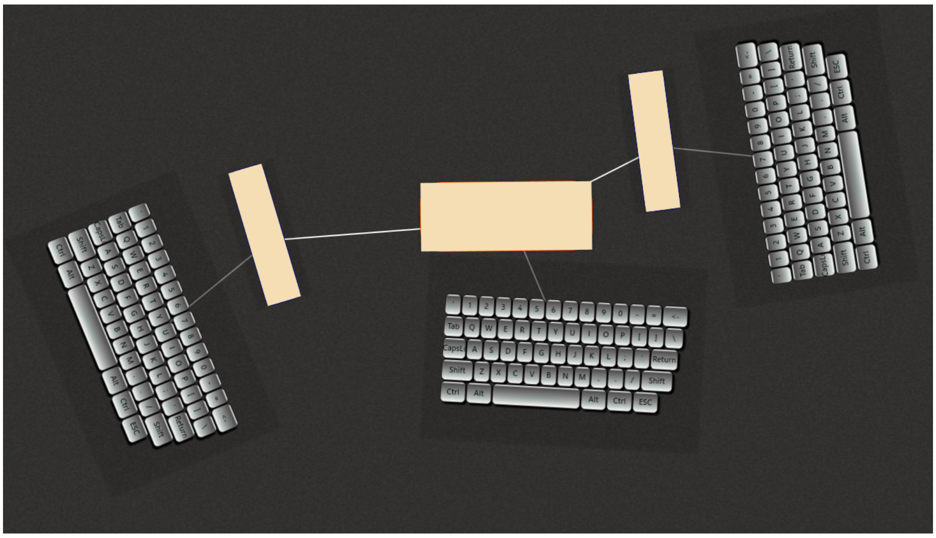
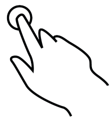
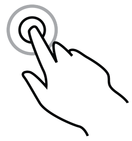
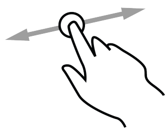
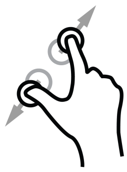
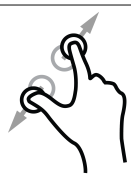
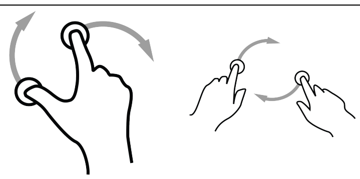


Figure 4.11 Virtual Keyboards

### Gestures

Six basic hand gestures used in this system: single tap, double tap, drag, pinch, spread, and rotate. Table 4.1 presents major user actions by touch gesture systems.

Table 4.1 Major User Actions (Figures from ideum [2014] )

| User Action | Gesture | Description |
|---|---|---|
| Select | Single Tap  | Briefly touch surface with one fingertip. |
| Open | Double tap  | Rapidly touch surface with one fingertip. |
| Move | Drag  | Move one fingertip over surface without contact. |
| Zoom in | Pinch  | Use two fingertips and bring them closer together. |
| Zoom out | Spread  | Use two fingertips and move them apart. |
| Rotate | Rotate  | Use two fingertips and move them in a clockwise or counter-clockwise direction. |

### 4.2.3 Android User Interface

Android application was conducted to support multiple displays. The main android user interface is presented in Figure 4.12. and when the system menu is disappeared. It provides two menus: refresh and add node. The former menu is to refresh or start to connect with the tabletop and load the items from the tabletop. The latter menu is to add a new node. The system menu will be disappeared when it loses focus as shown in Figure 4.13. Furthermore, a bin is also provided at the bottom left corner of the screen for discarding objects. Likewise the tabletop system, user can simply drag the unwanted items and then drop over the bin.

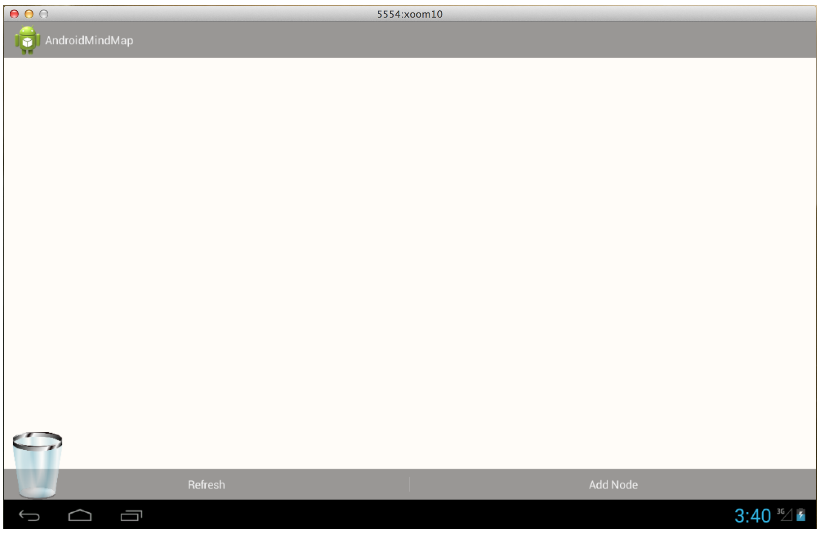



Figure 4.12 Android mind map workspace


Figure 4.13 Android mind map workspace (2)

### Add Node

In this system, users allow to create either private or public node by tapping "Add Node" menu, then a new node will appeared. The node was automatically created as a private node. It can be changed to public node by selecting public mode as seen in Figure 4.14.

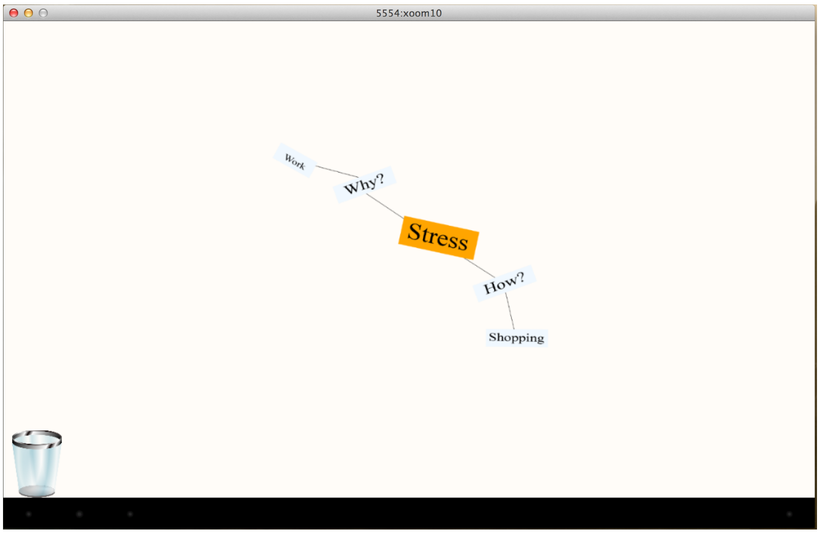



Figure 4.14 Android mind map example

## 4.3 System Architecture

The tabletop mind map system consisted of two main components: tabletop mind map application and Android mind map application. The system shares a common object data. Therefore, we divide the infrastructure into a server and a set of clients. The two components connected by a network (i.e. WiFi) as presented in Figure 4.15.

The tabletop is considered to be the server. It is specialised to hold persistent objects and to provide them to clients on request. In this case, the sever contains the Windows Communication Foundation (WCF) service. WCF is a framework for building service-oriented applications [Selly et al., 2006]. WCF service includes two main services: *get data service* and also *store data service*. The XML file will be created to store and retrieve data. The services are all written in C#. The XML data structure will be presented in section Data Structure.

Android client side run the application that request access to the objects via the network. The application will call the *get data service*, then draw the map on the device. When users create the nodes, they are automatically store into the storage using *store data service*.

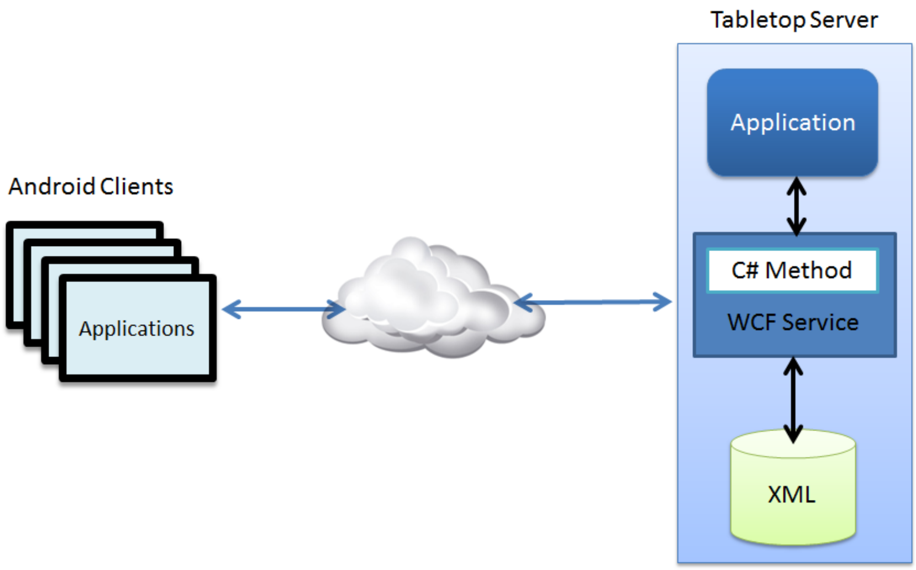



Figure 4.15 System architecture

The relationship between the activities and services components is illustrated in Figure 4.16. Three main activities are provided for each condition. First, add node activity allows user to create new node then the node attributes will be stored in the XML file via the store data service. Likewise the add node activity, the manage node activity is also involved with the store data service in case the node has been modified such as relocate, rotate, edit content and so on. Finally view map activity, is for requesting the data from XML file and present on the surface.

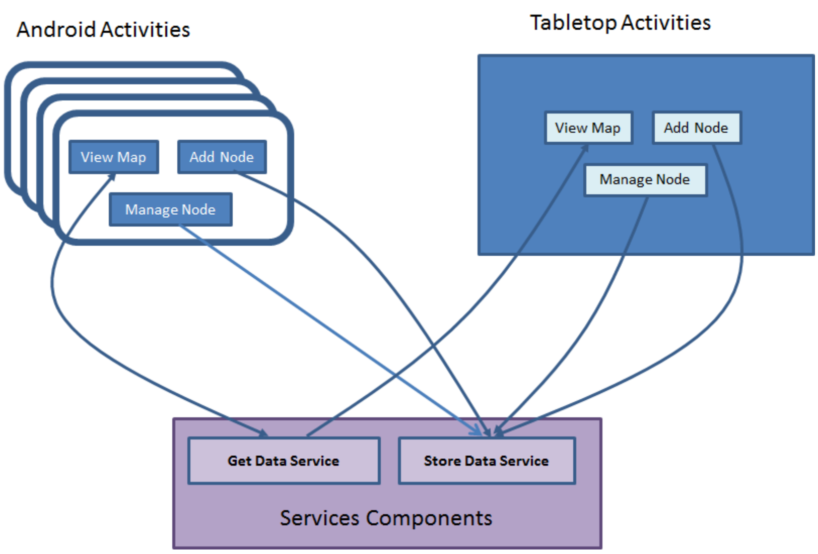



Figure 4.16 Services components

### Data Structure

Data structure was designed to store data in XML file. Table 4.2 presents the mind map node data structure. Each node has a unique *id* to identify itself. The XML example is shown in Listing 4.1

Table 4.2 Data Structure

| Field Name | Description |
|---|---|
| id | Node id |
| parentid | pointer to parent node |
| content | Text data |
| foreground | font colour |
| background | background colour |
| owner | who create the node |
| position | position of the node |
| rotation | rotation of the node |
| timestamp | when the node is created |
| private | boolean value |

Listing 4.1 XML data example

```xml
<?xml version="1.0" encoding="utf-8"?>
<mindmap>
  <Node ID="3">
    <parent>1</parent>
    <content>Content</content>
    <position>906.25455493112,372.861899670454</position>
    <rotation>13.906265821172399</rotation>
    <foreground>Red</foreground>
    <background>Green</background>
    <onwer>user1</owner>
    <timestamp>27/05/2014 17:47:16</timestamp>
    <private>F<private>
  </Node>
</mindmap>
```

## 4.4 System Implementation

Two applications were developed: tabletop and Android mind map applications. Each application will be explained as follow.

### 4.4.1 Tabletop Mind Map

The mind map application was run on a touchscape table with 47 inch (1190mm) LCD screen diagonal with a display resolution of 1920x1080 full HD pixel as seen in Figure 4.17. The tabletop application code is in C# under Windows Presentation Foundation (WPF) using the Surface 2.0 SDK [Surface®, 2012] under Windows 7 operating system. Community Core Vision (CCV) [CCV, 2011] is used in this system to detect touch events in the form of figures. CCV is a popular open source multi-touch library (See Figure 4.18). Additionally, Blake.NUI [NUI, 2011] was adapted to used for gesture recognition. Blake.NUI is a multi-touch library that support WPF 4 multi-touch development.


Figure 4.17 A touchscape table

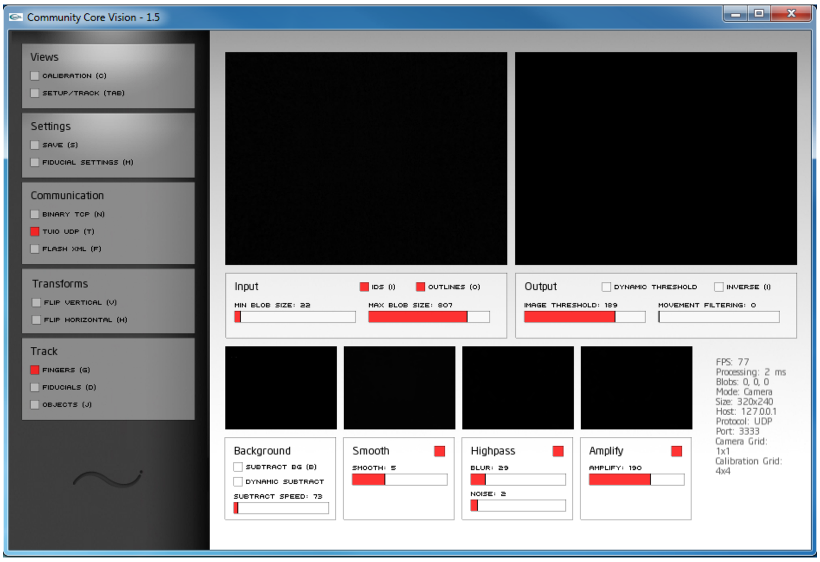



Figure 4.18 A screenshot of Community Core Vision

The architecture of the tabletop mind map application is illustrated in Figure 4.19. The lower layer is formed by input hardware which generates raw tracking data consists of a set of multi-touch libraries. The next layer is *gesture recognition*, which is to generate a stream of positions of fingers. Then the next layer is *transformation*, which transforms the position data from device to screen coordinates. The top layer is the actual application, the layer will use the lower layers provides.

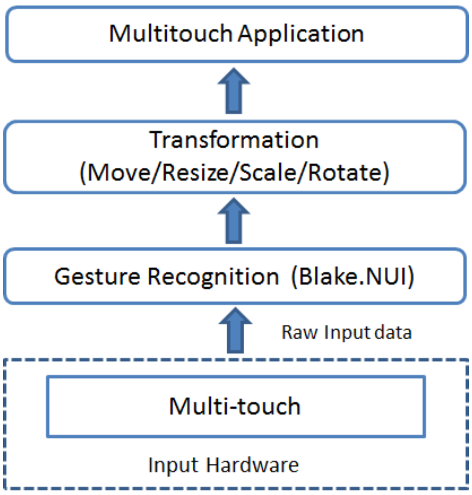



Figure 4.19 Tabletop Mind Map Architecture

### Model-View-ViewModel Design Pattern

This mind map application was developed by using Model-View-ViewModel(MVVM) design pattern. MVVM is a design pattern which separate data model and presentation logic from its user interface [Microsoft, 2014]. MVVM includes three main parts: view, view-Model and Model.

The View is a user interface which can be created by XAML (Extensible Application Markup Language). XAML is a declarative markup language. It is used for creating rich interactive user interfaces. Model is business rule or data classes. ViewModel is an adapter between the XAML mark up of the view and C# of the model.

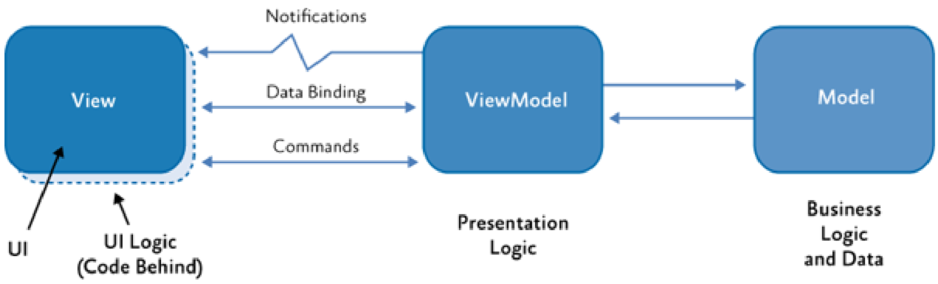



Figure 4.20 Model-View-ViewModel Design Pattern [Microsoft, 2014]

## 4.4.2 Android Mind Map

Android is based on Linux version 2.6 series kernel for core system services such as security, memory management, process management, network stack, and driver model [Brahler, 2010]. Next layer is libraries which are all written in C/C++. The main core libraries include standard C system library (libc), media library such as MPEG-4, MP3, JPG and PNG, surface manager for display subsystem, the SQL database SQLite and the web browser engine Webkit. The Android runtime layer consists of the Dalvik virtual machine and the Java core libraries. The application framework is base of developing Android application such as the activity manager, the window manager and the view system. The application is the uppermost layer which provides a set of core applications including an email, SMS program, calendar, browser and many more. All application are written using the Java programming language. Android architecture is shown in Figure 4.21.

The environment requires to develop applications for Android consists of the Android Software Development Kit (Android SDK), the Eclipse IDE and the Java Development Kit (JDK). The JDK has to be preinstalled for the installation of Android SDK and Eclipse.

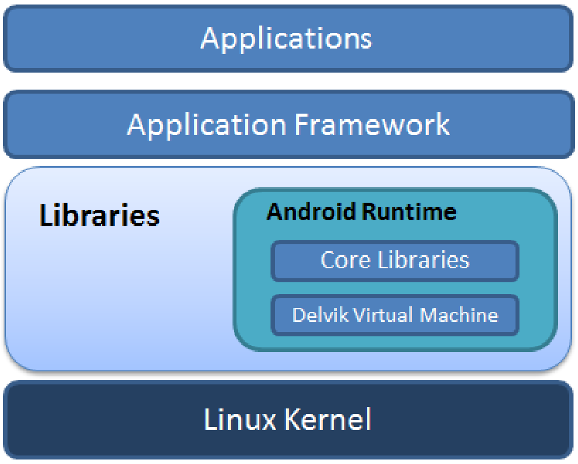



Figure 4.21 Android Architecture

Android SDK includes a comprehensive set of development tools for helping developers with debugging, monitoring and profiling. This also includes a mobile device emulator which supports the Android Debug Bridge (ADB) configurations.

## 4.5 Summary

This chapter presents the original group meeting application that aimed to use for collaboration around the interactive table. However, the application was changed and become the tabletop mind map applications to encourage students to work together on the table. The system requirements were discussed. Then user interfaces, system architecture and system implementation were explained.

# Chapter 5

# Results

This chapter presents both experiments' results: experiment one and experiment two. The first experiment compared the use of the tabletop mind map system with a conventional pen-and-paper conditions. The second one combined our tabletop mind map application with personal devices and compared this combined application with the traditional approach. The results produced by analysing the collected data during the experimental sessions. Four main aspects were analysed: performance, collaboration, usability and emotion attitudes. Each results section starts with the related research questions and then shows the results that answer these questions.

The following results were based on live observations of 10 groups per each experiment. The results were analysed using the Friedman test for comparing samples using SPSS version 21. The level of significance was set to 0.05 for these nonparametric statistical tests.

## 5.1 Participants

Each experiment involved 40 students from local universities. The participants were divided into ten groups of four. The groups were randomly formed according to availability. The age range was from 18 to 45 years old. Figure 5.1 shows the number of students participated in our experiments.

The graph shows that experiment one involved 18 male and 22 female while the another one had 16 male and 24 female. None of the subjects had prior experience of using a TouchScape table, but all were experienced computer users. 80% percent of the participants for experiment one had a background of using a smartphone and/or tablets.The members chosen had a variety of backgrounds, such as economics, business, linguistics, chemical engineering, mechanical engineering, architecture, medical and computer science. In terms of mind mapping, they all had experienced drawing a mind map.

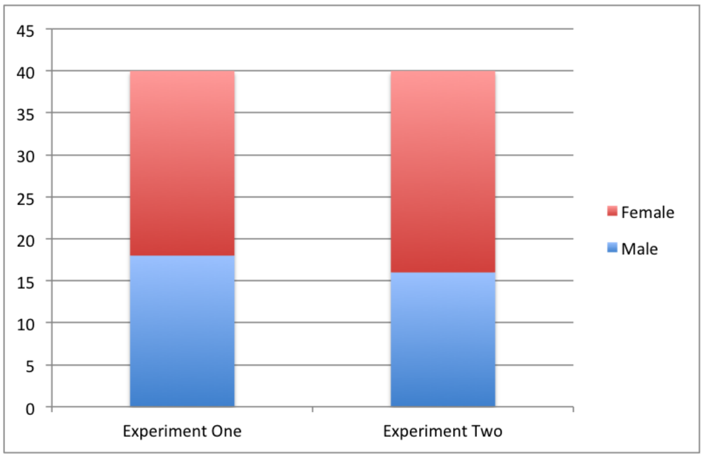



Figure 5.1 The number of participants

## 5.2 Performance

Collaborative work using mind mapping is a group activity in which there is no right answer Buisine et al. [2007]. Therefore, to study the performance of users in each task, a number of ideas and completion times were recorded and are summarised in Table 5.1 and 5.2 respectively.

With regard to the results for the effectiveness and efficiency, it was hypothesised that there would be no significant difference between the tabletop and pen-and-paper approaches in the performance metric for both experiments.

### 5.2.1 Effectiveness

**Question Q-1**: *Does the tabletop mind map application encourage users to create more ideas than paper-based conditions?*
**Hypothesis H1** *The interactive tabletop may encourage users to create more ideas than paper-based conditions.*

To study this research question, the total number of ideas were counted. Table 5.1 is a summary of the number of ideas from each group on the task in both conditions for the two experiments.

According to experiment one, seven groups (70%) created more ideas using the tabletop than the paper-based condition while three groups created more ideas using the pen-and-

Table 5.1 Number of ideas per group in both conditions for the two experiments.

| Group | Experiment one | | Experiment two | |
|---|---|---|---|---|
| | Paper-Based | Tabletop | Paper-Based | Tabletop |
| 1 | 35 | 36 | 35 | 40 |
| 2 | 35 | 35 | 35 | 35 |
| 3 | 29 | 28 | 28 | 29 |
| 4 | 26 | 27 | 32 | 33 |
| 5 | 26 | 31 | 25 | 25 |
| 6 | 19 | 18 | 33 | 33 |
| 7 | 23 | 25 | 35 | 34 |
| 8 | 30 | 32 | 32 | 32 |
| 9 | 25 | 28 | 22 | 24 |
| 10 | 24 | 25 | 23 | 22 |

paper environment. For experiment two, four groups (40%) conducted more ideas using the digital approach. However only two groups generated more ideas using pen-and-paper approaches over the tabletop conditions.

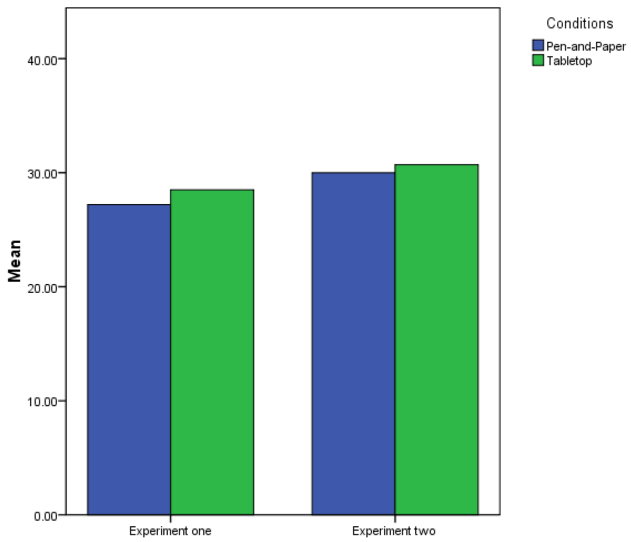



Figure 5.2 Means of the number of ideas on the pen-and-paper condition compared with the tabletop approaches for both experiments.

The Friedman test was conducted to evaluate whether users were more concerned with the traditional approach or the tabletop condition for both experiments. The results indicated that the mean concern for the tabletop was greater than the mean concern for the traditional condition for the two experiments (see Figure 5.2). However, the comparison did not show any significant differences (p=0.96 for experiment one and p=0.414 for experiment two)

Therefore, the hypothesis (H1) can be rejected as the interactive tabletop encourages users to create more ideas than paper-based conditions. Finally, the answer for Q-1 is that the tabletop mind map application does not encourage users to create more ideas than the paper-based condition.

### 5.2.2 Efficiency

**Question Q-2**: *Does the tabletop application support users to complete the task faster than paper-based conditions?*
**Hypothesis H2** *The interactive tabletop helps users to complete the task faster than paper-based conditions.*

Table 5.2 The completion time per group in both experiments.

| Group | Experiment one | | Experiment two | |
|---|---|---|---|---|
| | Paper-Based | Tabletop | Paper-Based | Tabletop |
| 1 | 21.03 | 18.19 | 15.02 | 22.56 |
| 2 | 18.51 | 21.25 | 18.35 | 25.32 |
| 3 | 12.48 | 21.27 | 20.24 | 20.43 |
| 4 | 20.00 | 22.25 | 21.35 | 22.00 |
| 5 | 18.05 | 23.56 | 22.09 | 18.12 |
| 6 | 21.42 | 20.24 | 10.08 | 25.04 |
| 7 | 18.36 | 21.12 | 8.04 | 24.05 |
| 8 | 20.23 | 22.25 | 12.11 | 23.55 |
| 9 | 17.40 | 19.15 | 15.12 | 28.33 |
| 10 | 15.17 | 22.30 | 11.10 | 18.26 |

The results obtained from the experimental analysis of the completion time of the task in the two experiments are also shown in Table 5.2. It is apparent from this table that 80% of 10 groups spent more time on the tabletop than the pen-and-paper approach. What is more, Figure 5.3 shows that the mean for the tabletop was greater than the pen-and-paper condition for both experiments, which means users spent more time on the interactive tabletop. However, the comparison showed that this difference can not be considered significant (p=0.58 for experiment one and p=0.11 for experiment two).

Hence, the results rejected the hypothesis (H2) that the attractiveness of the interactive tabletop helps users complete the task faster that the paper-based condition. So the answer for Q-2 is that the tabletop application does not help users to complete the task faster than the paper-based condition.

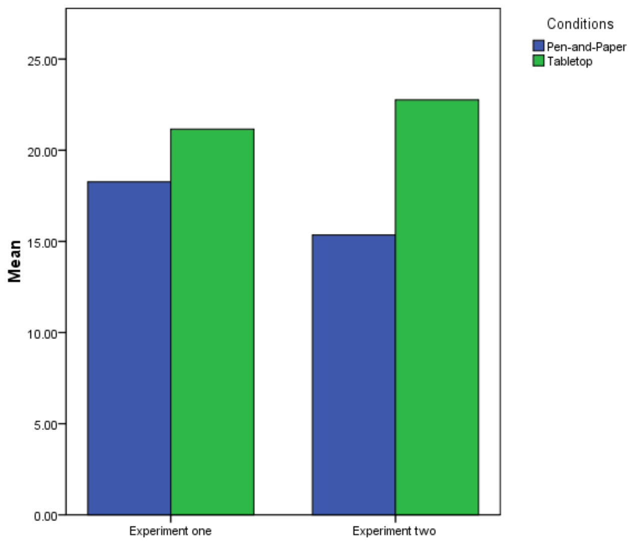



Figure 5.3 Means of completion time on the pen-and-paper condition compared with the tabletop approach.

## 5.3 Collaboration

### 5.3.1 Communication

**Question Q-3**: *Does the tabletop mind map application encourage more effective collaboration among group members than paper-based conditions?*
**Hypothesis H3** *The interactive tabletop promotes group members to collaborate more effectively than pen-and-paper conditions.*

In this context, participants were observed working together. The participants' collaboration behaviour was noted. Information was collected (i.e. giving an idea, requesting clarification about what others said/ideas, bringing group focus back to the agenda, moving the group forward when an agreement is reached, making suggestions to resolve disputes, asking for ideas and summarising the ideas) as explained in chapter 3. As seen in Figure 5.4, the mean for the tabletop was higher than the pen-and-paper approach for both experiments. For experiment one, the Friedman test was conducted to evaluate whether users were more concerned with the traditional approach or the tabletop condition. The results showed that the mean concern for the tabletop (M=26.12, SD=6.22) was significantly greater than the mean concern for the traditional condition (M=21.10, SD=11.56). Therefore, there was a significant positive correlation between the use of both conditions (p=0.009).

With regard to experiment two, however, the mean for the both conditions were slightly difference (table:M=32.30, SD=5.88, pen-and-paper:M=28.60, SD=7.01). Therefore, there

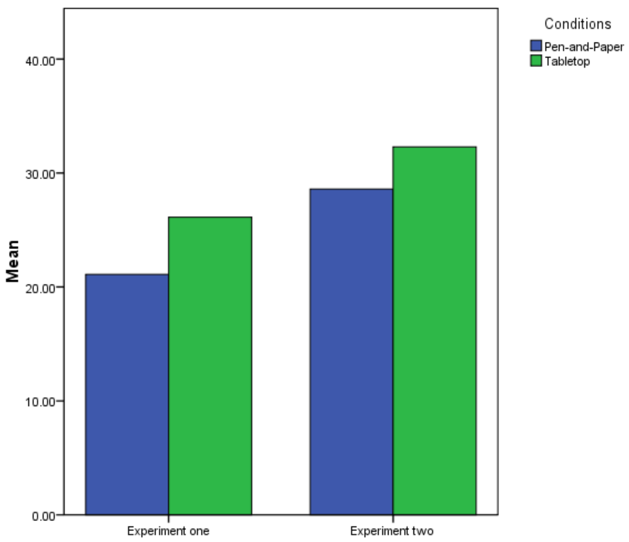



Figure 5.4 Means of collaboration on the pen-and-paper condition compared with the tabletop approach.

were no significant difference between the two conditions (p=0.058). Therefore, the results rejected hypothesis 3 (H3) that the interactive tabletop promote group members to collaborate more effectively than pen-and-paper conditions. Then the answer for Q-3 is that the tabletop mind map application does not encourage more effective collaboration among group members than the paper-based condition.

## 5.4 System Usability

System usability consists of four major issues: motivation, ease of use, enjoyment and collaboration rating.

### 5.4.1 Motivation

**Question Q-4**: *Does the tabletop motivate users to work with others more than paper-based conditions?*
**Hypothesis H4** *The interactive tabletop may increase individual engagement and motivation, which can also be a moderating factor of social learning.*

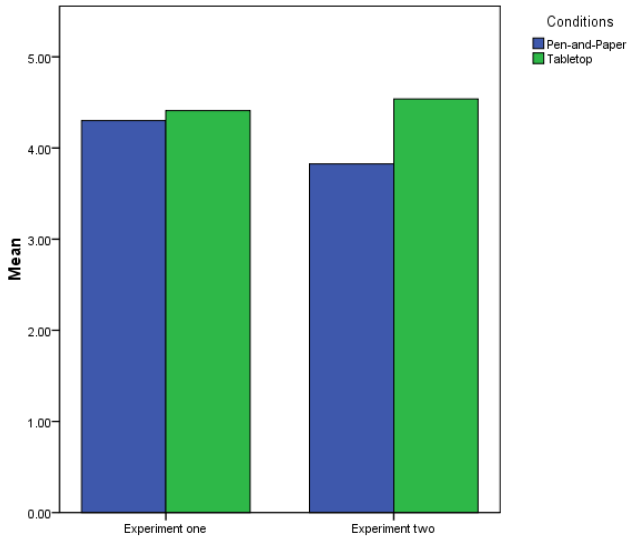



Figure 5.5 Means of motivation scale on the pen-and-paper condition compared with the tabletop approach for both experiments.

To answer this research question, after completing all tasks the subjects were asked to rate the statement "I was motivated to do well". Figure 5.5 shows the means for both experiments.

According to experiment one, the mean for the tabletop was slightly higher (M=4.40, SD=0.778) than the pen-and-paper approach (M=4.30, SD=0.911). However, no significant differences were found in this context between both conditions.

Regarding to experiment two, however the mean for the tabletop condition were significantly higher (M=4.55, SD=0.552) than the conventional approach (M=3.82, SD=0.747). Then there was a significant positive correlation between the two conditions ($p<0.001$) for this experiment.

Therefore, the results of experiment two accepted the hypothesis that the interactive tabletop increase individual engagement and motivation, which can also be a moderating factor of social learning. Then the answer for Q-4 is the tabletop condition motivated users to work with others more than pen-and-paper conditions. While the results of the first experiment does not.

### 5.4.2 Ease of Use

**Question Q-5**: *Is the interactive tabletop easier to use than pen-and-paper?*
**Hypothesis H5:** *The interactive tabletop is easier to use than pen-and-paper conditions.*

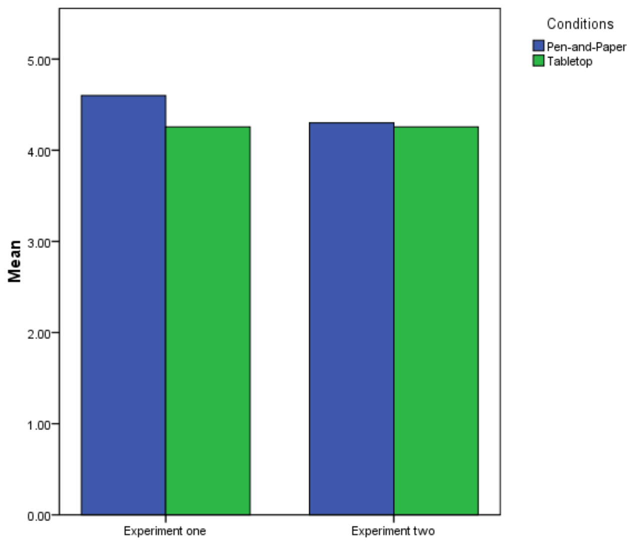



Figure 5.6 Means of ease of use in the pen-and-paper condition compared with the tabletop approach for both experiments.

To test this hypothesis, the subjects were asked to rate their impression on a questionnaire with the statement "The device was easy to use". Figure 5.6 presents the answer to this question.

What is interesting in the figure is that the mean for the pen-and-paper condition was higher than the tabletop approach for both experiments. However significant difference was found only in experiment one (p=0.004). While there was no significant difference between the two considered conditions (p=0.637) for experiment two.

Therefore, the results rejected the hypothesis (H5) that the interactive tabletop is easier to use than the pen-and-paper approach. The answer to Q-5 is that the pen-and-paper condition was easier to use than the tabletop condition.

### 5.4.3 Enjoyment

**Question Q-6**: *Is the interactive tabletop more enjoyable to use than pen-and-paper conditions?*
**Hypothesis H6** *The interactive tabletop is more enjoyable to use than pen-and-paper conditions.*

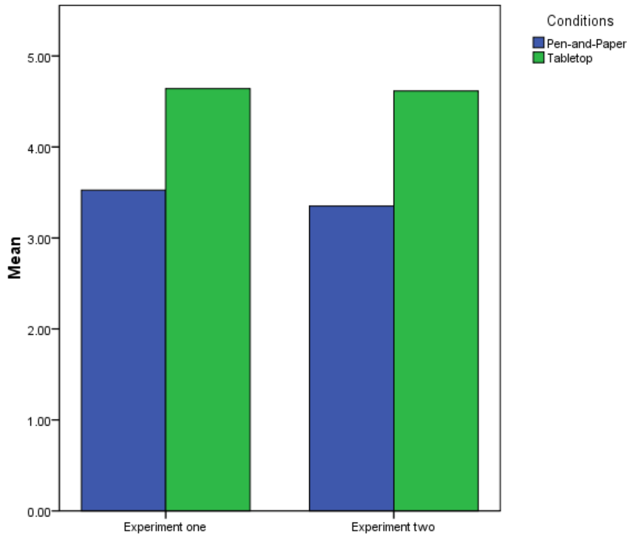



Figure 5.7 Means of enjoyment in the pen-and-paper condition compared with the tabletop approach.

To answer this research question, after completing all tasks the subjects were asked to rate the statement "It is enjoyable". Figure 5.7 shows the means for both experiments.

According to Figure 5.7, it can be seen that the mean concern for the tabletop for both experiments were significantly greater than the mean concern for the traditional condition. Therefore, the test comparison showed that this difference can be considered significant ($p<0.01$).

Hence, the results retained the hypothesis (H6) that the interactive tabletop helps users complete the task more pleasantly than the paper-based condition. The answer for Q-6 is that the tabletop application supports users to complete the task more pleasantly than the paper-based condition.

### 5.4.4 Collaboration Rating

**Question Q-7**: *Do users collaborate with others on the interactive tabletop more efficiently than under pen-and-paper conditions?*
**Hypothesis H7:** *The interactive tabletop supports users to work with others.*

In order to test the collaboration rating, seven questions were asked. These statements ("C1-I had a lot of ideas","C2-I was satisfied with my participation", "C3-I had high quality ideas", "C4-The results are important to me", "C5-I collaborated with other participants", "C6-It was agreeable" and "C7-I tried my best") were asked to rate their impressions.

#### C1-I had a lot of ideas

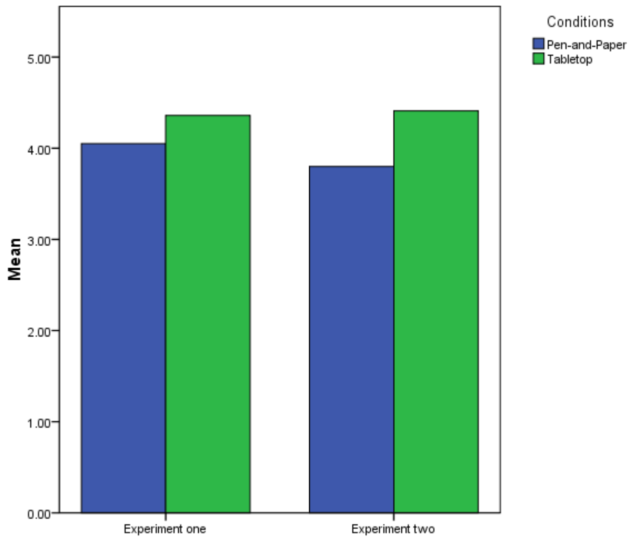



Figure 5.8 Means of the statement "I had a lot of ideas" in the pen-and-paper condition compared with the tabletop approach for both experiments.

The participants rated their agreement with the statement “I had a lot of ideas”. This question aimed to determine which condition the subjects felt they had more ideas when using the tabletop condition and the traditional approach. Figure 5.8 shows the means for this question for the two experiments.

Experiment one, the mean for the tabletop (M=4.38, SD=0.774) was higher than pen-and-paper conditions (M=4.05, SD=0.876). Hence, the subjective users perceptive consistently showed that there was a significant difference in tabletop approach over the traditional experiment (p=0.046).

As well as experiment two, participants felt that they had a lot of ideas while using the tabletop than using the convention approach as seen in Figure 5.8. The Friedman test also indicated that the mean concern for the tabletop (M=4.42, SD=0.712) was significantly higher than the mean concern for the paper-based approach (M=3.80, SD=0.882). Hence, the subjective user perceptive consistently showed that there was a significant difference in tabletop approach over the traditional experiment ($p<0.001$).

### C2-I was satisfied with my participation

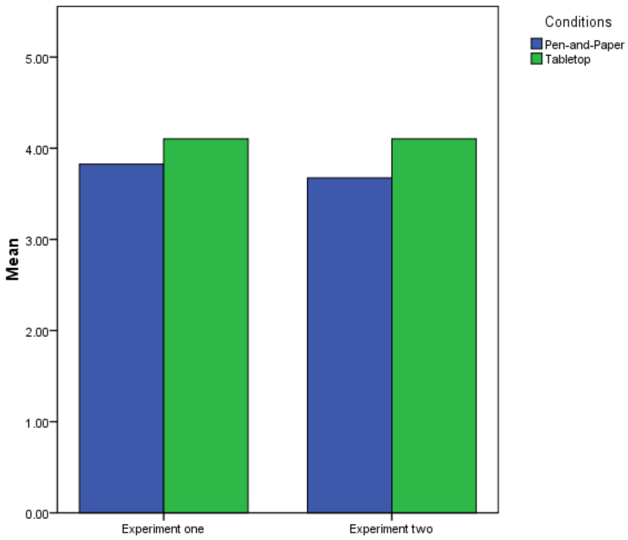



Figure 5.9 Means of the statement "I was satisfied with my participation" in pen-and-paper conditions compared with the tabletop approach.

Participants were also asked if they agreed with the statement "I was satisfied with my participation". This question aimed to determine which condition the subjects were more satisfied with their participation in the tabletop condition and the traditional approach. The Figure 5.9 presents means with the answers obtained for this question.

According to experiment one, the Friedman test indicated that the mean concern for the tabletop (M = 4.08, SD = 0.888) was higher than the mean concern for the paper-based approach (M=3.83, SD=0.903). However, the different between the conditions was not significant ($p=0.162$).

In terms of experiment two, however, the mean concern for the tabletop (M=4.12, SD=0.757) was statistically higher than the mean concern for the paper-based approach (M = 3.67, SD=0.693). Therefore, the difference between the conditions was significant ($p=0.003$).

### C3-I had high quality ideas

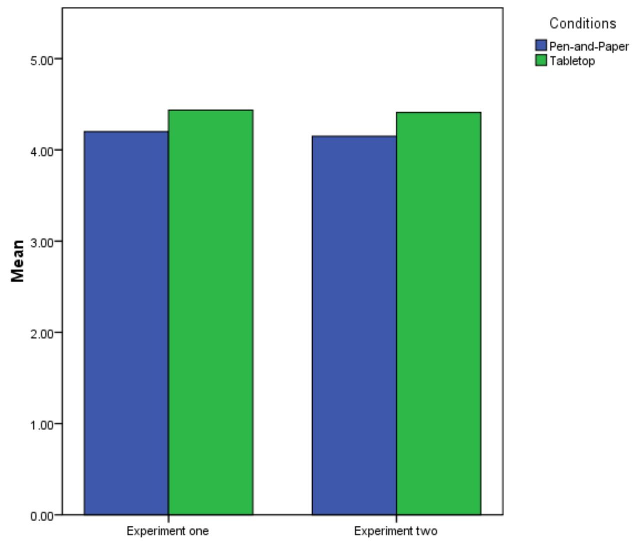



Figure 5.10 Means of the statement "I had high quality ideas" in the pen-and-paper condition compared with the tabletop approach for both experiments.

The results in Figure 5.10 show whether participants agreed with the statement "I had high quality ideas".

Regarding experiment one, the test indicated the mean concern for the tabletop (M=4.43, SD=0.636) was slightly higher than the mean concern for the paper-based approach (M=4.20, SD=0.823). Although the mean for the tabletop was greater than the pen-and-paper condition, the difference between the conditions was not significant (p=0.371).

Also in experiment two, it can be seen that the mean for the tabletop was higher than the paper-based. The mean concern for the tabletop (M=4.42, SD=0.635) was higher than the mean concern for the paper-based approach (M=4.15, SD=0.699, p=0.157). However, there was no significant difference between the two considered conditions.

### C4-The results are important to me

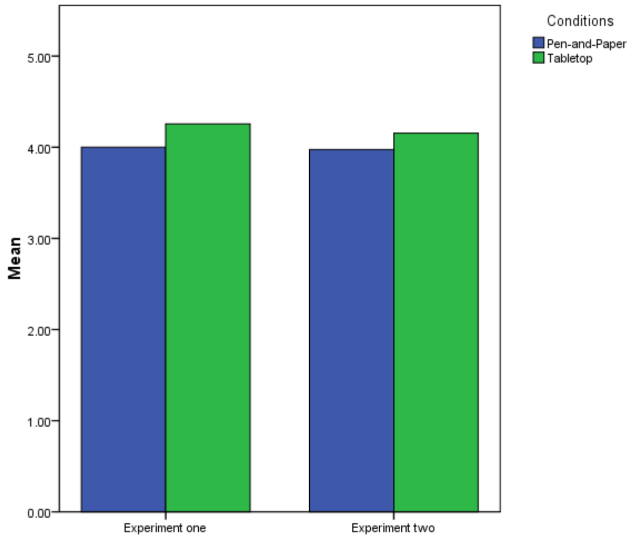



Figure 5.11 Means of the statement "The results are important to me" in the pen-and-paper condition compared with the tabletop approach for both experiments.

There were also no significant differences between the both considered conditions with the statement "The results are important to me" in experiment one. The results in Figure 5.11 show the mean for the tabletop was higher than the pen-and-paper condition. Furthermore, the analysis revealed that the mean concern for the tabletop (M=4.25, SD=0.954) was higher than the mean concern for the paper-based approach (M=4.00, SD=0.934, (p=0.513).

As well as experiment two show whether participants agreed with the statement "C4-The results were important to me". The analysis revealed that the mean concern for the tabletop (M=4.17, SD=0.930) was higher than the mean concern for the paper-based approach (M=3.97, SD=0.946). However, the difference between the conditions was not significant (p=0.827).

### C5-I collaborated with others well

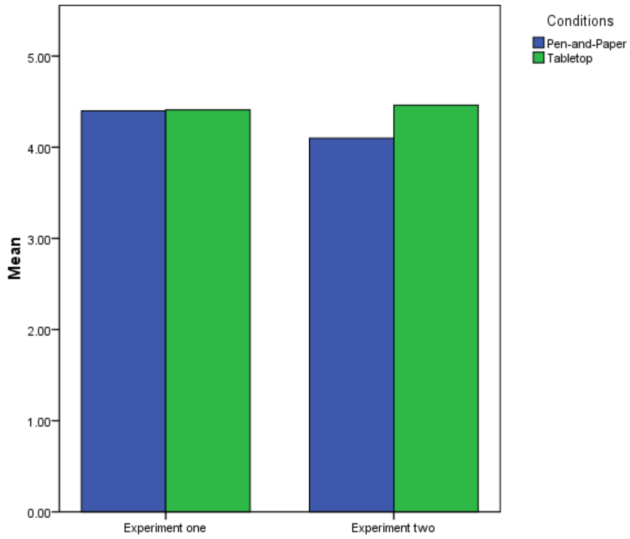



Figure 5.12 Means of the statement "I collaborated with other participants" in the pen-and-paper condition compared with the tabletop approach for both experiments.

In addition, subjects were also asked whether they agreed with the statement "I collaborated with other participants". This question aimed to determine which condition the subjects participated in more. Figure 5.12 presents means with the answers obtained for this question for both experiments.

The results for experiment one indicated that the mean concern for the tabletop (M=4.43, SD=0.774) was slightly higher than the mean concern for the paper-based approach (M=4.40, SD=0.876). Therefore, the difference between both conditions was not significant (p=0.808).

However, the results for experiment two showed that the mean concern for the tabletop (M = 4.47, SD = 0.598) was significantly higher than the mean concern for the paper-based approach (M = 4.10, SD = 0.708). Hence, the difference between the conditions was significant (p=0.007). Users felt they collaborated with other better when using the tabletop conditions.

### C6-It was agreeable

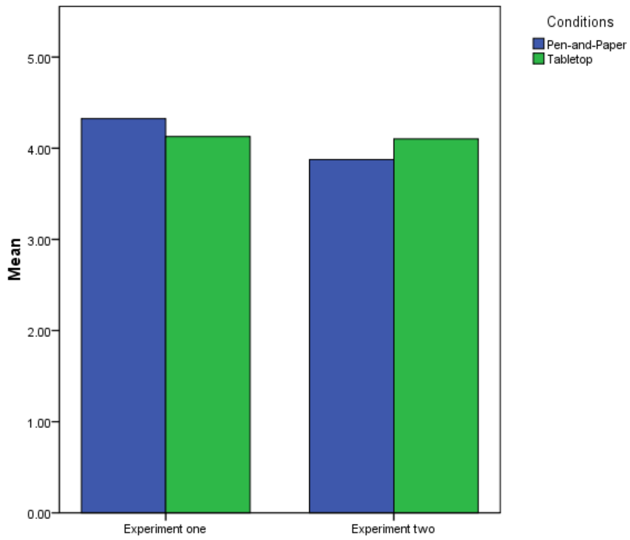



Figure 5.13 Means of the statement "It was agreeable" in the pen-and-paper condition compared with the tabletop approach for the two experiments.

Participants were asked to rate their impression with the statement "It was agreeable". The results for both experiments obtained for this statement are presented in Figure 5.13.

Experiment one, the analysis revealed that only slight differences between the mean of the tabletop condition (M=4.13, SD=0.723) and the pen-and-paper approach existed (M=4.33, SD=0.764). The statistic test showed that this difference cannot be considered significant (p=0.88).

Experiment two, however, participants felt significantly agree with the results. The analysis also revealed that the mean for tabletop condition more significantly differences (M=4.12, SD=0.722) than the pen-and-paper approach (M=3.82, SD=0.695). Therefore there was significant difference can be considered between the both conditions (p=0.028).

### C7-I tried my best

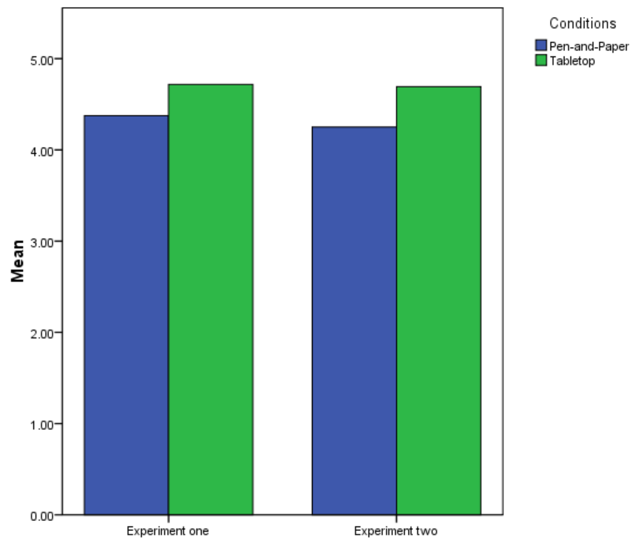



Figure 5.14 Means of the distributions of the statement "I tried my best" in the pen-and-paper condition compared with the tabletop approach for the two experiments.

Participants were also asked to rate on a 5-point scale their agreement with the statement "I tried my best". Figure 5.14 shows the means for the answer obtained for this question for both experiments.

Regarding experiment one, the Friedman test confirmed that the mean for the tabletop was significantly higher than the pen-and-paper condition. This subjective user perception showed that self-rated motivation in the digital platform was on average higher (M=4.70, SD=0.464) than the traditional approach (M=4.38, SD=0.774). Consequently, differences can be considered between the both conditions(p=0.029) for the former experiment.

With regard experiment two, the results were clearly seen in Figure 5.14 that users tried to do well on the tabletop setup. The median for the tabletop was greater than the paper-based condition. As well as the mean for the tabletop (M=4.70, SD=0.464) was statistically higher than the pen-and-paper condition (M=4.25, SD=0.742, p=0.003). Therefore, differences were found between both considered approaches.

### Collaboration Rating Summary

Table 5.3 summarises the results from seven statements above for both experiments. The significant results will be represented by ✓ and × for non-significant results.

For experiment one, it can be seen that there were only two statements that can be considered significant differences (C-1 and C-7). While no significant differences appeared for the remaining statements between the tabletop condition and the pen-and-paper approaches.

However the experiment two's results show that there were significant differences for the statement C1, C2, C5, C6 and C7. While no significant differences appeared for the remaining statements (C3 and C4) between the tabletop and pen-and-paper approaches.

Table 5.3 Collaboration rating summary

| Statement | Experiment one | Experiment two |
|---|---|---|
| C1-I had a lot of ideas | ✓ | ✓ |
| C2-I was satisfied with my participation | × | ✓ |
| C3-I had high quality ideas | × | × |
| C4-The results are important to me | × | × |
| C5-I collaborated with others well | × | ✓ |
| C6-It was agreeable | × | ✓ |
| C7-I tried my best | ✓ | ✓ |

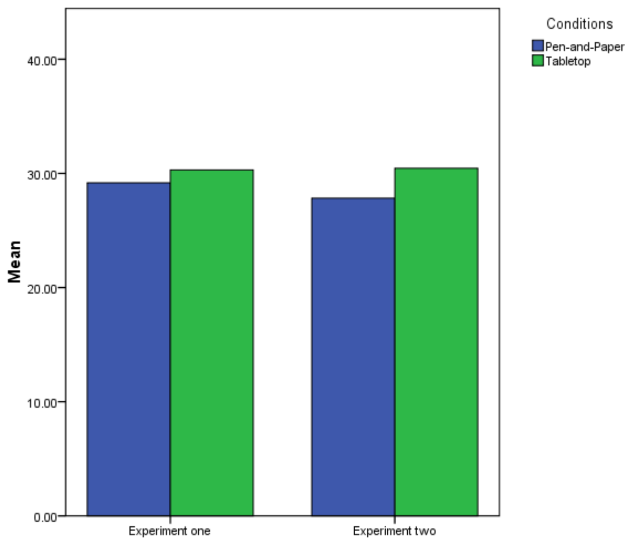



Figure 5.15 Means of total satisfaction of collaboration rating using the pen-and-paper condition compared with the tabletop approach for both experiments.

To determine the overall results, these questions were also grouped to investigate users' satisfaction. Figure 5.15 presents the means of total satisfaction for collaboration rating for the two experiments.

In terms of experiment one, Figure 5.15 illustrates that the mean for the tabletop (M=30.375, SD=4.264) was higher that pen-and-paper conditions (M=29.175, SD=4.551). However, the comparison did not show any significant differences (p=0.480).

The results of experiment two that the Friedman test was conducted to evaluate whether users were more concerned with the traditional approach or the tabletop condition. The results showed that the mean concern for the tabletop (M=30.450, SD=3.573) was statistically greater than the mean concern for the traditional condition (M=27.825, SD=3.514). Therefore, the comparison show significant differences (p=0.016) between the two considered conditions.

Hence, the results for experiment two accepted the hypothesis (H7) that the interactive tabletop supports users to work with others. The answer for Q-7 is that users collaborate with others on the interactive tabletop more efficiently than the pen-and-paper condition. while experiment one does not.

## 5.5 Emotion Attitudes

Emotional attitudes were analysed using a 10-point Likert scale answers, in which 1 = strongly disagree and 10 = strongly agree. The emotional attitudes questionnaire contains 12 questions.

**Question Q-8**: *Do users experience positive emotions using tabletop conditions more than the pen-and-paper conditions?*

**Hypothesis H8** *Users experience positive emotions using tabletop.*

### 5.5.1 Positive Emotions

#### Alertness

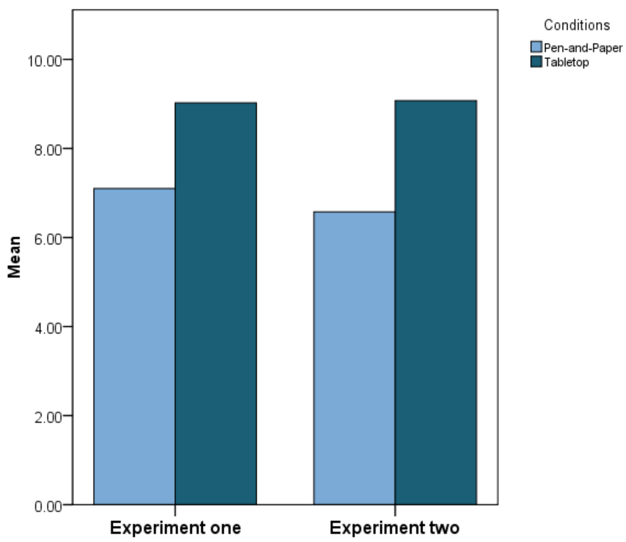



Figure 5.16 Means of alertness using the pen-and-paper condition compared with the table-top approach for both experiments.

Participants were asked if they agreed with the statement "I feel alert". The results obtained for this question are presented in Figure 5.16 for both experiments. It is apparent from this figure that the means for the tabletop (experiment one: M=9.03, SD=1.310, experiment two: M=9.07, SD=1.327) were significantly higher than the means for pen-and-paper condition (experiment one: M=7.10, SD=2.18, experiment two: M=6.57, SD=2.48). Therefore there was a significant difference between the two approaches ($p<0.01$).

### Energetics

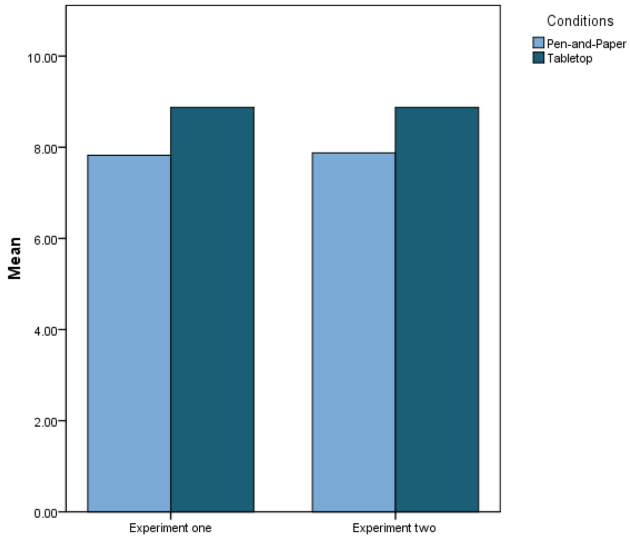



Figure 5.17 Means of energetics using the pen-and-paper condition compared with the tabletop approach for the two experiments.

In terms of energetics, participants clarified that they felt more energetic when using the tabletop (experiment one: M=8.88, SD=1.488, experiment two: M=8.87, SD=1.488) than in the pen-and-paper condition (experiment one: M=7.83, SD=1.796, experiment two: M=7.87, SD=1.712) as seen in Figure 5.17. Hence, there was a significant difference between the tabletop and paper-based conditions for both experiments ($p<0.01$).

### Enthusiasm

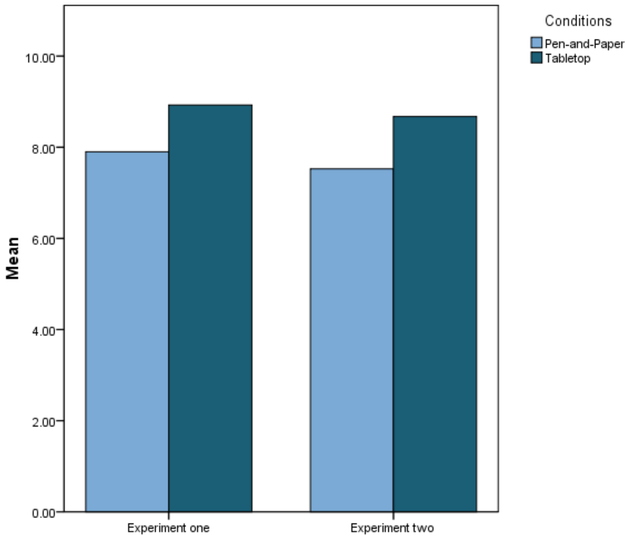



Figure 5.18 Means of enthusiasm using the pen-and-paper condition compared with the tabletop approach for both experiments.

As well as the results if users felt enthusiastic when performing the task in both conditions. Users were also asked to clarified whether they felt enthusiastic for both approaches. Figure 5.18 presents that the means concern for the tabletop (experiment one: M=8.93, SD=1.421, experiment two: M=8.67, SD=1.542) were significantly greater than the pen-and-paper condition (experiment one: M=7.90, SD=1.823, experiment two: M=7.52, SD=1.867) in both experiments. What is interesting in this data is that statistical differences were found on this feeling (experiment one: $p<0.01$, experiment two: $p=0.01$).

### Calm

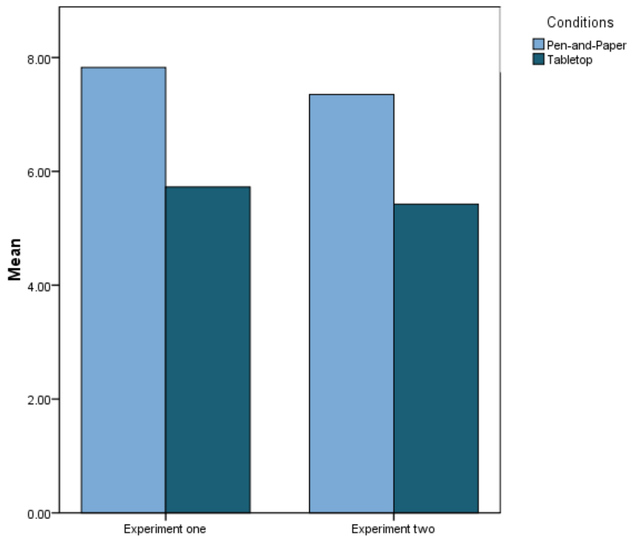



Figure 5.19 Means of calm using the pen-and-paper condition compared with the tabletop approach for the two experiments.

In contrast, there were significant differences between the tabletop condition and the pen-and-paper condition for the statements "I feel calm" for the paper-based condition. Participants were asked to rate the two statements. Users felt more calm when using the traditional condition than the digital approaches. Also, the results obtained for this question are presented in Figure 5.19. The test revealed that the mean concern for the pen-and-paper (experiment one: M=7.83, SD=2.099, experiment two: M=7.35, SD=2.423) was significantly greater than the tabletop (experiment one: M=5.73, SD=2.195, experiment two: M=5.42, SD=2.06). Therefore, there was a significant difference between the two approaches (experiment one: p<0.01, experiment two: p=0.01).

### Relaxation

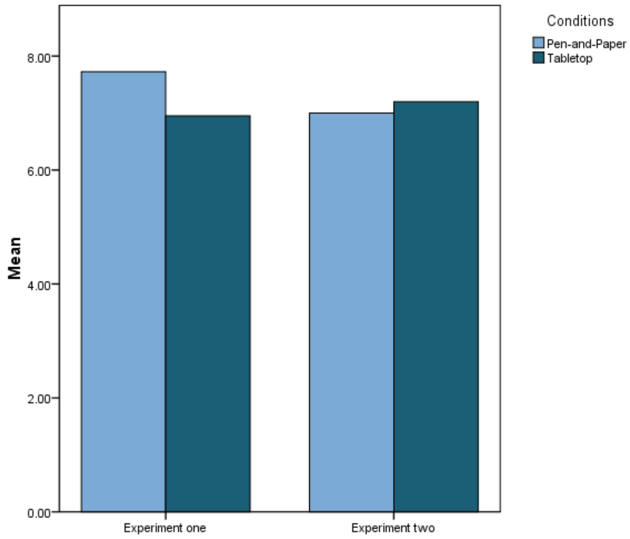



Figure 5.20 Means of relaxation using the pen-and-paper condition compared with the tabletop approach for the two experiments.

Users were also asked to rate if they felt relaxed. Figure 5.20 illustrated the means concern for both experiments.

Interestingly, in experiment one, there were significant differences between the tabletop condition and the pen-and-paper condition for the statements "I feel relaxed" for the paper-based condition in experiment one ($p<0.01$). Members clarified that they felt more relaxed when using the pen-and-paper (M=7.73, SD=1.633) than the tabletop condition (M=6.95, SD=1.947).

However, in experiment two, group members clarified that they felt more relaxed when using the tabletop (M=7.72, SD=2.102) than using the pen-and-paper conditions (M=7.00, SD=1.73). Even though the mean for the digital approach were higher than the traditional one, but no significant difference found between the tabletop and paper-based conditions ($p=0.257$).

### Happiness

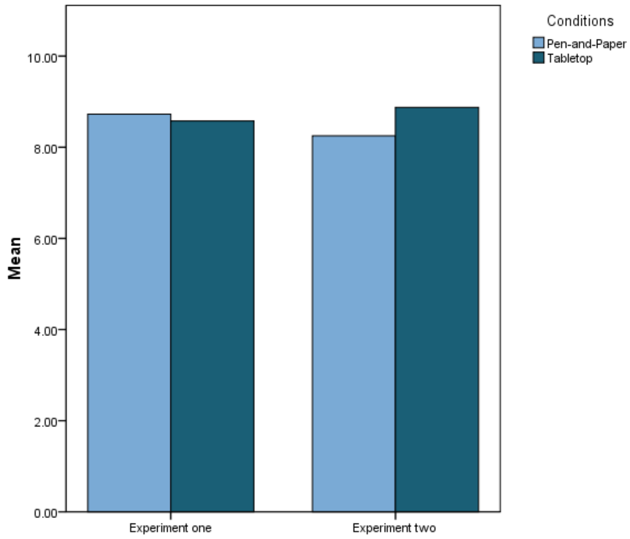



Figure 5.21 Means of happiness using the pen-and-paper condition compared with the table-top approach for both experiments.

With regard to happiness, users were also asked to clarify their feelings. Figure 5.21 shows data distributions for this question. The experiment one's results show that they felt slightly less happy using the tabletop condition (M=8.53, SD=1.567) than the paper-based condition (M=8.73, SD=2.099). While they felt happier using the digital condition (M=8.87, SD=1.571) in experiment two than using the conventional approach (M=8.25, SD=1.255). In this statement, the significant difference found between both considered conditions for experiment two (p=0.004) while experiment one does not (p=0.513).

### 5.5.2 Negative Emotions

#### Anxiety

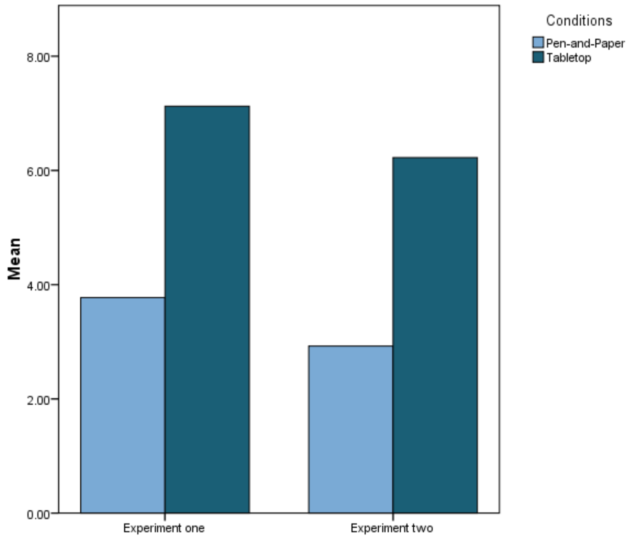



Figure 5.22 Means of anxiety using the pen-and-paper condition compared with the tabletop approach for the two experiments.

To study whether participants felt anxious during the tabletop and pen-and-paper approaches, they were asked to estimate their level of anxiety. Figure 5.22 shows the means for the two experiments. It can be clearly seen that the means for tabletop were significantly higher than the pen-and-paper conditions. Furthermore, the Friedman test was conducted to evaluate whether users felt more anxious with the traditional approach or the tabletop condition. The results indicated that the mean concern for the tabletop (experiment one: M=7.13, SD=1.652, experiment two: M=6.22, SD=1.95) was greater than the mean concern for the traditional condition (experiment one: M=3.78, SD=2.475, experiment two: M=2.92, SD=2.129). Thus, there were significant differences between the two considered conditions ($p<0.01$).

### Tiredness

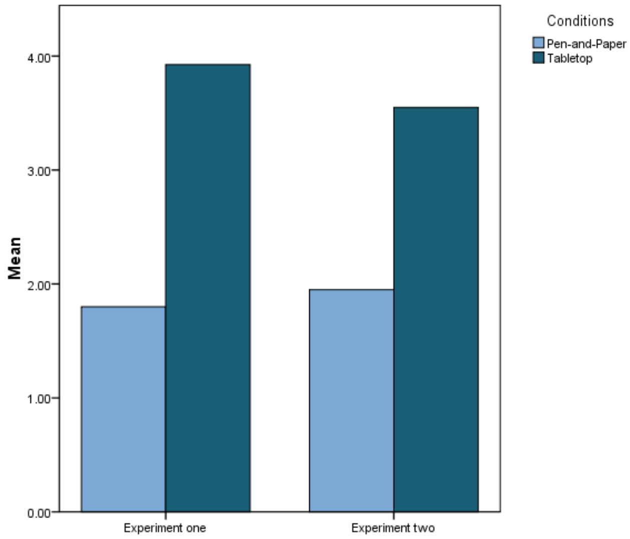



Figure 5.23 Means of tiredness using the pen-and-paper condition compared with the tabletop approach for the two experiments.

Reference to the statement "I feel tired", Figure 5.23 shows that participants felt tired when using the digital tabletop rather than using the pen-and-paper condition for both experiments. Also, the mean concern for the tabletop (experiment one: M=3.93, SD=2.664, experiment two: M=3.55, SD = 2.669) was higher than the paper-based (experiment one: M=1.80, SD=1.363, experiment two: M=1.95, SD = 1.319). Therefore, significant difference found between both considered conditions ($p<0.01$) in both experiments.

### Depression

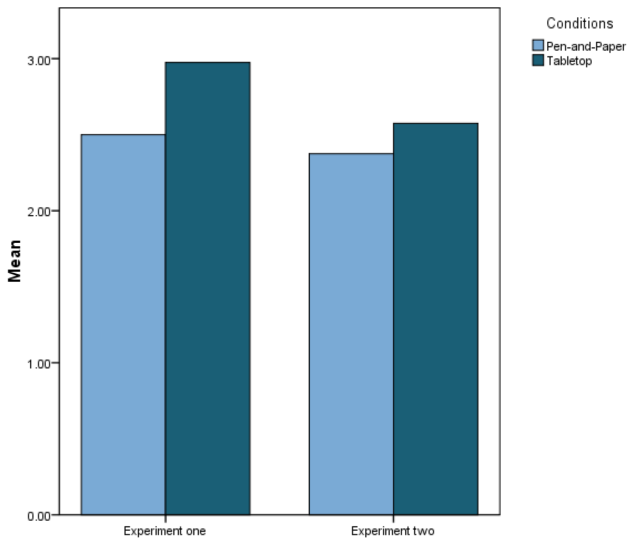



Figure 5.24 Means of depression using the pen-and-paper condition compared with the tabletop approach for the two experiments.

Participants were also asked to rate if they felt depressed after performing the tasks. The results show in Figure 5.24 that they were slightly depressed when using the tabletop in both experiments. Also, the mean for the tabletop (experiment one: M=2.98, SD=2.465, experiment two: M=2.57, SD=1.810) was slightly higher than the pen-and-paper condition (experiment one: M=2.50, SD=1.895, experiment two: M=2.37, SD=1.674). However, there was no significant difference found in this question (experiment one: p=0.102, experiment two: p=0.201).

### Sadness

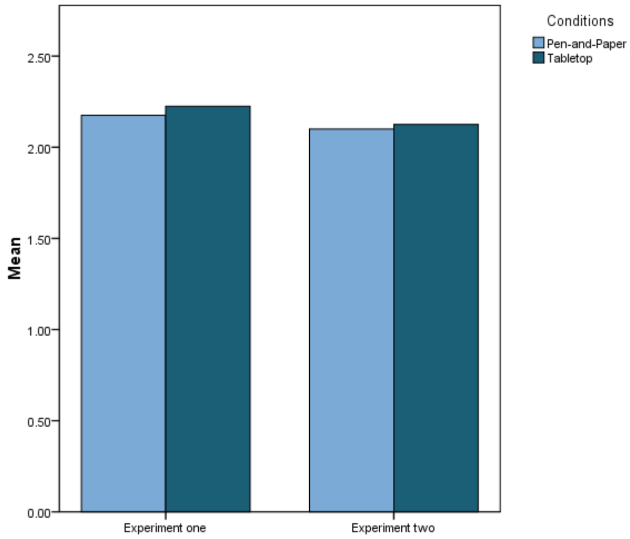



Figure 5.25 Means of sadness using the pen-and-paper condition compared with the tabletop approach for the two experiments.

In term of sadness, the participants were asked if they felt sad after performing the tasks. Figure 5.25 indicated that the mean for the two conditions were lower than 2.5 out of 10. Furthermore, the results from the Friedman test found that the mean for the tabletop (experiment one: M=2.23, SD=1.310, experiment two: M=2.12, SD=1.244) was slightly higher than the paper-based condition (experiment one: M=2.18, SD=1.130, experiment two: M=2.10, SD=1.032). Nonetheless, the difference between the two conditions was not significant (experiment one: p=0.683, experiment two: p=1.000).

### Tenseness

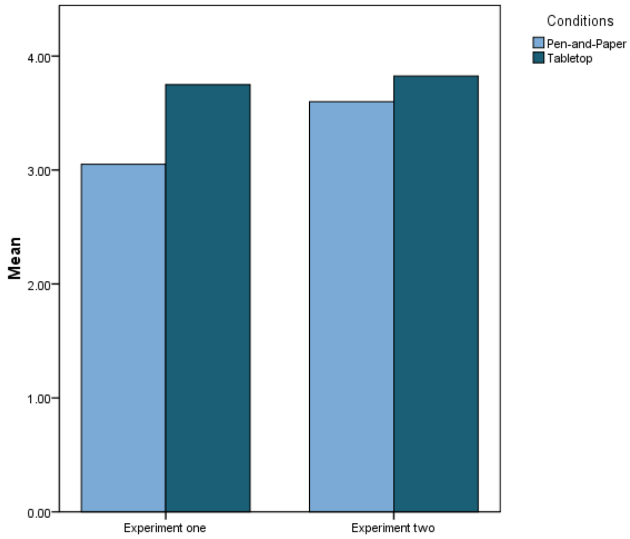



Figure 5.26 Means of tenseness using the pen-and-paper condition compared with the tabletop approach for both experiments.

To investigate whether the participants felt tense after completing the two tasks, they were asked to estimate their level of tenseness. Even though there was no significant difference for this question (experiment one: p=0.144, experiment two: p=1.000), participants felt tenser using the tabletop than in the pen-and-paper condition (See Figure 5.26). The results from the Friedman test found that the mean for the tabletop (experiment one: M=3.75, SD=2.570, experiment two: M=3.82, SD=2.50) was slightly higher than the paper-based condition (experiment one: M=3.05, SD=2.298, experiment two: M=3.60, SD=2.250).

### Boredom

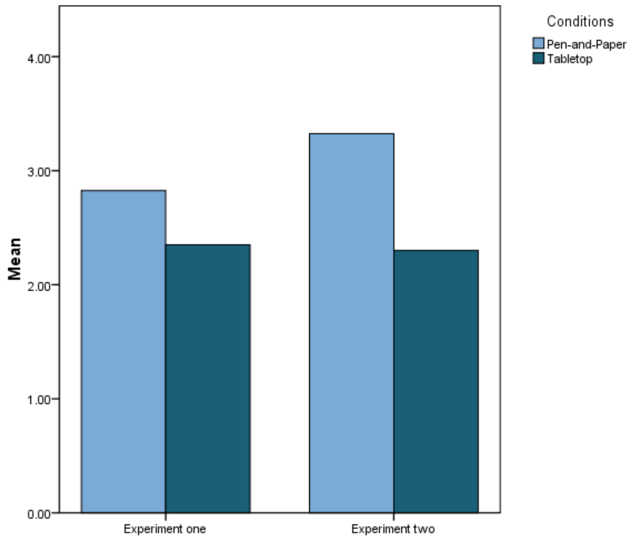



Figure 5.27 Means of boredom using the pen-and-paper condition compared with the tabletop approach for the two experiments.

Finally, the participants were asked if they felt bored. Figure 5.27 shows the answer obtained for this question. The Friedman test revealed that the mean for the tabletop (experiment one: M=2.35, SD=1.748, experiment two: M=2.30, SD=1.651) was less than the paper-based condition (experiment one: M=2.83, SD=1.852, experiment two: M=3.32, SD=1.817). However, the difference between the conditions was not significant in experiment one (p=0.050) while experiment two does (p=0.004);

### 5.5.3 Emotion Attitudes Summary

Table 5.4 summarises the emotion attitudes for both experiments. The significant results will be represented by ✓and × for non-significant results. It can be seen that users experienced positive feeling when using the tabletop over the traditional pen-and-paper conditions.

Table 5.4 Emotion attitudes summary

| Statement | Experiment one | Experiment two |
|---|---|---|
| Alertness | ✓ | ✓ |
| Energetics | ✓ | ✓ |
| Enthusiasm | ✓ | ✓ |
| Calm | ✓ | ✓ |
| Relaxation | ✓ | × |
| Happiness | × | ✓ |
| Anxiety | ✓ | ✓ |
| Tiredness | ✓ | ✓ |
| Depression | × | × |
| Sadness | × | × |
| Tenseness | × | × |
| Boredom | × | ✓ |

To determine the overall of user's feelings, all emotion attitudes were also grouped. Figure 5.28 presents the means of the total emotion attitudes.

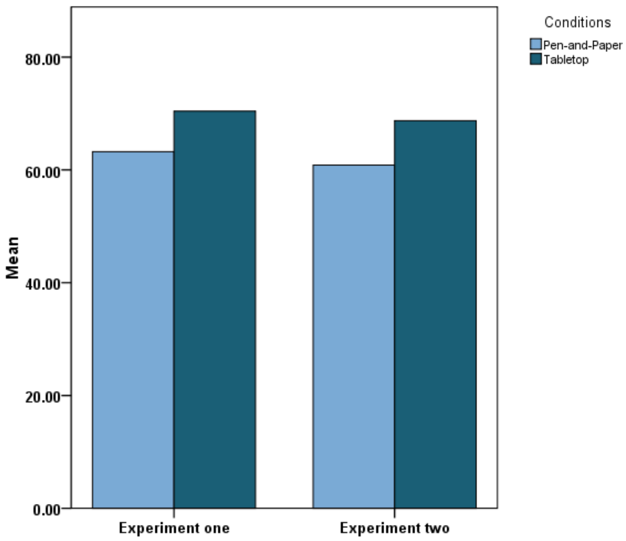



Figure 5.28 Means of total emotions using the pen-and-paper condition compared with the tabletop approach for the two experiments.

Figure 5.28 presents that the means of the experiment one that the tabletop was greatly higher than pen-and paper conditions. Also, the Friedman test analysed the mean for the tabletop (M=70.425, SD=6.262) was significantly greater than the paper-based conditions (M=63.225, SD=7.152). Hence, the test comparison showed that this difference can be considered significant ($p<0.001$).

As well as the result of experiment two, Figure 5.28 also shows that the mean for the tabletop was greatly higher than pen-and paper conditions. The test analysed the mean for the tabletop (M=68.725, SD=5.058) was significantly greater than the paper-based conditions (M=60.850, SD=5.789). Thus, the test comparison showed that this difference can be considered significant ($p<0.001$).

In conclusion, the results retained the hypothesis (H8) that user experienced positive emotions when using the interactive tabletop than using pen-and-paper condition in both conditions.

## 5.6 Qualitative feedback

Qualitative feedback was received through the questionnaire and user comments during the experiments.

According to experiment one, the comments from users were summarised and are presented in table 5.5 and Figure 5.29 demonstrates the percentages of comments.

Table 5.5 Positive feedbacks (N=42)

| **Theme** | **Frequency** |
|---|---|
| Easy to Use | 7 |
| Enjoyable | 11 |
| Support collaboration | 13 |
| Suggestions | 7 |
| Useful | 4 |

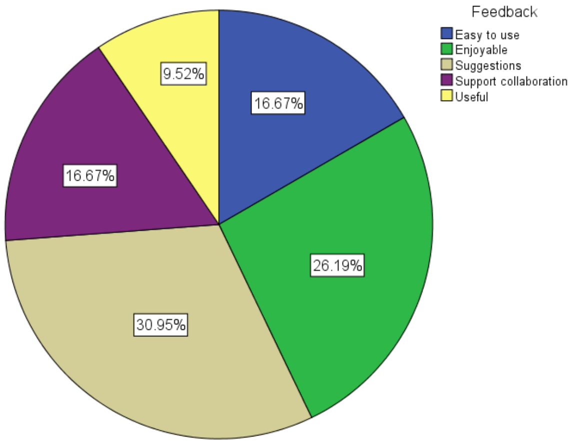



Figure 5.29 Percentage of positive feedback

The pie chart show the amount of users' feedbacks for experiment one. 30.95% of the feedback indicated some recommendations to improve text data entry by using correction algorithms that automatically correct spelling mistakes and unnecessary letters. Also, it was recommended to allow the use of a stylus for handwriting. Additionally, in terms of application features, it was suggested that nodes should be hidden as the screen seems smaller when users have many ideas on the screen at one time. 26.19% of overall comments stated that that system was more pleasant to use. 16.67% of the comments highlighted that it was very easy to modify the mind map using the tabletop. Likewise, the system supported collaboration by 16.67%. Only 9.5% of the total stated that the tabletop system was useful.

However, some participants indicated that the reflection of the sunlight may cause issues with the usability of the tabletop. For example, shadows may accidentally interact with objects on the table. Also when the tabletop was sensitive to detect objects such as a piece of paper, user's cloths.

In terms of experiment two, qualitative feedback was also received through the questionnaire and user comments during the experiment. The users' recommendations were summarised and presented in table 5.6. Figure 5.30 presents the percentages of the feedback.

Table 5.6 Users' feedbacks (N=19)

| Theme | Frequency |
|---|---|
| Easy to use and learn | 3 |
| Enjoyable | 4 |
| Support collaboration | 3 |
| Suggestions | 7 |
| Useful | 2 |

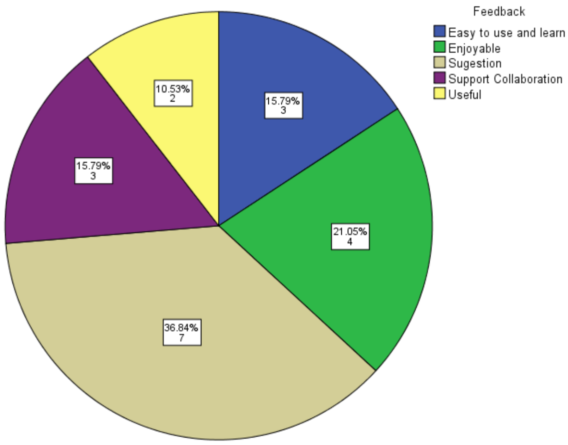



Figure 5.30 Percentage of positive feedback

It can seen that 36.84% of the feedbacks indicated some recommendations to improve the tabletop mind map application. For instance, the sensitive of the tabletop. Users found that it detected any objects such as paper and users clothes. Next, the android devices were useful to create public or private ideas, however it was small to display whole mind map. Another interesting point was about distinguishing each user on the table when they created an idea. Some said it would be better if users had the same text colour when input. 21.05 % of the comments highlighted that users enjoyed using the digital application. 15.79% for enjoyable, likewise easy to use and learn. 10.53% of the total stated that the system was useful.

## 5.7 Summary

In this chapter, the results of both experiments were described and reported. This experiment aims to investigate the effectiveness and the usability of the interactive tabletop and traditional pen-and-paper approaches and the impact of these on the collaborative work of small groups. The results of the experiment highlighted in Table 5.7.

Table 5.7 The brief summary of experiment one results.

| | **Hypothesis** | **Experiment one** | **Experiment two** |
|---|---|---|---|
| H1 | The interactive tabletop encourages users to create more ideas than paper-based conditions. | Rejected | Rejected |
| H2 | The interactive tabletop helps users to complete the task faster than paper-based conditions. | Rejected | Rejected |
| H3 | The interactive tabletop promotes group members to collaborate more effectively than pen-and-paper conditions. | **Accepted** | Rejected |
| H4 | The interactive tabletop increases individual engagement and motivation, which can also be a moderating factor of social loafing. | Rejected | **Accepted** |
| H5 | The interactive tabletop is easier to use than pen-and-paper conditions. | Rejected | Rejected |
| H6 | The interactive tabletop is more pleasant to use than pen-and-paper conditions. | **Accepted** | **Accepted** |
| H7 | The interactive tabletop supports collaborative work. | Rejected | **Accepted** |
| H8 | Users experience positive emotions from using the tabletop. | **Accepted** | **Accepted** |

# Chapter 6

# Discussion

This research explored the effectiveness of the tabletop application in collaborative work context. Two experiments were conducted. The results of both experiments are presented in Chapter 5. This chapter discusses the research results of the previous chapters. The discussion focuses on four variables: performance, collaboration, usability, and emotion attitudes. Furthermore, limitations of the study are also included in the last section of the chapter.

Hypotheses were formulated to answer the research questions presented in Chapter 3. The results are summarised and presented in Table 6.1. The table illustrates a summary of all hypotheses used in this research and shows the accepted (✓) and rejected (×) hypotheses.

Table 6.1 A brief summary of the experimental results.

| | **Hypothesis** | **Experiment One** | **Experiment Two** |
|---|---|---|---|
| H1 | The interactive tabletop encourages users to create more ideas than paper-based conditions. | × | × |
| H2 | The interactive tabletop helps users to complete the task faster than paper-based conditions. | × | × |
| H3 | The interactive tabletop promotes group members to collaborate more effectively than pen-and-paper conditions. | ✓ | × |
| H4 | The interactive tabletop increases individual engagement and motivation, which can also be a moderating factor of social learning. | × | ✓ |
| H5 | The interactive tabletop is easier to use than pen-and-paper conditions. | × | × |
| H6 | The interactive tabletop is more pleasant to use than pen-and-paper conditions. | ✓ | ✓ |
| H7 | The interactive tabletop supports collaborative work. | × | ✓ |
| H8 | Users experience positive emotions from using the tabletop. | ✓ | ✓ |

## 6.1 Performance

This section discusses the performance of the use of the tabletop mind map system compared with pen-and-paper conditions in experiment one and experiment two. This metric consists of two metrics: effectiveness and efficiency. The former metric was measured by the number of ideas. The latter was measured by the duration for successfully completed task. Table 6.2 presents a summary of performance metric results for both experiments. It can be concluded that the interactive tabletop did not encourage users to create more ideas. In addition, users spent more time when using the digital tools than using pen-and-paper. The following subsections will discuss these two metrics in detail.

Table 6.2 Performance metric results

| Metrics | Experiment One | Experiment Two |
|---|---|---|
| Effectiveness (H1) | × | × |
| Efficiency (H2) | × | × |

### 6.1.1 Effectiveness

The results show that there were no significant differences between the tabletop and pen-and-paper conditions for each experiment. However the statistical tests showed that the means for the tabletop were higher than the pen-and-paper conditions for producing ideas in both experiments. This is because users had virtual keyboards to write their own ideas. The tablets also supported individual work. These two tools may cause users to create more ideas than the pen-and-paper conditions.

The results also confirmed the work by Buisine et al. [2007] that no significant difference appeared between the tabletop and pen-and-paper conditions. Likewise, Do-Lenh et al. [2009] argued that groups using desktop computers created significantly more nodes when using tabletop interface.

In conclusion, tabletop did not encourage users to create more ideas. There are three reasons to argue why the hypothesis have got rejected. First, users were not familiar with the tabletop applications. They needed some more time to practice how to use the application. Also, some users preferred a stylus to interact with the surface rather than using their fingers [Tse et al., 2006]. Second, regarding creativity work, users should have a very relaxed attitudes. Finally, the location users performed the experiment may affect them as the location is one major factor for collaborative work [Marshall et al., 2011b; Patel et al., 2012; Ryall et al., 2006].

### 6.1.2 Efficiency

The duration of tasks were measured in both experiments. Table 6.2 shows that there was no significant difference between the two experiments with regard to effectiveness and efficiency. The completion time that users took to accomplish the mind map task on the computerised tools was longer than the traditional pen-and-paper conditions. This is because there were some issues when using the tabletop. For example, the light reflection caused unexpected interact with other objects. Moreover, some participants also deleted other nodes/ideas by accident. It could be observed that some participants enlarged a virtual keyboard as big as the monitor size making it impossible for others to work. However, the enlarged keyboard did not create major problems as the participants were still able to work together. In addition, they seemed amused by the unpredictable behaviour. Furthermore, rather than focusing on the tasks, subjects seemed to enjoy playing around to acquaint with the system, especially on the tabletop and tablets conditions .

Interestingly, the results in experiment two showed that there were significant differences between the two conditions. That meant users spent more time using the combination of the tabletop and tablets. Perhaps subjects had to learn both novel technology in the limited time.

The use of pen-and-paper conditions, people fully aware with the tools and mind mapping which make them easily to work without learning the new technology. They were able to write as fast as they could speak. Also pen-and-paper tools offer the required amount of flexibility, speed and natural interaction [Aliakseyeu et al., 2006].

This work was involved with creation which means if users were seat in a control room, and been observed perhaps they felt uncomfortable to work properly Patel et al. [2012]. The results, however, confirmed the previous study as found as in Buisine et al. [2007] that there was no significant difference between tabletop and paper conditions. However, in terms of creativity, time on task factor does not necessarily require for collaborative work.

## 6.2 Collaboration

This section discusses the collaboration by collecting users behaviour during the experiments. Table 6.3 presents the summary of performance metric results of both experiments. The results showed that there was a significant difference between the tabletop over the pen-and-paper conditions in experiment one. However, there was no significant difference between the two conditions in experiment two.

Table 6.3 Collaboration metric results

| Metrics | Experiment One | Experiment Two |
|---|---|---|
| Communication (H3) | ✓ | × |

For the pen-and-paper conditions, the results showed that there was an inequality in participation across the groups. During the discussion phase, in each group, there was a person who was in charge of the task. They invited others to participate and brought the group focus back to the agenda, asked to clarify the questions, restated what others have said, and moved the group forward to reach an agreement. In the meantime, the leader was in charge of writing as well. In some groups there were two different leaders, one was in charge of the session and another was in charge of writing. Some groups drew the mind map during discussion while only two groups in the experiment one and three groups in the experiment two discussed the ideas and took notes on an A4 paper before drawing the mind map.

In the tabletop approach, a pattern of parallel work was observed. Four members worked by themselves to type their ideas and create nodes. They also discussed to reach agreements.

In this environment, no one was in charge of writing. During discussion phase, participants also talked to neighbours asking about their ideas. Some wrote their ideas down and placed the nodes in their space waiting for others to get ready, then they grouped the ideas together.

The results showed that one person is in charge and the members participate unequally across the groups in the paper-and-pen approach as found in Buisine et al. [2007]. On the other hand, in the tabletop application, users did participate very actively and more equally. While on the traditional approach, they merely expressed their ideas to the leader to write them down. Therefore, our results suggest that the interactive tabletop supports them working together in parallel. The results also confirmed a study by Magerkurth et al. [2002].

In terms of experiment two, even though the results found no significant differences appeared between the two conditions (p=0.059), it can be seen that the mean and the median for tabletop conditions were higher that the pen-and-paper conditions. In this case, it can be concluded that the combination of the tabletop and tablets encourage people to work together.

## 6.3 Usability

This section discusses the usability of the experiments. Participants answered questionnaires about their experience for each experiment. The usability metric includes four major issues: motivation, ease of use, enjoyment, and collaborative rating. Table 6.4 presents a summary of usability metric results of both experiments. The following subsections will discuss in detail for each issue.

Table 6.4 Usability metric results

| Metrics | Experiment One | Experiment Two |
|---|---|---|
| Motivation (H4) | × | ✓ |
| Ease of Use (H5) | × | × |
| Enjoyment (H6) | ✓ | ✓ |
| Collaboration Rating (H7) | × | ✓ |

### 6.3.1 Motivation

The results showed that there was significant difference for experiment two, but not for the experiment one.

In experiment one, however, the results show that the means for the tabletop was higher than the pen-and-paper conditions. Although, the tabletops have potential to encourage people to work simultaneously, but creative activity concerns more factors such as location, work environment [Patel et al., 2012].

According to MBTI, some people can work perfectly with others, while some prefer working on their own [Barkhi, 2002]. Perhaps this is the reason why this hypothesis (H4) has been rejected. Anyway, in terms of collaborative work, people need to share their ideas instead of working alone.

Nonetheless, the combination of the tabletop and tablets has potential to motivate people to work together. This results also confirm the previous study of Seifert et al. [2012] that presented the combination of the tabletop and personal devices motivate subjects to work with others collaboratively.

It can be concluded that the tabletop and tablets can motivate people to work with others more than the tabletop only does.

### 6.3.2 Ease of Use

In terms of ease of use, as you can see from the results in the previous chapters that tabletop and the combination of the tabletop and tablets were not easy to use. Users prefer the traditional condition on the easiness to draw the mind map. Perhaps this is because hand-drawing gives more freedom to the users than the limited range of options provided by the interactive tabletop. Possibly the sensitivity of the tabletop which cause to make some mistake on the table, may have reduced the feeling that it was easy to use. However, the results contradict to some extent the results reported in Buisine et al. [2007].

The art of hand drawing never dies. While digital tools offer a tremendous array of powerful features, they do so at the cost of introducing functions requiring experience to learn and use effectively that collectively complicate the user's workflow and interaction with content.

### 6.3.3 Enjoyment

Undoubtedly, the use of the interactive tabletop was more enjoyable than the use of the pen-and-paper. This supports natural user interface elements that should be enjoyable, leading to skilled practice and appropriate to context [Wigdor and Wixon, 2011]. This confirms the results found in a previous study Buisine et al. [2007]. Furthermore, recent developments in related research into tabletops found that interactive tabletops are enjoyable to use and support group awareness [Baraldi et al., 2008; Chi et al., 2011; Lee et al., 2009; North et al., 2009; Pantidi et al., 2009].

### 6.3.4 Collaborative rating

In this section, users were asked their opinions about their participations. The Tabletop 6.4 showed it was hypothesised there was no significant difference between the tabletop alone and pen-and-paper conditions in the experiment one. However, a difference was found in experiment two.

Table 6.5 presents the results from experiment one and experiment two. The significant results will be represented by ✓and ×for non-significant results.

Table 6.5 A collaboration rating summary from the two experiments

| Statement | Experiment One | Experiment Two |
|---|---|---|
| C1-I had a lot of ideas | ✓ | ✓ |
| C2-I was satisfied with my participation | × | ✓ |
| C3-I had high quality ideas | × | × |
| C4-The results are important to me | × | × |
| C5-I collaborated with others well | × | ✓ |
| C6-It was agreeable | × | ✓ |
| C7-I tried my best | ✓ | ✓ |

Participants thought they had a lot of ideas and they tried their best when they used the tabletop in experiment one and also the combination of the tabletop and personal devices in experiment two. In section 5.4.4 and 6.4.4 showed significant differences found in both experiments.

Participants also believed that they were satisfied using the digital approaches in both conditions over the pen-and-paper conditions. This issue showed significant differences in experiment two, but experiment one.

Moreover, users felt that they had quality ideas on using the tabletop and also the combination of the tabletop and personal devices. Additionally, subjects also felt that the results were important to them when using the digital tools. However, these issues did not show significant differences in the two experiments.

Interestingly, in experiment one users also thought they collaborated with others slightly better when using pen-and-paper conditions. Also, participants felt the results were agreeable when using the traditional approaches. However, there were no significant differences between the two considered conditions. On the other hand, in experiment two, users felt significantly difference using the tabletop.

This caused by the potential and the attraction of tabletops, which provided users the virtual keyboards to create mind map. What is more, this system encourage users to create a mind map by providing these basic functions: delete, scale, relocated and rotate the nodes.

## 6.4 Emotion Attitudes

This section discusses emotional attitudes of the participants after done the experiments. The questionnaires were used to gather data. The results shows that users experienced positive emotions when using the tabletop and the combination of the tabletop and tablets as illustrated in Table 6.6.

Table 6.6 Emotion attitude results

| Metrics | Experiment One | Experiment Two |
|---|---|---|
| Emotion attitude (H8) | **Accepted** | **Accepted** |

Users were explored their feelings about alertness, anxiety, energetics, calm, enthusiasm, relaxation, happiness, tiredness, depression, sadness, tenseness, and boredom.

Table 6.7 summarises the emotional attitudes. The significant results for tabletop condition will be represented by ✓, ✓ for pen-and-paper conditions, and ×for non-significant results. It can be seen that users experienced positive feeling when using the tabletop over the traditional pen-and-paper conditions in both experiments.

The results showed user significantly experienced negative feelings. They felt anxious and tired when using the tabletop approaches in both experiments. Besides users also felt bored when using pen-and-paper conditions in the experiment two.

However, participants significantly experienced positive emotions using tabletop. They felt alert, energetic and enthusiasm in the two experiments and plus happiness when using the combination devices in experiment two. On the other hand, user strongly felt calm using pen-and-paper in both experiments, also they felt extremely relax in the experiment one.

Table 6.7 Emotion attitudes summary

| Statement | Experiment One | Experiment Two |
|---|---|---|
| Alertness | ✓ | ✓ |
| Energetics | ✓ | ✓ |
| Enthusiasm | ✓ | ✓ |
| Calm | ✓ | ✓ |
| Relaxation | ✓ | × |
| Happiness | × | ✓ |
| Anxiety | ✓ | ✓ |
| Tiredness | ✓ | ✓ |
| Depression | × | × |
| Sadness | × | × |
| Tenseness | × | × |
| Boredom | × | ✓ |

The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the pen-and-paper approaches in both experiments. It is interesting to note that the tabletop application was mostly driven by user curiosity to explore and play with the tools.

Emotions are relevant for individual and social computation. They could drive participation or avoidance and also underlie cognition. Emotions also affect for decision making Damasio [2008]. It is well established that emotional attitudes are important factors that influence the effectiveness of collaborative work Ashforth and Humphrey [1995]. It has been shown González-Ibáñez et al. [2011] that positive emotions such as happiness and alertness are significantly more influential factors for collaborative working than for individual work. Positive emotions also indicate self-fulfillment of participants in the context of collaborative work Fredrickson and Losada [2005]. In contrast, negative emotions such as anxiety, sadness, and anger, may be associated with reduced accuracy on tasks and executive functioning by biasing cognitive processing, or may lead to reduction of the production of ideas Fredrickson [2001].

## 6.5 Limitations

The experimental design and results obtained must be considered in the context of the limitations and constraints being faced. The limitations of our study are as follows.

- First of all, finding participants to take part in this study was greatly challenging. Each experiment needed forty people: ten groups of four participants. Due to the experiment lasted around one hour, and also the location where we took place was in a PhD office, which the tabletop is located. They preferred to perform the experiment on weekends. Therefore, all participants involved in the experiments were students. Most students were from Newcastle University. They also were allowed to form their group member.

- Users lack of familiarity with the tabletop mind map application, even though they had a short training session before the experiment. The training session lasted 15 minutes, which users may not yet fully be familiar with the technology. Furthermore, they had no experience with the tabletop but a mobile phone or a tablet. This unfamiliarity may cause the participants focus on learning how to use it rather than working on the task. This issue is a barrier to effective collaboration [Patel et al., 2012]. Users should be trained with appropriate training to improve productivity and user satisfaction.

- In terms of the application features, when users put many ideas, the screen seems cluttered. Therefore, to improve this feature, the application should be able to group nodes, as well as in the Android mind map application.

- One of the main issues is the tabletop itself. From the observation, the sensitivity of the tabletop can detect any object such as paper, users' arms, users' clothing and reflection of the sunlight. These may cause issues with the usability of the tabletop.

- This study supports only touch input. It may not help some participants who preferred to use a stylus work with the tabletop rather than using their fingers.

## 6.6 Summary

This chapter discussed the results obtained from the experiment one and the experiment two. Four main variables were discussed: performance, collaboration, usability, and emotion attitudes.

*Performance:* There were no significant differences between the two considered condition in both experiments. However, the means for the computerised tools were higher than the traditional conditions in the *effectiveness* factor.

*Collaboration:* The results showed that there was a significant difference between the tabletop over the pen-and-paper conditions in experiment one. However, no significant found in experiment two. In terms of experiment two, even though the results found no significant differences appeared between the two conditions (p=0.059), the results showed that the mean and the median for tabletop conditions were higher that the pen-and-paper conditions. It can be summarised that the combination of the tabletop and tablets encourage people to work collaboratively.

*Usability:* The results clearly indicate that the interactive tabletop is more enjoyable to use than pen-and-paper approaches. Furthermore the combination of a tabletop and personal devices support and encourage multiple people to work collaboratively.

*Emotion attitudes:* The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the pen-and-paper approaches in both experiments.

# Chapter 7

# Conclusion

The research examined the effectiveness of interactive tabletops for the creation of mind maps and compared these with the use of traditional pen and paper approach in the context of collaborative work. The proposed application was designed to support multiple users, support simultaneous user actions, consider the appropriate arrangement of users, support individual differences, and support transition between individual and collaborative work. The design aims to encourage users to collaborate more efficiently.

This research focuses on tabletops that people can work together in a situation of synchronous co-located collaboration. The main aim of this research was to investigate the effectiveness and the usability of the tabletop mind map system in the context of support for collaborative work. The principal objectives of this research were as follows:

1. To increase an understanding of the use of interactive tabletops in the context of collaborative work.

2. To review the existing tabletop applications and identify challenges and weaknesses in this regard.

3. To design and implement a framework for collaboration using tabletops.

4. To evaluate the approach by conducting experiments.

5. To propose design guidelines for tabletop application in the context to collaborative work.

So as to achieve the research aim and objectives, a methodology was prepared to cover all research aspects. The tabletop mind map system were developed. The system consisted of two components: tabletop application and Android application. Both application were desired to support touch input. The applications was adapted from Buisine et al work as explained in Chapter 2. Table 7.1 gives a summary of TMM and the proposed applications features.

The Tabletop Mind-Maps (TMM) application used MERL DiamondTouch Dietz and Leigh [2001] which was conducted with the DiamondSpin toolkit. The TMM mind maps were built top-down from the root label. All users could create or move nodes but editing these nodes must be consensual.

The proposed tabletop application in this study run on Touchscape table. The tabletop application code was in C# using the Surface 2.0 SDK. The application placed the central idea at the centre of the tabletop display. Users could either create the node by tapping the "add a new node" menu in front of them or using the node's ElementMenu. This application supported multiple display.

Table 7.1 Summary of the TMM approach described

| **Aspects** | **TMM approach** | **Our approach** |
|---|---|---|
| Flow | Top-Down | Top-Down and Freedom |
| Editable | Yes | Yes |
| Input devices | A wireless Keyboard | Soft Keyboards and Tablets |
| Multiple Display | No | Yes |
| Tabletop | DiamondTouch | Touchscape |
| Toolkit | DiamondSpin | Surface SDK |

After the system development, the system usability test scenario were designed. Two experiments were conducted. Experiment one compared tabletop without personal devices and pen-and-paper condition. This experiment recruited 40 participants. Finally, experiment two compared combination between tabletop and personal devices with pen-and-paper condition. This experiment also recruited 40 participants.

A number of quantitative and qualitative data were gathered from observation of naturally occurring activities. All groups were observed by the researcher, who took notes throughout. The collected data consisted of an observation form, and field notes. The study did not focus on the accuracy of the information presented in the mind-maps. After using the system, each user had to quantify their impression on a 5-point and a 10-point Likert scales for the satisfaction and emotional attitudes sections respectively. They were also particularly prompted to complete with free qualitative comments.

The results were divided into four main factors:

*Performance:* There were no significant differences between the two considered condition in both experiments.

*Collaboration:* The computerised tools encouraged people to work collaboratively.

*Usability:* The interactive tabletop was more enjoyable to use than pen-and-paper approaches. Additionally, the combination of a tabletop and personal devices support and encourage multiple people to work collaboratively.

*Emotion attitudes:* The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the paper-and-pen approaches in both experiments.

## 7.1 Summary of Contributions

This thesis had provided a number of key contributions to address in the area of supporting collaborative work using interactive tabletop. These are summarised below:

- The design of the table mind map system for collaborative work. The requirements for the developed system were based on a review of previous literature and also on requirements elicited from potential users. The design was guided by the work of Bachl et al. [2010] which presented the challenges for designing user experience and a given specific guidelines for co-located collaboration by Scott et al. [2003]. The design of the system aims to 1) support simultaneous user actions 2) consider the appropriate arrangement of users 3) support individual differences and 4) support transition between individual and collaborative work. The system allow multiple users input and have their own visual keyboard. Also it is able to distinguish between individual users. Any object on the table is able to rotate, resize and relocate freely. Moreover, users are able to use a personal device to view contents on the surface.

- The implementation of the tabletop mind map system. The proposed implementation consists of two main components: tabletop mind map application and Android mind map application. The tabletop mind map component was for supporting users work simultaneously in the same surface. To support privacy and may help the creativity and feeling well of participants, the Android hand-help component was developed.

- The evaluation of two controlled laboratory experiments. The first experiment compared the use of our mind map application with pen-and-paper condition. The second experiment combined our tabletop mind map application with personal devices and compared this combined application with the conventional approach. The results clearly indicate that the combination of a tabletop and personal devices support and encourage multiple people to work collaboratively. The comparison of the associated emotional attitudes indicates that the interactive tabletop facilitates the active involvement of participants in the group decision making significantly more than the use of the pen-and-paper approach.

## 7.2 Future Work

The following points summarise some suggestions for future work that may extend and improve this work.

- This study involved 80 students for participating. We believe that the proposed tabletop applications can be applied for any collaborative work and decision making. Therefore, it would explore the usability of this system by conducting experiments with a wider range of potential users such as health care teams.

- To avoid unfamiliarity with the digital tools, training sessions would be in an appropriate and longer way to improve productivity and user satisfaction. Another way to extend this research is to investigate by observing users applying the applications in real situations. This might achieve further collaboration style results and significant discussions.

- The current tabletop mind map applications consisted of two components: tabletop application and Android application. The results reported clearly that the combination of a tabletop and personal devices support and encourage multiple people to work collaboratively. Therefore, it would be developed for other platforms such as iPad to enhance collaborative work.

- Virtual keyboards were used in the study. The results also showed that the keyboards encouraged users to produce more ideas than pen-and-paper conditions. However, touch screen technology does not provide tactile feedback when touched, compared to a physical keyboard. Bachl et al. [2010] also suggested this design challenge could improve performance of the use of interactive tabletop. Consequently, user tactile feedback is still need to be explored.

- To enhance the power of the tabletop, the system should provide alternate touch input such as using a stylus or tangible. The art of drawing should be considered to be added in the future.

- Ergonomics must be concerned in collaborative work. The height of the tabletop might impact users while interacting with the table.
- In this study, the experiments took place in a research room. It might lead users felt uncomfortable to work. Also, the ambient environment (e.g. light, air and temperature) may impact the outcome of satisfaction and performance of users. Hence, we believe that the ambient environment of the workplace should be considered in the future.

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# Appendix A

# Questionnaire

## A.1 Experiment One

# Questionnaire: How interactive tabletop system influences collaboration?

We are interested in your views about our tabletop software that we are studying on interactive tabletop system influences collaboration. Please fill in this questionnaire and give as much information as you can. This survey should take no more than 10 minutes to complete.

Thank you very much for your co-operation and your helps.

**Section A – About you**

A-1 Gender ☐ Male ☐ Female

A-2 Age ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 45+

A-3 Ethnic origin
☐ White
☐ Black
☐ Mixed
☐ Asian
☐ Others ……………………………………………………………………………

A-4 What is your mother tongue? ……………………………………………………………………………

A-5 How long have you been residing in the UK? …………………………………………………

A-6 Are you studying in Newcastle University?
☐ Yes ☐ Master Student in …………………………………………………
☐ PhD Student in …………………………………………………………
☐ No. ……………………………………………………………………………………………………

A-7 How long have you been using computers?

☐ Less than 1 year ☐ 1-5 years ☐ 6-10 years ☐ 11-15 years ☐ More than 15 years

A-8 How many hours a day do you spend using computers?

☐ 0 ☐ 1-3 ☐ 4-6 ☐ 6-10 ☐ 10+

A-9 Please list your favourite top 3 computer software tasks

1. ………………………………………………………………………………
2. ………………………………………………………………………………
3. ………………………………………………………………………………

**Section B** – This section of the questionnaire explores your satisfaction and your emotion into our study.

---

B-1 Please rate your agreement with the following statement

| Statement | Flip Chart | | | | | Tabletop | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Agree | | | | Strongly Disagree | Strongly Agree | | | | Strongly Disagree |
| 1. The device was easy to use | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. It was fun | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. It was agreeable | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I was satisfied | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. I collaborated with other participants | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I had a lot of ideas | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I had high quality ideas | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I was motivated to do well | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. The results are important to me | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I tried to do my best | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

B-2 Please rate your emotional level during the brainstorming with the following statement:
(0 = lowest emotional intensity; 10 = highest emotional intensity)

| **Emotional** | **Flip Chart** | | | | | | | | | | **Tabletop** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 11. Alert | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. Anxious | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. Calm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. Happy | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. Depressed | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. Energetic | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. Enthusiastic | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. Tired | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. Sad | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. Relaxed | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. Tense | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. Bored | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Are there any additional comments you would like to make?

______________________________________________________________________________

______________________________________________________________________________

## A.2 Experiment Two

## Questionnaire: How interactive tabletop system influences collaboration?

We are interested in your views about our tabletop software that we are studying on interactive tabletop system influences collaboration. Please fill in this questionnaire and give as much information as you can. This survey should take no more than 10 minutes to complete.

Thank you very much for your co-operation and your help.

**Section A – About you**

A-1 Gender ☐ Male ☐ Female

A-2 Age ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 45+

A-3 Ethnic origin
☐ White
☐ Black
☐ Mixed
☐ Asian
☐ Others ……………………………………………………………………………

A-4 What is your mother tongue? ……………………………………………………………………………

A-5 How long have you resided in the UK? …………………………………………………

A-6 Are you studying at Newcastle University?
☐ Yes ☐ Master Student in …………………………………………………
☐ PhD Student in …………………………………………………………
☐ No. ………………………………………………………………………………………………

A-7 How long have you been using computers?

☐ Less than 1 year ☐ 1-5 years ☐ 6-10 years ☐ 11-15 years ☐ More than 15 years

A-8 How many hours a day do you spend using computers?

☐ 0 ☐ 1-3 ☐ 4-6 ☐ 6-10 ☐ 10+

A-9 Please list your favourite top 3 computer software tasks

1. ………………………………………………………………………………
2. ………………………………………………………………………………
3. ………………………………………………………………………………

**Section B** – This section of the questionnaire explores your satisfaction and your emotion into our study.

B-1 Please rate your agreement with the following statement

| Statement | Flip Chart | | | | | MindMap System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Agree | | | | Strongly Disagree | Strongly Agree | | | | Strongly Disagree |
| 1. The device was easy to use | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. It was fun | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. It was agreeable | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I was satisfied | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. I collaborated with other participants | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I had a lot of ideas | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I had high quality ideas | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I was motivated to do well | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. The results are important to me | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I tried to do my best | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

B-2 Please rate your emotional level during the brainstorming with the following statement:
(0 = lowest emotional intensity; 10 = highest emotional intensity)

| **Emotional** | **Flip Chart** | | | | | | | | | | **MindMap System** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 11. Alert | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. Anxious | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. Calm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. Happy | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. Depressed | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. Energetic | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. Enthusiastic | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. Tired | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. Sad | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. Relaxed | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. Tense | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. Bored | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

B-3 Please rate your satisfaction on aspects of integrating of the tabletop and the Android devices.

| Statement | Strongly Agree | | | | Strongly Disagree |
|---|---|---|---|---|---|
| 23. How well does the data transfer from the tabletop to personal device and vice versa? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. How well does the interaction with the tabletop and personal device? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25. This system had the quality of group creativity | ☐ | ☐ | ☐ | ☐ | ☐ |
| 26. This system provides collaborative working opportunity | ☐ | ☐ | ☐ | ☐ | ☐ |
| 27. This system has motivated me. | ☐ | ☐ | ☐ | ☐ | ☐ |

B-4 Please rate your satisfaction on aspects of collaborative support with the following statement:

| Statement | **Flip Chart** | | | | | **MindMap System** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Agree | | | | Strongly Disagree | Strongly Agree | | | | Strongly Disagree |
| 28. How well does the system support collaborative working? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 29. How well did the system support you to discuss the particular information with the other users? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 30. How well did the system support you to view the other was talking about? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 31. How well could you show information to the other person? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Are there any additional comments you would like to make?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

# Appendix B

# Consent Form

# Consent Form

**TITLE OF RESEARCH: Supporting Collaborative Work using Interactive Tabletop**

**NAME OF STUDENT: MISS Kanida Sinmai**

*I hereby give agree to participate in the research being carried out for the above research. I confirm that I understand participation is voluntary and that I can withdraw from the project at any time, without needing to give a reason.*

Thank you for agreeing to take part in this research.

The researcher will provide a written document for you to read (*or refer to statements above*) before you agree to take part. If you have any questions arising from this, ask the researcher before you decide whether to take part. You will be given a copy of this consent form to keep.

*I confirm that I have read the statement provided for the above research project and have had the opportunity to ask questions.*

| | | |
|---|---|---|
| Name of participant | Date | Signature |
| Researcher | Date | Signature |

# Research Consent Form

*This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.*

**TITLE OF RESEARCH: Supporting Collaborative Working and Decision Making using Interactive Tabletop**

**NAME OF STUDENT: MISS Kanida Sinmai**

**Experiment Purpose**

The purpose of this experiment is to observe and record the ways that computer users solve certain tasks.

**Procedure**

This session will require about an hour of your time. You will be asked to fill in a short questionnaire about your experience with the system and then to solve two or more problems using common applications on a conventional paper-and-pen approach and a tabletop. You may be asked to repeat variations of the problems. None of the tasks is a test – our objective is to find out how you approach the tasks.

**Data Collection**

A questionnaire will be used to gauge your computer experience at the beginning of the session. The researcher will take notes your actions as you work on the task. There will be no video or audio recorders.

**Data Archiving/Destruction**

Data will be kept securely. The investigator will destroy study data after it is no longer of use. Usually, this will be at the end of the research project when results are fully reported and disseminated.

**Confidentiality**

Confidentiality and participant anonymity will be strictly maintained. All information gathered will be used for statistical analysis only and no names or other identifying characteristics will be stated in the final or any other reports.

**Agreement**

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to take part as a participant. In no way does this waive you legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to not answer specific items or questions in interviews or on questionnaires. You are free to withdraw from the study at any time without penalty. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact the researcher.

______________________________ __________ ______________________________

Name of participant Date Signature

______________________________ __________ ______________________________

Researcher Date Signature