Ubiquitous Personalisation at Interactive Surfaces

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Abstract

Interactive surfaces have the ability to provide information to multiple users in public venues, such as museums. They may be located ubiquitously throughout the environment, to support users in performing various tasks wherever they may be. Although such surfaces provide a wealth of applications that may be engaging and useful, there has been minimal work on exploring how personalisation may be applied. The value of personalisation lies in its ability to assist the user with locating information more efficiently as well as navigating the user interface, perhaps through the use of personalised gestures or arranging the interface to suit the user. In addition to providing ubiquitous personalisation for individual users, we must also allow *groups* of users to receive personalised experiences, as interactive surfaces are typically shared amongst multiple people.

This honours thesis explores the concept of presenting personalised interfaces on an interactive tabletop. A key component of personalisation includes the user model, which is similar to a profile of the user's interests and preferences. The information within the user model is used to provide an interface that is tailored to the user. It was identified that user scrutiny was an important factor to consider when applying personalisation, as users may have privacy concerns when releasing their personal information. The ability to provide personalisation for groups of users was also a key issue to address. This thesis contributes a novel tabletop application, MyMenu, which provides the ability for users to personalise a restaurant menu and to examine how this process occurs. An evaluation of the personalised tabletop interface revealed that it was usable, learnable and provided an effective means for allowing users to understand the personalisation process. Importantly, the collaborative nature of the study provides insights into how personalisation at tabletops may be achieved in group work settings. The work resulting from this thesis may be generalised to other interactive surfaces and provides a foundation for further exploration of ubiquitous personalisation.

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To my parents,

Thank you for providing me with daily meals and a roof to sleep under. Without these basic building blocks of life, accomplishing anything would be an immense struggle. You have always been loving and caring, watching over me and you have taught me many things that are important to life, for which I am eternally grateful. Thank you.

Preface and Notes

Use of Work by Others

The software for the tabletop interface presented in this thesis has been built using Cruiser (Apted, 2008), an existing software framework for developing tabletop and surface applications. Some of Cruiser's built-in features are included in the software and discussed in parts of this thesis. These include the black hole and browsers. Their functionality and implementation are detailed in (Apted, 2008).

The functionality regarding personalisation has also used the TabletopUM framework (Kim, 2011), which includes a mobile application (called UMController) that may be used to exchange information with Cruiser for the purposes of personalisation. The mobile application was slightly modified for the study in this thesis to improve the usability of the application. Within TabletopUM is PersonisJ, which is a client side user modelling framework developed by the CHAI Research Group at the School of Information Technologies, The University of Sydney.

Human Ethics

The user study presented for this thesis was conducted under human ethics protocol number 15020, approved by The University of Sydney Human Research Ethics Committee. All of the documents given to participants (e.g. information sheets and consent forms) are included in Appendices B–E.

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CHAPTER 1

Introduction

Interactive surfaces, such as tabletops and wall displays, are found in many different locations and are used for a wide range of purposes. In particular, tabletops have the ability to deliver information to many users at once and can support tasks that require collaboration between a group of people. For example, a tabletop may act as an information kiosk in public locations, such as museums, to provide information about that location.

The notion of *ubiquitous computing* envisions that computer systems will become integrated into our surrounding environment (Weiser, 1991). This applies to interactive surfaces, including tabletops, and has resulted in a need for personalisation at these devices. Ubiquitous personalisation posits that users will be able to approach any kind of device, including surfaces, and engage in activities that are personalised for them. Many applications could benefit from personalisation so that users may receive better support in achieving their goals or tasks. For example, when searching for documents at a tabletop, personalisation could adapt search results to each user, allowing for better efficiency when looking for information.

However, due to the multi-user nature of tabletops, integrating personalisation is particularly challenging because existing methods are targeted at single users and, as such, do not translate easily to multi-user scenarios. There are also challenges with storing information about the user that is necessary for personalisation, as confidentiality of personal data needs to be respected, and also enabling them to examine how their information is used for personalisation.

This thesis presents a conceptual framework that has been developed to achieve personalisation at interactive tabletops which addresses the aforementioned challenges. The approach involved developing a tabletop application that presented restaurant menus, which could be personalised to provide recommendations of dishes that the user might be interested in. Importantly, the interface also supported personalisation for groups of users, by making recommendations for all of them together. This thesis also presents an evaluation of the tabletop interface for its effectiveness in facilitating personalisation for collaborative use, including the results of a user study that was conducted. Although this research focuses on interactive tabletops, the conclusions are shown to be generalisable to other interactive surfaces as well.

1.1 Definitions

Personalisation: The process of providing information that is tailored or adapted to the user's interests.

Ubiquitous Personalisation: The concept of personalisation being available and consistent to a user across different devices in many physical locations.

Interactive Tabletop: A table with a surface that provides a digital interface to allow multiple users to interact.

User Modelling: The concept of gathering information about an individual and storing that information in some location so that it may be retrieved later on for purposes such as personalisation.

1.2 Motivation

The motivation for personalisation comes largely from being able to meet the needs of the user. A user who interacts with an application will commonly have a purpose or a goal, such as a task to complete. Personalisation is one method of supporting and simplifying the processes that users need to undertake, so that their goals may be achieved more efficiently. In particular, information retrieval and recommendation services have been identified as areas which could benefit from personalisation (Dolog, Henze, Nejdl, and Sintek, 2004).

Information retrieval refers to the user's task of locating particular information while interacting with a computer. Personalisation could be used as a technique of allowing users to search for information that is tailored to their own preferences or interests. For example, a programmer may search for resources on concurrent programming in Java. A system without personalisation would simply return all results related to the topic. However, a personalised system would be able to take into account the experience and skill level of the programmer in order to retrieve results that are suitable for her. This idea of personalised information retrieval has been termed *personalised search* (Dolog et al., 2004).

Personalisation has also been viewed to play a significant role in *recommendation services* (Berkovsky, Kuflik, and Ricci, 2007). The ability to recommend certain information or items to users has a wide range of potential benefits in many different areas. In e-commerce, recommender systems could provide users with suggestions on products and services they may like (Berkovsky et al., 2007). In e-learning, recommendation services may be able to suggest resources that the user may find helpful, based on their level of understanding of certain topics (Dolog et al., 2004). Both of these examples involve personalisation, in the sense that they focus on delivering a tailored service that is appropriate and valuable to user.

Related to the notion of personalised search is the handling of information overload. With the ever increasing amount of information on the Internet, users are presented with the problem of having to look through large amounts of data to find exactly what they need. A personalised system would be able to address this problem by filtering out irrelevant information and providing additional information that the user might be interested in (Gauch, Speretta, Chandramouli, and Micarelli, 2007).

In addition to the situations just described, which focus on personalising content in the output, personalisation may also be applied to user input. By allowing the user to have their own personalised input mechanisms to an interface, their experience with using it could be simplified, thereby improving their productivity and efficiency of task completion. For example, different types of personalised gestures could correspond to different actions that should be executed. There are some commercial applications that provide support for custom gestures, one of which is All-in-One gestures [1], which is a Firefox plugin that enables the user to use mouse gestures to perform functions such as page navigation. Such personalised gestures may be extended to interactive tabletops, which could simplify the user experience for many users interacting at the same time.

1.3 User Scenario

The following user scenario depicts how a personalised application may be used and illustrates the motivation for personalisation and the approach to this thesis.

Anna, Bill and Charles are at an Italian restaurant for dinner. Whenever the trio go out for dinner together, they always try to order a selection of dishes that suits everyone. In particular, Bill can only

[1]https://addons.mozilla.org/en-US/firefox/addon/all-in-one-gestures/

eat gluten free foods, Anna is allergic to peanuts and Charles is vegetarian. The table they are seated at is interactive and allows them to view the restaurant menu. The group decides that they will order a pizza to share and then an individual dish each. Each person then places their mobile phone on the table and starts an application that connects to the tabletop. They use the application to send information to the menu about their dietary preferences and requirements. The menu is then updated to provide a list of dishes that satisfy all of their requirements. They look through the list of pizzas, all of which contain no gluten, peanuts or meat, and agree on one to share. Each person then takes a menu for themselves so that they can choose their individual dish. They use their mobile application again to send their dietary information to their own menu. Each menu is then updated to provide a list of recommended dishes for the person who personalised it. Bill is able to see why certain dishes were recommended for him by pressing an "Info" button on the menu. After selecting a menu item each, Anna, Bill and Charles place the order.

In this scenario, the users' interactions are enhanced by the interface being personalised to each of them. Firstly, the use of the mobile device in sending information about the user's preferences implies that this information is stored on that device. This concept of user modelling will be discussed in detail in Section 2.2. Also, the group is able to personalise a menu together in order to achieve a result that takes into account all of their preferences. This demonstrates an interface that is personalised for the group, which is important, as tabletops support collaborative tasks for groups of users. Finally, Bill is able to find out why certain dishes were recommended for him, which allows him to understand how his personal information has been used by the application. Although this simple scenario is targeted towards restaurants, personalisation can have significant benefits for a range of other applications, such as medical consultations, health goal management and education. Some of these will be explored later in this thesis.

1.4 Challenges

Users will often move between different interactive devices on a daily basis to carry out various tasks. The distributed nature of these devices poses a challenge for personalisation, as it is difficult to conceive a model that allows every device to have some knowledge about every user who interacts with it. Interactive surfaces fall into this situation, as they are often found in public spaces. The idea of ubiquitous personalisation, where users may interact with any device and still receive a personalised experience, aims to solve this problem. The goal is to allow the user to receive personalised services seamlessly, unobtrusively and independent of the device they are using, which will be a key point to explore in this thesis.

Another challenge that needs to be addressed is maintaining privacy of personal information. The benefits of personalisation are paralleled by issues regarding the storage and use of private user information that is required for personalisation. Toch, Wang, and Cranor (2010) present an analysis of privacy issues with regard to recent developments in personalisation technologies, namely social-based and location-based personalisation. In social networking services, large amounts of user data are gathered, such as lists of friends, personal photos and inter-personal communications, which may be used for purposes such as personalising applications and online marketing. Although the user may find this customisation useful, there are risks associated with the handling of sensitive information over the web. Interactive tabletops themselves may be considered as untrusted devices. As tabletops are often contained in public venues, users will not want the tabletop to retain their personal information after they have finished interacting with it. Section 2.2.2 provides a further discussion on security and privacy issues with personalisation and ways to address this problem. Additionally, users have the right to know how their personal information is used by applications. Hence, the concept of scrutability, which is discussed in Section 2.2.3, is also a challenge that must be taken into account.

The fact that current methods of personalisation are primarily targeted at single users presents another issue for personalisation. The key value of tabletops and other shared display environments is in facilitating group interaction and collaboration. Hence, a key challenge that needs to be addressed is in allowing for multiple users to receive personalised experiences. This may be considered at two different levels. The first addresses the issue of personalisation for each user at the tabletop individually without regard to other users. The second level takes into account the presence of all users at the tabletop in order to provide personalisation to the group as a whole.

1.5 Thesis Goals

The goal of this thesis is to develop a novel, personalised application at a tabletop. Importantly, the application should address the numerous challenges that have been described. In particular, the design of the application should be made to allow multiple users to receive personalised experiences at once, both at the individual level and at the group level. The challenges of maintaining privacy and allowing users to scrutinise the use of their personal information will also need to be addressed.

Another goal is to evaluate the personalised application by studying its use in the context of a small group of users. This will be done by designing a user study to examine how users interact with the application and to assess the effectiveness of the application's interface in its ability to provide personalised information to users.

Although the application is developed for an interactive tabletop, its design is generalised to allow it to be applied to any type of shared interface on an interactive surface. The personalised tabletop application forms part of a broader conceptual framework that aims to provide a solution to the research question of how personalisation may achieved in ubiquitous computing environments.

1.6 Contributions

The outcome of this thesis has made the following contributions to the research on personalisation at interactive surfaces:

(1) A tabletop application that demonstrates personalisation, in a group context, by providing users with the ability to personalise a restaurant menu to support health and dietary goals.
(2) An evaluation of this application for its effectiveness in providing personalisation for small groups of users.
(3) A novel, conceptual framework that enables effective personalisation at interactive surfaces through the design of the infrastructure and interfaces required to realise personalisation.

The first two statements are the key contributions of this thesis, which resulted from the implementation and evaluation of the approach to achieving personalisation at interactive tabletops. For the third statement, this thesis makes a secondary contribution, due to the analysis and design that was required to realise the functionality to achieve personalisation at the tabletop.

1.7 Thesis Structure

This thesis begins with an introduction to the research topic by first providing a definition of key terms to be used and then discussing the motivation, challenges, goals and contributions of the thesis.

Chapter 2 provides a literature review of the current research on three key areas that are central to this thesis: personalisation, user modelling and interactive tabletops.

Chapter 3 introduces the design of the conceptual model in enabling personalisation at tabletops and describes how this has been influenced by previous work. The conceptual foundations of the nature of tabletop interaction and personalisation are discussed.

Chapter 4 describes the approach and presents a walkthrough of the user interface of the personalised application.

Chapter 5 explains the technical details of how the application was implemented, including the software frameworks, data formats and algorithms that were used.

Chapter 6 presents the evaluation design, including the hypotheses to be tested, the experimental design and the procedure that was carried out in the user study.

Chapter 7 discusses the results from the evaluation and analyses the findings in terms of the hypotheses to identify features of the personalised interface that were effective and also those that were problematic for the users.

Chapter 8 closes the thesis by drawing conclusions from the results with reference to the goals. A discussion of future work that may be carried out to enhance the resulting personalised interface is also provided, followed by revisiting the contributions of this thesis.

CHAPTER 2

Background

This chapter provides a review of the current research on *personalisation*, *user modelling* and *interactive tabletops*. Current methods of personalisation will first be discussed, followed by a discussion of existing applications of personalisation. The concept of user modelling will then be introduced, providing an overview of its purpose and current uses in facilitating personalisation. In particular, key issues of existing user modelling systems will be identified and methods to address these will be explored. This will be followed by a discussion on developments in interactive tabletops and how initial concepts of personalisation have been explored for tabletops. Finally, a summary of the three key areas will discuss how user modelling may be used to enable ubiquitous personalisation.

2.1 Personalisation

In the context of computing environments, personalisation refers to the process of providing relevant content based on individual user preferences (Fan and Poole, 2006). This involves tailoring or adapting the user interface to support the needs of the user, thereby enhancing their interactive experience (Kramer, Noronha, and Vergo, 2000). Personalisation may encompass supporting personalised information access, such as adapting textual or visual content to the preference of the user, as well as the personalisation of input, to improve ease of use through mechanisms such as input gestures.

2.1.1 Components and Processes

Goy, Ardissono, and Petrone (2007) provide an overview of the components required for personalisation. The major components consist of: information about the *user* as well as information about the *device*.

Information about the user needs to be aggregated so that the system knows how to adapt the interface. Such information may include the user's knowledge, interests, preferences, needs and goals. This results in a repository of information about the user, which is often referred to as a *user model*. (An overview of *user modelling* is provided in Section 2.2). With regard to interactive tabletops, it would be beneficial to store the user information in a location that is readily accessible, since multiple users will interact with them.

The device information is important in providing the system with the environmental conditions that it must take into account when personalising information. Since every device has different characteristics such as screen size, input and output mechanisms and the type of network connection it uses, the way in which personalisation occurs will need to be adjusted to these characteristics. For multi-user interactive tabletops, this may mean that applications will need to adjust their content to fit the space available on the screen to cater for each user.

Goy et al. (2007) also describe the processes involved in personalisation, which include: the *acquisition* of user data, *inference* of this data and *production* of the final tailored result. One approach to obtaining user data is with the support of the user, where the user explicitly declares information about themselves. Alternatively, the system may autonomously gather data about the user based on their behavioural habits. For example, a system may use machine learning to collect data about a user from their search history. Inference of the data typically involves the use of rules or heuristics to determine how the personalisation shall be carried out. *Rule-based matching* involves analysing the data and then deciding what action to take based on certain conditions that are met. This is similar to the use of heuristic rules for recommendation services described by Dolog et al. (2004). Following the inference of data is the presentation of the final tailored result. For personalised information retrieval, this would include the personalised content itself and the presentation of the content adapted to the user and the device. For example, a user may be searching for information at an interactive tabletop and is only interested in images, so the result could be a series of images arranged to fit the display size.

2.1.2 Existing Applications of Personalisation

The benefits of personalisation have already been realised in multiple domains and as such, personalisation is being integrated into many different types of applications. There are currently numerous commercial systems that incorporate personalisation as well as research prototypes that aim to explore further applications of advanced interaction and personalisation features (Goy et al., 2007). A complete review of existing personalisation systems falls out of the scope of this thesis. Instead, a summary of personalisation systems in e-commerce, health and education will be discussed to provide a general idea of how it has been applied to support user needs. Additionally, a system which personalises input will be discussed briefly.

One of the most important factors that has been identified as being the key to success for e-commerce websites, such as *Amazon.com*, is in maintaining a one-to-one relationship with the customer (Goy et al., 2007). This has been the main motivation for exploring how personalisation can be used in online marketing to advance the growth of online business. The specific aim is to incorporate personalisation into the recommendation of products or items that the user may be interested in. One approach to doing this is to recommend products based on past items that the customer has purchased before (also known as *content-based filtering*) (Goy et al., 2007). Another approach uses the preferences of other customers and tries to match the current customer's profile to other similar customers. This in turn allows for product recommendation that targets similar customer groups (also known as *collaborative filtering*) (Canny, 2002). In both approaches, the recommended products are personalised for the user based on information that has been acquired about them. However, since the focus of these types of systems is typically one-to-one with the user, these methods of recommendation may not translate easily to a shared environment, such as an interactive tabletop. Hence, to achieve personalisation in this scenario, ways of extending current methods to suit multiple users need to be explored, which is a key challenge of personalisation.

Health and medicine is also an area which may benefit from personalisation. Cawsey, Jones, and Pearson (2000) present a thorough evaluation of a personalised health information system for cancer patients. Their motivation for experimenting with an adaptive system lies in the fact that medical information provided to patients is too general and not targeted at the patient's individual problems and interests. They created a system that would generate hypertext pages based on the patient's medical record and hypothesised that patients would prefer this personalised approach over a general one, since it would communicate details more relevant to the individual. The researchers designed a rigorous and thorough user study to evaluate their approach. A pilot study with fifteen patients was first run to determine the feasibilty of a full study. Upon success of the pilot study, the full study was run with 525 patients over three months and various evaluation techniques were used to gather data about the patients' thoughts and experiences on interacting with the system including questionnaires, surveys and interviews. They obtained statistically significant results across various measures demonstrating that patients indeed had a higher preference towards a personalised system, which confirmed their hypothesis. Interactive tabletops could be particularly useful for health applications, as it would allow patients and medical practitioners to examine various medical documents and records in an interactive manner. Hence, a personalised health application for a tabletop could be explored and evaluated for its effectiveness in supporting the user's goals related to health.

In the education sector, research has been carried out in examining how personalisation can support e-learning. Dolog et al. (2004) identify a problem with e-learning where learning resources that may be valuable to e-learners are distributed around many locations on the web, making it difficult to gather similar types of resources together. They developed a prototype system called *Personalised Learning Assistant* that aims to simplify the process of looking for learning resources by integrating several types of personalisation services. These services include *query rewriting*, a form of personalised search which refines the user's query based on their preferences and language capabilities and recommendation, which annotates resources with different levels of understandability specific to the user. An evaluation of the prototype was not carried out but labelled as further work to be done after additional personalisation methods were integrated. Tabletop interfaces may provide a supportive environment for e-learning applications, especially in a classroom setting, where a teacher may have several students to cater for. The ability for tabletops to support collaboration among users could provide a platform upon which to evaluate how personalised e-learning applications can be used in classroom education.

Santos, Pimentel, and Teixeira (2006) developed an architectural approach to support personalised input devices. They were motivated by users with disabilities, especially those with motor impairment, who may require specialised forms of input. Their work involved the development of a software architecture that enabled input devices to be personalised and example applications that they built to test it. One such application was a mouse cursor that could be controlled by head movements by means of gyroscopic sensor readings. Hence, this demonstrates the possibility of personalising input to accommodate the needs of the user. In the context of interactive tables, personalised input may include gestures that are unique to each user, whether they have a disability or not. By being able to use personalised gestures, users may find it easier to navigate through the interface to perform tasks more efficiently.

2.1.3 Personalisation for Multiple Users

The personalisation systems just described are predominantly for use by a single user. They may cater to the needs of many different individual users, but generally, they do not accommodate situations where groups of users are interacting with a single interface at the same time. The motivation for having multi-user personalisation comes from the move away from the desktop into more shared environments, which have the ability to support group interactions and collaboration (Jameson and Smyth, 2007). Information kiosks, wall displays and interactive tabletops are just some of these, and will be discussed further in Section 2.3.

There has been some research conducted on multi-user personalisation, especially with recommender systems. Masthoff (2004) used group modelling techniques to recommend television items to a group, while Ardissono, Goy, Petrone, Segnan, and Torasso (2003) presented INTRIGUE, a prototype that could support the recommendation of tourist attractions for groups. Jameson and Smyth (2007) provide a review of various group recommender systems, including the two just mentioned. By examining these types of systems, they identified the essential subtasks required when designing such systems. They concluded that recommending for a group of people can be very different to recommending for one person in some aspects, such as supporting the final decision of the group, which would not be needed for a single user. Jameson and Smyth (2007) also indicate that their conclusions on recommending to groups may be generalised to any type of system that provides personalisation. For example, in the area of personalised information access, a group of users may use an interactive tabletop to find certain information to plan a holiday together. If the system knows the interests of each user, it may be able to provide an optimised result for the group as a whole. The concept of multi-user personalisation is becoming increasingly significant with situations like the one just described, which means that alternative approaches to personalisation need to explored.

2.1.4 Summary

Personalisation is essentially a way of providing users with added support when carrying out tasks. There are already many systems in place that utilise personalisation for various applications in a desktop environment. However, since these types of applications are designed primarily for single user interaction, the majority of them do not address personalisation at the multi-user level, which is becoming more important at shared interface devices, such as tabletops. There are also a number of challenges associated with personalisation, such as achieving it ubiquitously and maintaining privacy of user information.

2.2 User Modelling

One of the necessary components required for personalisation is information about the user (see Section 2.1.1). The result of gathering such information may be considered as a user model, or user profile.

As the process of obtaining data about the user is fundamental to personalisation, there is extensive research that examines how user modelling can be used specifically for personalisation. Although user modelling may be used for other purposes, such as data mining (Webb, Pazzani, and Billsus, 2001), the focus here will be on its contribution to enabling personalisation and issues associated with this. Many existing user modelling systems have problems with security and privacy of information as described by Toubiana, Narayanan, Boneh, Nissenbaum, and Barocas (2010) and scrutability (Kay, 2008) is another problem that needs to be addressed. Such issues provide motivation for research into alternative methods of user modelling, which will be discussed in Section 2.2.4. The user modelling research is particularly important to consider for interactive tabletops. Due to the multi-user nature of shared, interactive environments, there exists the challenge of finding an elegant solution to store information about the users that may be used for personalisation.

2.2.1 Concept of User Modelling

Most of the structures and processes that were encapsulated by early user modelling systems were determined largely by developers' intuition and as such, there was a lack of empirical study into the specific components required of such systems (Kobsa, 2007). However, from a review of generic user modelling systems, Kobsa (2007) identified a list of important characteristics that are required of these systems. The main components include: generality and domain independence, so that the system may be used in different types of applications, and expressiveness and strong inferential capabilities, so that the data in the model may be used to form assumptions about the user.

In terms of how user information is obtained, this may be done either explicitly or implicitly (Bilenko and Richardson, 2011). In the former case, the user specifies what data to store by answering questions or filling out a form. In the latter case, data may be collected automatically by the system using intelligent inference techniques, such as machine learning (Goy et al., 2007). This may involve methods such as analysing the user's search history and activity on e-commerce websites like online shopping (Bilenko and Richardson, 2011). The collected information becomes a profile of the user which can then be accessed by applications to personalise content. For example, an interactive tabletop application may use this information to present documents where the text is in each user's preferred language.

As discussed by Kobsa (2007), user modelling plays a major role in web personalisation, which has consequently led to a large number of commercial personalised systems. Different types of web personalisation include behavioural or personalised advertising, where advertisements are adapted to the user

(Toubiana et al., 2010) and, as discussed before in Section 2.1.2, recommender systems, which provide recommendations to the user in domains such as news or buying online (Bilenko and Richardson, 2011). Both of these areas require access to user models and the accumulated data is often obtained implicitly by the system and stored on central servers. However, there are a number of concerns being raised about the notion of centralised data aggregation, including the security and privacy of user information (Bilenko and Richardson, 2011) and scrutability of the user model (Kay, 2006), which are discussed in the following subsections.

2.2.2 Security and Privacy

A key problem with server side aggregation is that it limits the user's ability to view and control what data is being stored about them (Bilenko and Richardson, 2011). Sensitive personal information could potentially be accessed by external third parties, which is not desirable for the user. As discussed by Bilenko and Richardson (2011), this has been demonstrated to be an issue in personalised advertising. Toubiana et al. (2010) have also shown that the protection of user information is a problem in recommender systems. Since the user's data is stored in a service's data centre, it may potentially be used for malicious purposes unrelated to the recommendation process, such as exchanging information for monetary benefit. The concerns regarding security in user modelling systems do not only apply to web personalisation. They may be generalised to any system that operates in conjunction with user modelling. For example, an interactive tabletop may contain applications that will need to access user specific data in order to personalise the interface. As users may use a range of different tabletops, it is equally important to address the problem of security in this domain as well.

The importance of ensuring user privacy provides a strong motivation for storing the user model on the client side (see Section 2.2.4). This puts the user in control of their own model, rather than in the hands of website owners or some remote service who could possibly use the information inappropriately. It would also enable the user to see exactly how their profile is structured and how their information is used in applications, which is discussed in the following section.

2.2.3 Scrutability

The concept of *scrutability* describes the ability for the user to scrutinise their user model to understand what the model contains and to see the processes that the system uses to make its inferences about them (Kay, 2006). The motivation for employing scrutable user models comes from the fact that users should have the right to see and appreciate the meaning of how their personal information is used by different applications. There may be cases where there are errors in the model and if these cannot be identified by the user, they would never be rectified and the system would continue to operate on false assumptions about the user. Additionally, scrutability allows users to exercise control over their model. One aspect of the model that may be controlled is the method by which information can go into the model. For example, the user may only permit data that they explicitly declare to go into the model. The sources of information may also be controlled, such as whether it comes from sensors, a user model interface or applications themselves. The user may also choose to control the flow of information out of their model, restricting applications to only have access to certain types of information about them. Such facilities allow the user to have a certain level of trust with the devices they use. For example, if the user receives a request from a tabletop application to use certain parts of their user model, they may accept or decline that request depending on what information is required.

Kay, Kummerfeld, and Lauder (2006) developed Personis, which is a user modelling server that specifically focuses on supporting user scrutiny and control. The role of Personis is to provide support for the reuse of user models to a series of adaptive hypertext systems. It uses an *accretion/resolution* approach to user modelling. *Accretion* involves the collection of evidence about the user through a *tell* operation and *resolution* involves the interpretation of the evidence through an *ask* operation, which would generate a result that could be used for purposes such as personalisation. Also, the user model was organised in a hierarchical structure of *contexts* to form an ontology of information that could be queried. Each context could have separate *components*, which were the basic elements of the user model that stored the *evidence*. In their description of the architecture of the Personis server, Kay et al. (2006) explain the use of a scrutiny interface contained within each hypertext application. This interface allows the user to examine and question their model in relation to core tasks of particular applications. This in turn allows them to understand why certain results were presented in a certain way and why these results may be different for other individuals. The concept of *views* is also explained, which essentially allows the user to control which parts of the model that applications have access to. Importantly, an evaluation of the performance of the server was carried out through empirical analysis. The results demonstrated that the Personis server would scale well, being able to handle a growing database of user model information. This is important, as the user model may constantly have information being added to it.

2.2.4 Client Side User Modelling

As indicated previously, the motivation for user modelling on the client side comes from the necessity to protect private user information as well as the importance of allowing users to scrutinise their user model to understand its purpose. It would seem that storing the user model locally on the user's machine, rather than remotely, may be a solution that addresses these issues. In particular, if the user model were to be contained within a mobile device, this would allow users to have the convenience of releasing their model to devices in different locations, such as interactive tabletops. However, problems may arise from moving to the client side, such as questions of whether this technique is able to match the performance requirements of existing server-based systems (Bilenko and Richardson, 2011). Such problems pose challenges for client side user modelling, which need to be explored further to determine the value and feasibility of such an approach. A review of current systems which use a client side approach, and the way in which they address the above issues will now be presented.

PersonisJ is a framework for developing context-aware, personalised applications on a mobile phone (Gerber, Fry, Kay, Kummerfeld, Pink, and Wasinger, 2010), which shares similarities in the user model structure with Personis (discussed in Section 2.2.3) in its structure. It is an Android application that stores the user model on a personal device, allowing other applications to access this model under certain conditions. Having the user model contained in a mobile device was also posited by Kobsa (2007), who states that mobile user models will play a significant role in ubiquitous computing environments. One of the major strengths in storing the user model on a mobile device lies in the portability aspect - the user is able to carry their user model wherever they go and connection to a network is not required to access the model. This is closely linked to the idea of ubiquitous personalisation, where users can move between different environments and still receive personalised experiences. PersonisJ itself was demonstrated to work in conjunction with a mobile application that provided personalised information about museums and the researchers presented a walkthrough of the processes involved with accessing the user model. The researchers evaluated the scalability of the PersonisJ framework, addressing the performance issues with client side user modelling. They conducted an empirical study to compare the time performance of the PersonisJ *ask* and *tell* operations against some simple operations such as *String.length()*. The results indicated that PersonisJ was able to run efficiently for the tasks required of it and that the space required by the framework was negligible compared to most Android applications. It was noted that a growing database for the user model could pose issues, which could be addressed by archiving data. Overall, PersonisJ was shown to be effective in serving its purpose as a client side user modelling framework.

However, the lack of an in-depth user study into its value motivates further exploration into how it may be used to manage personalisation, both at the single and multi-user levels.

Bilenko and Richardson (2011) explored the application of client side user profiling for personalised advertising. Many of the existing advertising platforms match keywords to user data in order to deliver personalised advertisements. As a form of web personalisation, online advertising is one area that is experiencing the concerns of privacy with aggregating and storing user data on central servers. The researchers proposed an approach that stores user profiles on the client side. Since the profile resides on the user's machine, data will only be sent to the server when required. After performing updates on the user profile at the server side, the profile is returned to the user along with the personalised response. The key difference between this approach and the server side approach to user modelling is that no information associated with the user is retained on the server, thereby maintaining privacy of the user's information. However, this relies on the compliance of the remote service not to retain such information, so this solution may not be ideal in terms of security. Nevertheless, this form of user profiling also allowed users to inspect, edit and delete elements of their model, providing scrutability and control over their model. An empirical evaluation was carried out by adjusting the values of each variable (such as number of keywords and cache size) in the client side profile and comparing the resulting performance to equivalent conditions for the server side approach. The results demonstrated that client side profiling could capture up to 97% of the revenue gain achieved through server side profiling. Hence, the practicality of user modelling on the client side was validated and shown to be effective.

2.2.5 Summary

The general concept of user modelling has been discussed, including examples of how current systems are implemented. The challenges of user modelling, including security and scrutability were also presented, with client side user modelling being suggested as a possible answer to solving these problems. A discussion was given on how storing the user model on a mobile device would provide portability and convenience of achieving personalisation in a ubiquitous computing environment. A portable user model may also provide a solution to achieving personalisation for multiple users, which is a key challenge at shared interfaces, such as interactive tabletops.

2.3 Interactive Tabletops

Interactive tabletops may be used for collaborative tasks among groups of people in many domains. Along with interactive walls and other multi-user displays, they are a form of *single display groupware* (SDG), which models a system as having a shared user interface with multiple input channels (Stewart, Bederson, and Druin, 1999). In contrast to traditional groupware systems, which create applications that are intended to be run on multiple workstations across a network, SDG facilitates collaboration between collocated users in a shared local environment. Consequently, interactive tabletops may be used for applications that require support for localised multi-user interaction, such as information kiosks in public venues and for educational purposes in classrooms (Stewart et al., 1999). Among the large body of work done so far on interactive tabletops and their applications, only a minority of the literature has focused on how personalisation may be brought to shared environments or workspaces. A discussion on the ways in which personalisation would be able to enhance existing tabletop applications will be presented as well as its contribution to SDG in general. The challenges associated with implementing personalisation at tabletops will also be discussed.

2.3.1 Interactive Tabletop Applications

Traditional desktop computers are typically used by a single user at a time and as such, many applications are designed for one user. Although tabletop applications may also be used by a single user, this does not take advantage of the shared interface a tabletop can provide. Hence, existing research into tabletop applications focus on supporting multiple users in a collaborative setting, which will now be discussed.

Morris, Paepcke, and Winograd (2006) developed TeamSearch, which is a tabletop application that enables a group of people to search through a digital collection of photos that are annotated with metadata, such as names of people in the photo and when it was taken. Users formulate queries by dragging tokens to designated areas that represent "search terms". For example, a user may place a token on "John" to search for photos of that person. The resulting photos that match the query search terms are displayed as thumbnails in front of each user and may be enlarged for closer inspection if desired. The application was implemented with two different styles of querying: *collective* and *parallel*. In the collective style, the system considers all tokens collectively as a single query no matter which user placed them, while in the parallel style, each user may form distinct queries with their own uniquely coloured tokens. The reason for having these two different styles was to evaluate whether a group of users working collaboratively was more appropriate than each user working individually in searching through the collection. If personalisation were also to be applied in both situations, it could be evaluated for its effectiveness in supporting the search process.

To evaluate TeamSearch, Morris et al. (2006) conducted a user study with sixteen participants, where groups of four users were asked to search among a collection of seventy-five photos to create a photo album. Their interactions were logged by the system and each user was asked to complete a questionnaire, giving details of their experiences. The results from the study indicated that the collective style of querying was effective in allowing users who were not as familiar with query-formulation to learn from those who were more confident. Although this was a positive conclusion, personalisation may be an alternative way of addressing this issue. If the user's level of skill with formulating queries were known to the system, it could perhaps adjust the interface so that they have the required assistance with using the application. Additionally, the query formulation process could also be initiated by having knowledge about the user's interests.

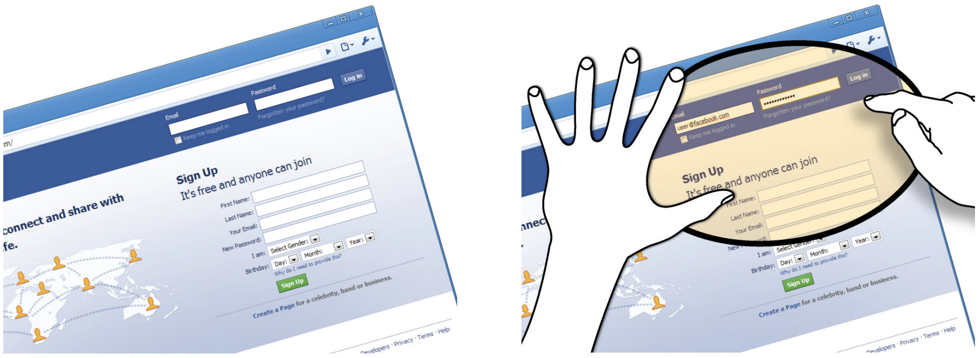
Another area in tabletop research that could potentially benefit from personalisation is in file system access. Collins, Apted, and Kay (2007) developed two different interfaces for accessing files at a tabletop. The first of these was called *OnTop*, which provided *associative* file access where a user selects a file of interest to initiate a search of all "related" files. The second interface was *Browser*, which allowed *hierarchical* access to files, similar to typical interfaces found in current operating systems. Both interfaces were designed to be able to access files across multiple file systems, which was motivated by the idea of information sharing among users at a tabletop. For example, users may use a tabletop to work on an assignment together, so the file systems available may be information from research that each user has done. An evaluation was conducted to gain a qualitative understanding of both the associative and hierachical approaches to file access. Ten participants were recruited to perform various collaborative tasks in pairs. Such tasks involved the pairs locating specific files related to a given topic and deciding together which ones should be included in a museum exhibit. The key results indicated that the associative approach facilitated better collaboration among users and that users seemed to display a stronger ownership of their files with the hierarchical approach. Importantly, the associative approach demonstrates a method of allowing multiple users to work together when locating information. This could be extended further through personalisation, as it would allow users to tailor their search to their own interests and preferences, not only with their own file system but other ones as well (provided they have permission to do so). The potential benefits of this would be increased productivity as well as efficiency with locating information.

2.3.2 Personalisation at Interactive Tabletops

Although there is a large amount of research on developing tabletop applications that allow collaborative interaction, there is still limited work on how personalisation may be applied to these types of applications. Among the current literature on personalisation at interactive surfaces, including tabletops, researchers have developed ways to adapt the interface to the user, such as modifying content on the display to suit the user as well as detecting user specific input. However, most of these novel systems do not address the issues discussed earlier in this chapter, such as those related to security and scrutability. A critical review of related work to personalisation at interactive tabletops will now be discussed, along with how their shortcomings may be addressed.

In previous work, Schmidt et al. (2010b) developed IdLenses, a novel interaction concept where users are able to generate their own personal space, or “lens”. IdLenses uses HandsDown (Schmidt, Chong, and Gellersen, 2010c) to identify users and is essentially a framework that facilitates the personalisation of input and output for each user. For example, to personalise input, a user may place their lens over the login fields for their email or preferred social network and have their credentials appear automatically, saving them from having to enter it manually (Figure 2.1). An example of personalised output would be to display the text within the lens in a predefined language determined by the user. Additional applications that could use IdLenses for personalisation include having a custom “toolglass” for each user, where a set of click through elements (like buttons) may appear on the lens which could lead to customised menus or other functions. Although there were many examples given of situations where IdLenses could be beneficial, the researchers did not provide details of any evaluation done in determining its effectiveness in such cases. This is an area that will be explored further along with examining how personalisation for groups of users may be achieved.

Identity-Differentiating Widgets (iDwidgets) is a similar framework to IdLenses that enables customised interactions amongst a group collaborating at a tabletop (Ryall et al., 2006). The notion of having user identity as a parameter to widgets (buttons, toolbars, scrollable lists) is presented and various demonstrations of applications of the concept are given. One such application is in customising content on the tabletop, such as lists and menus. A customised list could be a list of bookmarks, which would only display the bookmarks of the user who touches the widget, while a customised menu may reorder



(A) A regular protected webpage requiring login.

(B) Moving lens over login area fills in credentials automatically.

FIGURE 2.1. Example of personalised behaviour with IdLenses (taken from Schmidt et al. (2010b)).

items or only display certain items, based on the user who interacts with it. Another application was in customising the appearance of the interface. For example, if an elderly person is using a widget, the font size could be adjusted to be larger for improved readability. Both of these types of customisation demonstrate the personalisation of the interface, tailored to the user's preferences. As well as displaying personalised output, widgets for personalised group input were also described. For example, a voting widget may require input from multiple users at once. As with IdLenses, a formal study was not conducted to determine the value of the iDwidgets framework, which leaves further work to be done on evaluating such an approach to customising the interface.

Both Schmidt et al. (2010b) and Ryall et al. (2006) present two frameworks for personalising tabletop interfaces. However, a key component that neither framework specifies is where users define their preferences or personal information in order for personalisation to occur. In other words, there is no concept of a location where user data can be stored and retrieved as well as mechanisms to allow users to control the flow of such data. This motivates the notion of employing a user model (as discussed in Section 2.2), where information about each user can be stored and accessed whenever personalisation is necessary. Schmidt et al. (2010b) mention that mobile devices could be used as a proxy for their users in the IdLenses framework. This idea could be extended to include a user model on a user's personal device, so that they can always carry their model with them, as part of a client side user modelling approach.

Klinkhammer, Nitsche, Specht, and Reiterer (2011) created an interactive tabletop system that enabled the generation of personal territories on the interface. The tabletop was located in a public exhibition and presented detailed multimedia content about the exhibition. As users walk up to the tabletop, a region on the display appears in front of them, providing affordances to interact. Within this personal space, users may explore the various multimedia resources located on the system. If multiple users are interacting with the tabletop, a personal territory will be created for each of them and the system is able to track users as they move around the table. This concept of personal territories is similar to IdLenses (Schmidt et al., 2010b), where users are able to engage in personalised interactions within their own space. However, it has the similar problem of not specifying where user information is stored. Consequently, this provides a foundation upon which to explore how information from a user model may be used to personalise the territory for individual users as well as groups of users.

Kim (2011) developed a novel framework called TabletopUM that facilitates personalisation at interactive tabletops through client side user modelling. The user model is stored on a mobile device, and utilises the PersonisJ (Gerber et al., 2010) framework. In addition, a mobile application called UMController was developed to allow the user to control various aspects of their model. There were functions that allowed the user to connect to a tabletop so that it could access their user model, set permissions for which parts of the model could be accessed and view the outcomes of operations that were being made as information was transferred between the user model and the tabletop. A personalised tabletop application demonstrated the use of the framework, which was essentially a modification of Focus (previously OnTop, as discussed in Section 2.3.1). This application was used to demonstrate how information from the user model could be used to personalise the search interface that Focus provides. The TabletopUM framework was evaluated for its usability, learnability and understandability. Eight participants were recruited to perform certain tasks under a think aloud evaluation, such as connecting their user model to the tabletop and locating specific files related to a given topic. Although the analysis of the results did not seem entirely clear, it was generally shown that users had an overall understanding of the processes of the TabletopUM framework and that the interface rated positively for usability. However, it was noted that most participants did not understand that the user model was stored on the mobile device so this is an area that will be explored further. Additionally, the implementation and evaluation were targeted at single users only and thus does not encompass mutli-user personalisation.

2.3.3 Identifying Users

Enabling personalisation at interactive tabletops relies on the knowledge of who is interacting with the system. Consequently, the ability to first identify users at the tabletop is necessary for achieving personalisation (Schmidt et al., 2010b). A brief overview of user identification techniques will now be given.

DiamondTouch is a multi-touch interactive tabletop that is able to identify which users are touching the table (Dietz and Leigh, 2001). Each user sits on a chair that contains a receiver that is part of an electrical circuit. When a user touches the table, the electrical circuit is completed between the user and the table which allows the system to identify which point on the table that a particular user touched. HandsDown (Schmidt et al., 2010c) uses a biometric approach based on hand contour analysis to identify each user's hands as they place them on the table. Before users can be identified, they need to register their hand contour with the system. From that point on, the system will be able to recognise them when they place their hand on the table. However, a major limitation of this approach is that users need to constantly have a hand in contact with the table for the system to identify them. Ignition (Martinez, Clayphan, Kay, Yacef, and Ackad, 2012) is a system that tracks users in a classroom environment. It uses a depth sensor to identify users around a tabletop as well as a microphone array to distinguish between different users speaking. Although these approaches to identifying users are different, all of them provide an important technical foundation for personalising the tabletop interface according to the users present.

2.3.4 Mobile Device Interaction

The use of mobile devices together with interactive tabletops has become a popular research topic. As outlined already, the use of mobile devices in conjunction with interactive tabletops may form part of the solution to achieving personalisation. In particular, they could be used to act as a proxy for their users (Schmidt et al., 2010b) as well as for client side user modelling (Gerber et al., 2010). By storing a user model on a mobile device, such as a smart phone, users would be able to take their model with them wherever they go. As the user moves between different interactive environments, they would be able to release their model to each one and have a personalised interface presented to them. This is an essential part of the ubiquitous computing vision, of which mobile devices have been proposed to play a significant role (Weiser, 1991). A brief discussion of the current work in mobile device interaction with tabletops will now be presented.

BlueTable is a system that identifies mobile phones that are placed on a tabletop using computer vision techniques and allows transfer of data through a Bluetooth connection (Wilson, 2007). When a user places their phone on the table, the vision system will recognise the object and initiate a Bluetooth connection to it using handshaking mechanisms. From that point on, data may be transferred readily between the devices. As a demonstration of the prototype, Wilson (2007) developed a photo sharing application that allows the transfer of photos. Once a phone is placed on the table, the photos located on it will automatically be transferred to the table and appear on the interface. These may be manipulated just like any other photos on the tabletop, with operations such as resizing and rotating. Multiple devices may also be used at the same time to facilitate the transfer of photos between mobile devices. Photos may be dragged across the table to the vicinity of the target device and they will be copied to that device. The researchers state that they did not conduct a formal study to evaluate user performance. However, they made observations of people who were given a demonstration of the prototype. Results indicated that those people who watched the demonstration were easily able to understand that the connection was initiated by placing the phone on the table and that the photos were subsequently transferred as a result of this. They suggest that collaborative interactions will be made easier since other observers will be able to see that they can add their device to the table to experience the same form of interaction.

PhoneTouch is another technique for integrating the use of mobile phones with interactive tabletops (Schmidt, Chehimi, Rukzio, and Gellersen, 2010a). It uses the mobile phone as a touch input device to the tabletop, with the system being able to uniquely identify each phone. Applications of this form of interaction may include data transfer between mobile devices and the tabletop, authentication on shared surfaces with the phone acting as a security token and the opportunity for interface personalisation. An evaluation of performance was conducted to determine how well the system could distinguish between phone and finger touches. The results demonstrated an almost perfect rate of classification for correct phone touches and a small error rate of classifying fingers as phones, which shows that the system carried out its purpose extremely well.

2.4 Chapter Summary

This chapter has presented a critical discussion of the work relating to personalisation at interactive tabletops. Personalisation, in its traditional form, provides a foundation for developing an augmented approach for shared, interactive displays. The main drawback with current methods of personalisation is the inability to support multiple collocated users, which necessitates the exploration of alternative methods to provide a ubiquitous solution. In particular, employing scrutable user models at the client side would seem to provide an elegant approach, as users would have their user model readily available to release to any device that may provide a personalised interface. Importantly, a client side approach enables the protection of personal information as well as the control of which parts of the user model are available to applications. Such an approach allows for a wealth of new shared display applications that could take advantage of having knowledge about the users interacting with them. This may include applications that support personalised search when accessing files, health applications that provide dietary recommendations based on nutritional goals, as well as personalised e-learning applications, which may tailor learning processes to the pace of the e-learner. Regardless of the application, it will be important to evaluate it for its effect in supporting the user's needs through personalisation.

CHAPTER 3

Conceptual Model

This chapter presents a description of the conceptual model that underpins the approach to how personalisation may be achieved at tabletops and, ultimately, any interactive surface as part of the ubiquitous personalisation vision. The nature of tabletop interaction and the fundamental elements of personalisation are discussed, which are then synthesised to develop the conceptual approach to achieving the goals of this thesis. In particular, we justify the decision to develop a personalised application for a Single Purpose tabletop and outline the interface and system requirements of the application.

3.1 Nature of Tabletop Interaction

Personalisation is well established at desktops. However, as discussed in the previous chapter, existing methods of personalisation are primarily targeted at single users. When considering interactive tabletops and surfaces, much of the value they provide is in supporting multiple users interacting at once, so current methods of personalisation do not translate well to shared environments. Hence, it is first necessary to analyse and understand the way in which tabletops are used before developing the conceptual model for personalisation.

3.1.1 Context of Use

We first present and analyse different contexts in which tabletops may be found. Each of these contexts have a certain purpose and we illustrate how they are used in various situations. Although there are four contexts presented here, this is by no means an exhaustive list — the most common uses of tabletops were chosen and described.

3.1.1.1 Information Kiosk

Tabletops may act as a type of information kiosk to provide general details about a venue. Users will typically use a tabletop to look for information in public venues with large numbers of visitors such as museums, galleries and shopping centres. For example, at a museum, users may want to know what sorts of exhibits are currently on display or whether there are any activities suitable for children. Additionally, users may have the opportunity to provide extra information about themselves in order to refine their search. However, the disclosure of personal information requires careful management of that information. For example, storing personal information on the tabletop would not be desirable for users, since the tabletop will probably be used by many different people unknown to each other and who might be able to access that information. Also, the tabletop is owned by another organisation, which may be untrusted to the user.

3.1.1.2 Single or Specific Purpose

Tabletops may also be used for specific purposes depending on where they are located. For example, in a restaurant, a tabletop could be used as part of the ordering system, where it might display a menu and allow diners to select dishes to order. In a clothing store, it may act as a catalogue so that users can browse through the range available. For these types of situations, the user will often understand what the purpose of the tabletop is once they start interacting with it. In a similar manner to the information kiosk context, any information that the user might provide to the tabletop will need to be managed securely, since these tabletops are located in public spaces and are used by numerous people.

3.1.1.3 Shared Collaborative Environment

We may also consider tabletops as being located in less public spaces and being used by small numbers of users who collaborate together. In a business environment, employees may collaborate at an interactive tabletop during meetings or use it for other types of group activities. In such an environment, users of the tabletop are more likely to know each other and hence, the protection of information about certain users may not need to be as strict as it would be at an information kiosk or a special purpose tabletop. For example, storing user information on the tabletop itself may be reasonable since the tabletop is usually accessed within a known group of users. To prevent unauthorised access to other users' information, an authentication system may be used to ensure that users can only access their own information.

3.1.1.4 Private Use

In addition to the somewhat public contexts of use of tabletops, we may also find tabletops located in private spaces. In a household, a tabletop could function as a collaborative device for a family, which would enable family members to perform interactive tasks together, such as planning a holiday. We may also find that a tabletop in this situation could be used by just one person at a time, as is the case with conventional desktops. Consequently, there is more flexibility in protecting user information compared to the other contexts described. Users may be willing to leave their files or documents readily accessible since the tabletop is only used by people that they have a high level of trust in. Also, private use tabletops (and shared collaborative tabletops) may run several applications rather than a single one (Ackad, Collins, and Kay, 2010), which demonstrates their multi-purpose ability as opposed to information kiosks and single purpose tabletops.

3.1.2 Nature of Tasks

As with the contexts of use, we present a small selection of the types of tasks that users may perform at tabletops. However, these have been chosen as the most common elements of typical interaction at tabletops.

3.1.2.1 Structure

The nature of tasks may be considered to be *structured* or *unstructured*. Structured tasks are those that are concrete, meaning that a procedure is followed to complete the task. For example, if the tabletop is acting as a part of the ordering system in a restaurant, it may require users to first add dishes to an order list and then place their order by pressing a button on the interface. Unstructured tasks include those that involve more freedom in the work flow, such as collaborating at meetings or designing a floor plan for a house. In these situations, tasks tend to involve the exchange of information such as ideas or documents and users are not necessarily required to follow a certain procedure.

3.1.2.2 Production of Information

When using a tabletop to locate information, users will typically utilise a search interface. For example, a user might search associatively through a file collection (Collins et al., 2007) or else using a simple text query interface similar to a search engine. Tabletops may also be used in supporting users to create their own information and noting down their ideas. For example, it may be used for brainstorming ideas in a design task (Clayphan, Collins, Ackad, Kummerfeld, and Kay, 2011). It could also be possible for users to load images, videos or other types of files from external devices, such as mobile phones or tablets, onto the tabletop to support their search for or creation of information. This suggests that we will need to consider control mechanisms to allow tabletops to access files from certain locations.

3.1.2.3 Saving Information

Once the user has produced the information they need, they will often need to save it to some location. In the context of a tabletop in a public space that is used by many people who do not know each other, saving information to a personal device has the advantage of the information being stored securely. On the contrary, saving information locally on the tabletop itself may be reasonable if it is located in a more private space, such as a home or business.

3.1.2.4 Sessions

We may distinguish between single session and multi-session tabletop interactions. Single session interactions are completed with no break in time, such as a using a tabletop in a meeting. Multi-session tasks are completed throughout a certain time period, where users will use the tabletop for some time, leave and then come back to keep working on the task. For example, planning a holiday at a privately located tabletop in the home may be done over the course of two weeks.

3.1.2.5 Authentication

When using tabletops, some users may need to be authenticated before being able to proceed. This could be used in situations where confidentiality of information is required, such as in a business where certain documents may only be accessed by upper level managers. User authentication has the extra advantage of allowing the system to identify who is using the tabletop, which provides a simple mechanism in which to personalise the interface for that user.

3.1.3 Potential Users

In general, the demographic of tabletop users ranges broadly. Users of all ages and backgrounds may use tabletops for various purposes. However, rather than presenting the types of backgrounds that users might have, we provide an overview of key points to consider when designing for potential users.

3.1.3.1 Accessibility

Tabletops may be used by wide range of users including children, young and elderly adults and those who may have special needs or disabilities. When designing tabletop applications, it is important to consider usability and learnability for diverse groups of people. In particular, it has been shown that care must be taken when designing interfaces for elderly users (Apted, Kay, and Quigley, 2006), implying that a personalised interface would need to be simple to understand. Additionally, we need to consider users who may have mobility, visual or hearing impairments. Personalisation may benefit these users in particular, as the tabletop could be tailored to specifically support their impairment to simplify interaction.

3.1.3.2 Relationship with Other Users

Users may have a previous relationship with each other and use a tabletop to collaborate on areas of mutual interest. For example, a physician may use it for consultations with patients while a teacher might utilise a tabletop as a teaching device for students. In other cases, users may not know each other — a real estate agent could use a tabletop to show listings of properties to potential buyers.

3.1.3.3 Level of Experience

Users of tabletops will also have varying levels of experience with tabletops. Some may have never used one before, which is an important point to consider in designing a learnable interface. Others may have used a tabletop once or a few times before, such as using an information kiosk in a shopping centre or museum. Although this does count as experience, the interactive nature of tabletops can be very different, so a user's interactions, such as gestures, at one tabletop may not be applicable to another one. There may also be a small group of users who will be quite experienced with using tabletops, including those who require it for their profession.

3.2 Personalisation at Tabletops

Following the discussion of the nature of tabletop interaction, this section develops a model for applying personalisation to interactive tabletops, which may be generalised to other surfaces as well. The various uses of personalisation are first described, providing examples of how the tabletop interface may be personalised. This is followed by a discussion of the role of the user model, including the key attributes that are required for personalisation, including security, portability and scrutiny. The section concludes with a brief discussion on the potential benefits of enabling personalisation for multiple users.

3.2.1 Applications of Personalisation

There are many forms of personalisation that may be applied across the range of tabletop contexts described earlier. This section provides a summary of the key points of each application.

3.2.1.1 Personalised Recommendations

One type of personalisation is in providing recommendation services to users. On traditional desktops, as well as mobile platforms, such services may include product recommendations on e-commerce websites such as *eBay*. In the context of tabletops, product recommendation would be especially applicable to an information kiosk in a shopping centre. However, a key issue with current methods of recommendation is that they are targeted at only one user at a time, and therefore not easily translatable to the shared nature of tabletop interaction. Further discussion on multi-user personalisation is provided in Section 3.2.3. We may consider not only the recommendation of consumer products but other items as well. For example, in the context of a restaurant, users may have the structured task of selecting dishes to order using a tabletop. An interactive restaurant menu could provide the opportunity to recommend dishes to the user based on a user model of that person.

3.2.1.2 Personalised Search

Personalisation may also be applied to the task of information retrieval. When a user is searching for information on a subject, the process of doing so may be enhanced by allowing the user to provide extra information about their needs, thereby achieving results that are more relevant to their interests or preferences. With access to a user model, the system could infer the user's interests and then tailor the search results to match the user's needs. For example, at a museum, a visitor might be using an information kiosk to look up dinosaurs. The kiosk might learn that he is particularly interested in the velociraptor so among the search results that contain dinosaurs, it might also draw the visitor's attention to those that contain information about velociraptors.

3.2.1.3 Personalised Input

Personalisation has the potential to allow for the simplification of input of information, such as text. While using a tabletop that requires authentication, a user might enter their credentials using a soft keyboard on the tabletop. However, this method of text entry is error prone and often a tedious process for the user. We may consider using personalisation to alleviate these problems by storing the user's identity in their user model and allowing the tabletop to access this identity. The user's credentials could then be extracted and automatically entered without the user having to perform any manual input. A key benefit of such an approach to authentication is that it could be used for many different users. As long as the tabletop is able to identify who is at the tabletop, it will be able to infer the credentials of each user and authenticate them accordingly.

3.2.1.4 Personalised Gestures

Personalised gestures allow for the enhancement of user interaction with tabletops. One benefit of having personalised gestures is in allowing users to navigate an interface in a manner that they are comfortable with. Another benefit is that users are able to reuse their personal gestures at many different tabletops, thereby eliminating the need to learn new gestures at each tabletop that they encounter. For example, a user might use a certain set of gestures to manipulate files at a tabletop during a meeting at work. Once she gets home, she would be able to use the same set of gestures at her own private tabletop to perform the same tasks on her files. This ensures consistency for the user and improves usability. However, the tabletops that she uses may not all be the same in terms of the way user interaction (such as gestures) is supported. Hence, personalisation interoperability is an area that may need to be considered.

3.2.2 User Model

The purpose of the user model is to store information about the user that may be analysed to provide a personalised service or interface. This information may include any of the user's goals, needs, preferences or interests.

3.2.2.1 User Information Storage

The user model data may obtained either explicitly, through user specification of their personal information, or implicitly, through inferences from user behaviour while interacting with various systems. It is emphasised that the user model does not remain static and is constantly updated with new or changed information about the user. Once the data about the user is obtained, the tabletop is then able to use this information to personalise the interface, which may include any of the applications described in Section 3.2.1.

3.2.2.2 Security

As discussed in Section 2.2, server side user modelling aggregates user data in central locations. Although server side user modelling may have benefits in scalability and performance, there still remains the problem of user privacy, as users do not know exactly how their personal information is used by the organisations that hold this information. Storing the user model on the client side may provide a solution to these privacy issues presented by Bilenko and Richardson (2011) and Toubiana et al. (2010). Rather than allowing the user model to be controlled by remote administrators, the model is controlled by the users themselves. This is especially important at public tabletops that are used by large numbers of people, such as information kiosks, where users will want to ensure privacy of their information as much as possible.

3.2.2.3 Portability

The portability aspect of client side user modelling is another benefit of adopting a client side approach. Tabletops and other shared display groupware, are considered to be located ubiquitously. Hence, a portable user model is key to the overall solution of achieving ubiquitous personalisation. With their user model stored on a mobile device, users may bring their model to many tabletops in different contexts that may be able to provide personalised interfaces to them. As mentioned previously, this could include having personal gestures stored in the user model that may be used at various tabletops that the user interacts with.

3.2.2.4 Scrutability

Another attribute that is highly desirable of the user model is in being able to allow users to scrutinise it (Kay, 2006). This enables the user to examine their user model to understand exactly how the system uses their personal data to infer assumptions about them and to personalise their experience. Users may consider some of their information to be more sensitive and private than other information. By allowing users to inspect how the personalisation process occurs, users may restrict applications to only access parts of their model that they are willing to disclose for the purpose of that application.

3.2.3 Multiple User Personalisation

As discussed in Section 1.4, one of the key challenges to designing a model for personalisation at interactive surfaces is in being able to personalise the interface for groups of users. This is motivated by the nature of such environments in allowing multiple users to interact collaboratively at the same time.

3.2.3.1 Concurrent and Independent Interaction

Being a form of shared display groupware, tabletops provide a collaborative environment to support multiple users. For clarification, we distinguish between two different interpretations of “multiple users”. The first defines a group of users who collaboratively interact with the tabletop at the same time. We define this case as *concurrent interaction*. For example, a tourist group may use an information kiosk to locate tourist attractions together. Each member of the group might provide some input regarding their interests as a form of collaborative interaction. Hence, the personalisation would be targeted at the group as a whole. The second interpretation refers to “multiple users” as users of the tabletop over a certain period of time who interact independently of other users. In this case, each user may be treated individually, resulting in personalisation that only applies to each individual. We define this case as *independent interaction*. For the contexts of use described in Section 3.1.1, we will find that there are mixed occurrences of concurrent and independent interaction.

3.2.3.2 User Identification

As indicated by (Schmidt et al., 2010b), users at the tabletop must first be identified before personalisation may be applied. As discussed in Section 2.3.3, previous work has explored the use of using mobile devices for identification. This would seem to work well with a client side user model that is stored on a mobile device, as the user would then be able to use this device to both identify themselves and provide the necessary information required for personalisation. Once the tabletop has information about each user, it may then proceed to personalise the interface for them.

3.3 Linking Personalisation to Tabletop Contexts

After reviewing foundations of tabletops and personalisation, this section analyses how personalisation specifically applies to the contexts in which tabletops are used. Table 3.1 summarises the relevance of various components of personalisation with respect to each context.

TABLE 3.1. Components of personalisation and the nature of tasks relevant to tabletop contexts.

Component	**Subcomponent**	**Tabletop Context**			
		Information Kiosk	Single Purpose	Collaborative Environment	Private Use
Application of Personalisation (§3.2.1)	Recommendation	✔✔	✔✔✔	✔	✔
	Search	✔✔✔	✔✔	✔✔	✔✔
	Input	✔	✔	✔✔✔	✔✔✔
	Gestures	✔✔	✔✔	✔✔	✔✔
Multiple User Interaction (§3.2.3)	Concurrent (C) Independent (I)	C, I	C, I	C	C
User Model (§3.2.2)	Degree of Security	High	High	Medium	Low
	Degree of Scrutability	High	High	Medium	Low
	Location Preference (server, client)	client	client	server, client	server, client
Nature of Tasks (§3.1.2)	Structured (S) Unstructured (U)	S, U	S	U	U
	Sessions (single, multi)	single	single	multi	single, multi
	Information Production (internal, external)	internal, external	internal, external	internal, external	internal, external
	Information Storage (internal, external)	external	external	internal, external	internal
	Authentication required	N	N	Y	Y
Legend: ✔✔✔= Very Relevant, ✔✔= Relevant, ✔= Somewhat Relevant					

From the information in this table, it may be seen that each context of use has a different set of requirements when designing a model that facilitates personalisation.

Applications of Personalisation

In terms of the applications of personalisation, recommendation would be suitable for both information kiosks and single purpose tabletops because these contexts often provide users with a service. By providing recommendations, users may find the service more useful, as their needs are addressed at once, which reduces the required effort in looking for what they need. Although personalised search is common to all tabletop contexts, it is especially suitable for information kiosks. Users will use an information kiosk because they would like to find more information about something. Therefore, providing a search mechanism that is adapted to their needs or interests would benefit the user greatly in locating what they are looking for.

Multiple User Personalisation

When considering multiple user personalisation, it is important to cater to users interacting independently and concurrently. Firstly, personalising for independent users is especially important in public contexts, such as information kiosks and single purpose tabletops, since users will generally be unfamiliar with each other and hence, interact of their own accord. Concurrent user interaction is interesting because it essentially demonstrates the real value of tabletops in their ability to support many users interacting at once. Hence, accounting for concurrent users appears in all of the tabletop contexts described.

User Model

As discussed in Section 3.2.2, aspects of the user model that were important for personalisation included security, scrutability and the location of where the user model is stored. Since information kiosks and single purpose tabletops are often located in public spaces, security of the user model is highly important (Table 3.1), as user privacy is a high priority in these contexts. As a consequence, the preferred location of the user model is indicated as the client, since this enables the user to control how their personal information is used. For the reason of maintaining user trust, the degree of scrutability for information kiosks and single purpose tabletops is also marked as high. In these untrusted contexts, it is necessary for users to be able to know exactly how their information is used. On the other hand, for tabletops in collaborative environments and private use, security and scrutability are important to a lesser degree than the other two contexts, since they will usually be used by the same users.

Notwithstanding, scrutability should not be considered unnecessary because it is still important for users to be able to scrutinise the system at all times, especially if the personalisation process is incorrect. For example, a private use tabletop in a household might be used by different family members. If the user models of each member were stored on the tabletop (which is acceptable in this context, since it is private), there may be instances where the wrong user model was being used for personalisation — the interface might be personalised for the person who last used it, so when another person starts using it, they may realise that it is not tailored to their needs. Incorporating the ability to scrutinise the personalisation process would allow for the user to realise that it was someone else's user model being used, which in turn allows this type of problem to be mitigated.

Design for a Single Purpose tabletop context

In designing a conceptual model for personalisation, the Single Purpose tabletop context is targeted because this thesis aims to develop and evaluate a personalised application that addresses the issues of security and scrutability in an environment where these factors are critical. The notion of ubiquitous personalisation envisions that users will interact with a range of devices in various locations with different levels of trustworthiness. Although this suggests that it is necessary to account for the possibility that some devices may be completely untrusted, this thesis focuses on the interface and scrutiny requirements rather than the underlying infrastructure and security issues.

In selecting this context, an important conceptual element to define is the user model being stored on the client (3.1). This enables the user to remain in control of their information in choosing whether to allow certain tabletops to access this information, which maintains user privacy. Additionally, a high level of scrutability is required for Single Purpose tabletops, due to the untrusted nature of this tabletop context. In terms of the nature of tasks, the model will mainly need to consider single session tasks that are structured, meaning that users will generally perform tasks in a procedural fashion. Information may be produced internally, within the tabletop itself or externally, where it might be possible for the user to load information from an external device onto the tabletop. It is also necessary to consider that these tasks may either be collaborative, with multiple users interacting concurrently to achieve a certain goal, or individual, where users interact independently. Hence, the personalised application should be designed to support personalisation for groups of users, as well as individual users. With respect to the applications of personalisation, recommendation is marked as an important aspect for the Single Purpose context, which means that it would be suitable to include a recommendation service within the application. Finally, authentication is unlikely to be required, as tabletops in this context are located in public spaces and may be used by the general public.

3.4 Conceptual Requirements for Ubiquitous Personalisation of Tabletops

With the target context in place, the requirements for an approach to realising ubiquitous personalisation may now be defined at the conceptual level. As part of a client side user modelling approach, the user model will be contained within a personal, mobile device, such as a smart phone or a tablet. This provides a secure way of storing personal information and acts as a portable solution to user modelling, allowing users to ubiquitously personalise applications at tabletops, or other interactive surfaces. A set of interface requirements is defined as the visual elements of the interface that enable users to interact and achieve a personalised result, while the system requirements define the technical details of how the system is to be implemented. Each of these aspects are discussed below.

3.4.1 Interface Requirements

As part of the conceptual model for personalisation, two devices are required: the mobile device and the tabletop. Hence, an interface will be required for each of these devices.

3.4.1.1 Mobile Interface

Since the mobile device stores the user's personal information, it is essentially a representation of the user's identity. Therefore, the mobile device will require an interface that allows the user to create an identity that may be linked to the tabletop application in order for it to know who is present at the table. In allowing the user to maintain control of their user model, there should also be an interface that enables them to select which parts of their user model they are willing to release to the tabletop.

3.4.1.2 Tabletop Interface

As identified above, for the Single Purpose context, recommendation is a form of personalisation that would be suitable for the tabletop application. In achieving a personalised interface for the user, the tabletop interface will need to allow the user to distinguish between the recommendations that the service provides and the usual result of the service. This enables to user to understand that the user interface is personalised for them. Also, the interface must incorporate a method for users to examine how their user model is used in the process of personalisation, as part of the critical need for scrutability. Finally, a personalised interface to support concurrent use of the tabletop must also be implemented, as users may interact in this manner in a Single Purpose tabletop context.

3.4.2 System Requirements

The user model will require a database system that is implemented on the mobile device, which will store all of the user's personal information, such as their interests and preferences. A user model ontology will need to be defined to organise this information into a hierarchy that will simplify the process of providing the personalised result. In order to allow the tabletop to access this user model, a protocol must be defined for allowing communication between the two devices. In particular, in upholding security of the user model, the system must only allow the tabletop to access data that the user has granted permission for use by the tabletop. As described above in the tabletop interface requirements, a recommendation service will be implemented into the application, meaning that a recommendation algorithm for both individual users and groups will need to be devised, so that certain products or services can be determined as being recommended for the user or groups of users. In addressing the scrutability aspect of the interface, the recommendation algorithm forms the basis for the reasoning behind the recommendations and hence, this will need to be recorded so that it may be displayed to the user.

3.5 Chapter Summary

This chapter has provided a discussion of various tabletop contexts and how components of personalisation apply to each one. In particular, the Single Purpose context was identified as being the target context for the approach, as it provides a representation of an untrusted environment, which is a key factor that ubiquitous personalisation accounts for. The interface and system requirements outlined here were implemented to realise the conceptual model of personalisation and the outcomes of these are discussed in the following chapters.

CHAPTER 4

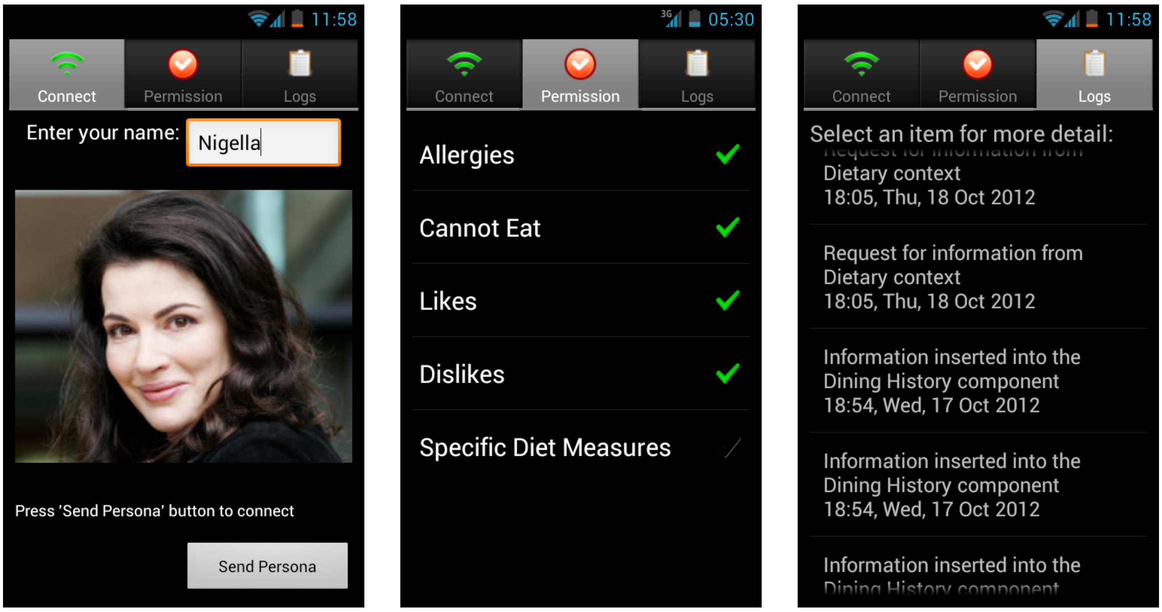
User View

In the approach to achieving a personalised tabletop interface, the two key components are the mobile interface and the tabletop application. The mobile interface enables users to establish an identity for themselves, by creating a Persona, which will be discussed in Section 4.1. Also, the user model is stored on the mobile device, as part of a client side approach to user modelling, which was discussed in Section 3.2.2. The tabletop application, MyMenu, has an interface that presents a restaurant menu to the user. It closely follows the layout of an actual dining table in an Italian restaurant, with the menu being representative of an Italian cuisine. Upon using the mobile device to connect their identity to the tabletop, the user is able to personalise the menu. Although the contribution of this thesis is in the personalised tabletop application, this chapter begins by describing the mobile interface, as it is necessary for the user to first establish their identity in order to release their user model to the tabletop.

4.1 UMController Mobile Application

The underlying system structure will be briefly discussed first, to provide an understanding of the relationship between the mobile device and the tabletop application (a detailed discussion of the system implementation is provided in Chapter 5). TabletopUM is a framework that provides the infrastructure for facilitating communication between a client side user model and a tabletop, whereby the user model is stored on a mobile device (Kim, 2011). This allows for information from the user model to be transferred to the tabletop and vice versa.

The UMController mobile application (Kim, 2011) is part of TabletopUM, and provides an interface to enable the user to link their identity, or Persona, to the tabletop. This then allows the tabletop to access the user model, so that the tabletop interface may be personalised. The user model itself is stored and queried using PersonisJ Gerber et al. (2010), which was discussed in Section 2.2.4. A tab bar located



(A) Connect tab. (B) Permission tab. (C) Logs tab.

FIGURE 4.1. UMController mobile application.

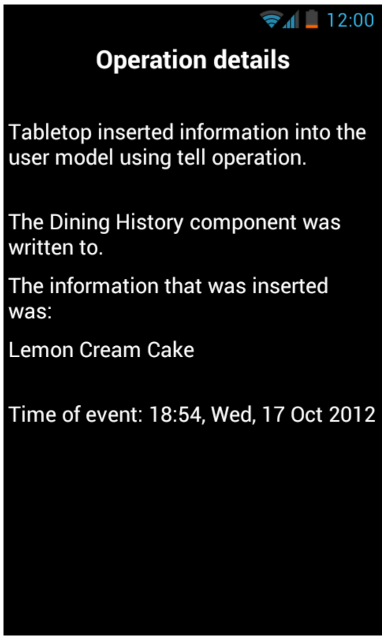
at the top of the interface (Figure 4.1a), allows the user to switch between the different functions of the application, each of which are described in more detail below.

When the user first starts UMController, they are presented with the Connect tab (Figure 4.1a). The user is able to enter their name and select an image, which will be used as their Persona (avatar) on the tabletop. Upon pressing the "Send Persona" button, their Persona image appears immediately on the tabletop, animating so that it is positioned in the centre of the table. The presence of the Persona enables the tabletop to exchange information with the user model stored on the user's mobile device.

The user may allow or deny access to certain user model components using the Permission tab (Figure 4.1b). This is done by tapping on the components for which they want to allow access, which results in the "tick" symbol being shown. Any unticked components will not be accessible to the tabletop. For example, the user might give permission for the tabletop to request information from all components except for "Specific Diet Measures", as shown in Figure 4.1b. This means that when UMController performs an "ask" operation on the user model, information from all components except for "Specific Diet Measures" will be returned.

The Logs tab allows the user to view information about all of the user model operations that have been performed by the tabletop connected to UMController (Figure 4.1c). Each log item provides a summary

(A) Information that was retrieved from user model ("ask").



(B) Information that was inserted into user model ("tell").

FIGURE 4.2. Details of user model operations.

of the operation, where the tabletop either requested information from the user model (using "ask") or inserted information into the user model (using "tell"). When the user selects a log item, further details of that operation are revealed (Figure 4.2). For "ask" operations, information that was retrieved from the user model and sent to the tabletop is displayed (Figure 4.2a), while for "tell" operations, information that the tabletop inserted into the user model is displayed (Figure 4.2b).

4.2 Personalised Tabletop Interface

The tabletop interface was implemented using Cruiser, a software framework that supports collaborative interaction at tabletops. Hence, this section begins by describing the core functionality of Cruiser that was used in developing the personalised application. Technical details on the implementation of Cruiser and the tabletop application are provided in the System Overview (Chapter 5).

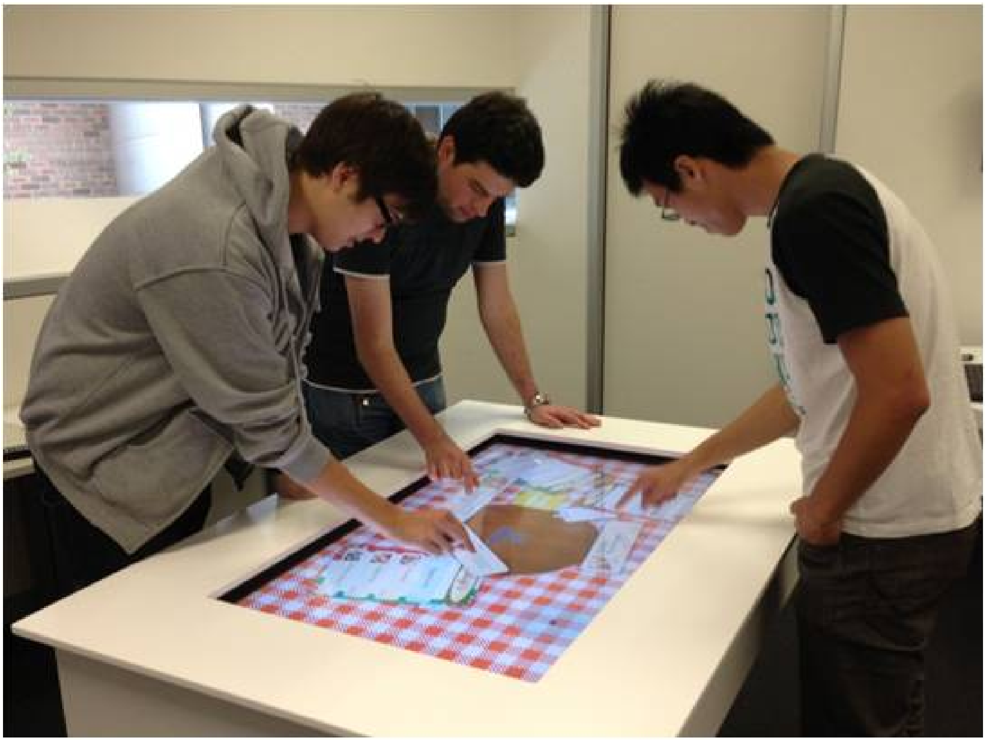


FIGURE 4.3. Participants interacting with MyMenu at a tabletop.

4.2.1 Cruiser framework

Cruiser (Apted, 2008) is a software development framework that provides an interface for collaborative interaction on shared display groupware, such as tabletops and wall displays. Cruiser supports touch and stylus interaction for multiple users, allowing them to move, resize and rotate objects on the interface.

Moving objects involves touching the object with one finger and dragging it along the surface to wherever the user desires. To resize an object, users select any corner of the object using one finger and then move their finger outwards or inwards to respectively enlarge or compress the object. Alternatively, users may use a two-finger "pinch" gesture to resize objects, where moving the fingers away from each other enlarges the object and moving the fingers towards each other shrinks the object to a smaller size. Objects may be rotated by selecting a corner with one finger and then moving their finger in a circular motion, using the centre of the object as a pivot. Alternatively, users may place two fingers on the object and then move both fingers in a circular fashion, pivoting around the centre point in the middle of the two fingers. Users are also able to drag objects out of or into other objects. In this way, some objects act as containers for other objects, acting as a storage mechanism.

The Black Hole is a feature of Cruiser that allows users to hide objects that they do not need (Figure 4.4). Dragging objects into the Black Hole will cause them to be “sucked” in until they become invisible so that the users’ workspace becomes less cluttered, allowing them to have more space to continue interacting.

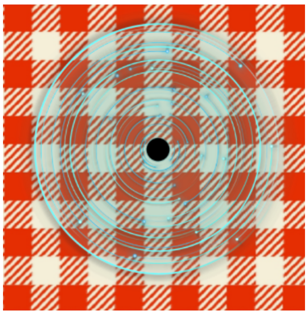


FIGURE 4.4. The Black Hole.

Some objects may also be “dwelt” on, which involves the user holding down on that object for about one second. The “dwell” operation may be used to perform any kind of action, such as starting or exiting an application or deactivating the Black Hole (so that objects cannot be “sucked in”).

4.2.2 MyMenu Tabletop Application

MyMenu is a tabletop application that presents interactive restaurant menus of an Italian cuisine that may be personalised. In an actual restaurant, the tabletop would be used as the dining table. Hence, when users view the menu, they interact with the same table that they would be eating from. In MyMenu, a personalised menu displays dishes that are recommended for the user, based on dietary information from their user model. There are two types of menus: individual menus and a group menu.

Inidvidual Menus

Each user is presented with an individual menu. Please refer to Figure 4.5 for an example of an individual menu. In its normal, *unpersonalised* state, this menu acts as a regular menu that displays a list of available dishes in various categories, such as Appetisers, Soups, Salads and so on. By scrolling through the list using the scroll bar on the right of the menu (Label 1), the user is able to browse through the dish selection. When the user drags out an item from this menu (as indicated by the arrow), a new “menu item card” is created that enables them to see more details about that dish. For example, in Figure 4.5, “Bruschetta” has been dragged out and the menu item card provides a description of the menu item (Label 2).

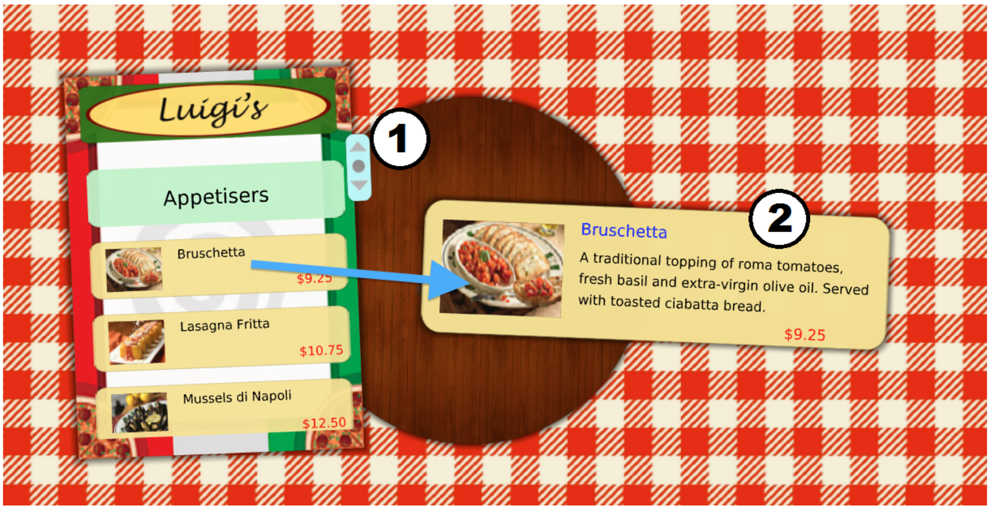


FIGURE 4.5. An unpersonalised menu showing the list of available menu items. When a menu item is dragged out, further details about the dish are shown.

FIGURE 4.6. Dragging a Persona onto a menu will trigger the personalisation process.

As identified in Section 2.3.3, user identification is required for personalisation. In MyMenu, users are represented on the tabletop by objects called Personas. Each user's Persona is shown as the image they had sent from UMController (as discussed in Section 4.1) with their name appearing on top of this image. For example, in Figure 4.6, Nigella's Persona is shown (Label 1). When the user drags their Persona onto a menu (within the boundary of the container) the menu becomes personalised.

Please refer to Figure 4.7 for an example of a personalised individual menu. In its personalised state, the Persona that was dragged onto the menu becomes part of the menu and is displayed at the top of the

FIGURE 4.7. A personalised menu, with recommended items indicated by a "thumbs up". The menu item card contains an inspection button that allows the user to find out why this dish was recommended.

menu. Also, a text label appears, indicating that the menu is personalised for the user. Here, Nigella has personalised her menu, so her Persona appears at the top (Label 1) and the menu also says "Personalised for Nigella" (Label 2). The list of dishes is the same as in the unpersonalised state. However, some dishes are now *recommended*, and will show a "thumbs up" symbol, indicating that it is recommended for the user who personalised it (Label 3). When the user drags out a recommended item, the menu item card will indicate who it is recommended for and the user's Persona is displayed at the top. In Figure 4.7, Nigella can see that Garden-Fresh Salad was recommended for her. After dragging out the menu item, she can see that the menu item card says that this dish is recommended for her (Label 4) and her Persona at the top (Label 5). Additionally, an inspection button appears, which the user may press to find out why this item was recommended for them (Label 6). Details of viewing the reasoning for recommendations are provided in Section 4.2.4.

Group Menu

The purpose of the group menu is to display dishes that are recommended for the whole group. Please refer to Figure 4.8. The group menu follows the design of a "lazy Susan", being represented as a circular object located in the centre of the table that may be spun around by any user. This is done by placing one finger on the lazy Susan and rotating it about its centre. There is only a single instance of the group menu, allowing all users to share the interface object for examining dishes that are recommended for all of them. The items located in the group menu are dishes recommended for the group and are determined

FIGURE 4.8. The universal group menu, following the design of a "lazy Susan". Users may spin the menu around to examine each dish.

using the intersection of recommended dishes for each personalised menu. As users personalise their individual menu, the group menu will update itself to display dishes that are recommended for the number of users that have personalised their menu. For example, in Figure 4.8, Nigella and Heston have personalised their menus, so the group menu provides recommendations for both of them. If Jamie came to the table and personalised another menu for himself, then the group menu would be updated to include recommendations for all three users.

FIGURE 4.9. The group menu and a group menu item card.

Please refer to Figure 4.9 for details of the group recommendations. All group recommendations display the Persona of each user it is recommended for (Label 1) and have an inspection button. Upon pressing the inspection button on a group recommendation, a notification appears, indicating who it is recommended for (Label 2). As with the individual menu items, users may also drag out group recommendations from the group menu to create a menu item card. The menu item card for a group recommendation displays the Persona of each person it is recommended for (Label 3) and also provides a textual indication of who it is recommended for (Label 4).

FIGURE 4.10. The order list on which users may place menu items to indicate what they would like to order.

There is also an order list object, shown as a clipboard, that enables users to select items that they would like to order for a meal. Please refer to Figure 4.10 for an example of an order list. Users drag menu items onto this order list to keep track of their order. As they do this, each menu item that is added appears below the previous item. There is also a scroll bar on the right hand side of the order list (Label 1) so that users may view the complete list of orders. On the top right of the order list is a “Place Order” button, which must be dwelt on to trigger the order process. A dwell action is used instead of a tap action to prevent users from accidentally placing the order when manipulating objects on the tabletop. In an actual restaurant, the order would be sent through to the restaurant’s ordering system and the kitchen would be notified of the order.

At the same time, after a user places the order, MyMenu attempts to insert information into the user model as part of the user's dining history. The insertion of information only occurs for recommended menu items, whether they are individually recommended or recommended for the group. For individually recommended items, it will send information about the menu item to the corresponding UMController mobile application. For group personalised items, it will send the menu item information to all UMControllers for which that item is recommended for. Currently, only the title of the menu item is sent to UMController. This information is then inserted into the Dining History component of the user model (using a "tell" operation) as evidence of the user's dining history. The purpose of recording this information is to update the user model so that it has more information about the user's dining preferences. This could then be used when the user returns to the restaurant, or visits a new one, to provide more accurate recommendations on what they might enjoy. An area for future work would be to explore the effectiveness of this method in enhancing the user's personalised experience, especially with more information than just the title, such as the nutritional content and the ingredients of the dish.

4.2.3 Personalisation Process

Although details of the personalisation process are not shown to the user, an overview of this process is provided here so that elements of the scrutiny interface, which are discussed in the next section, may be better understood. A comprehensive discussion of the personalisation process is provided in Section 5.2.3.

There are three main steps to the personalisation process:

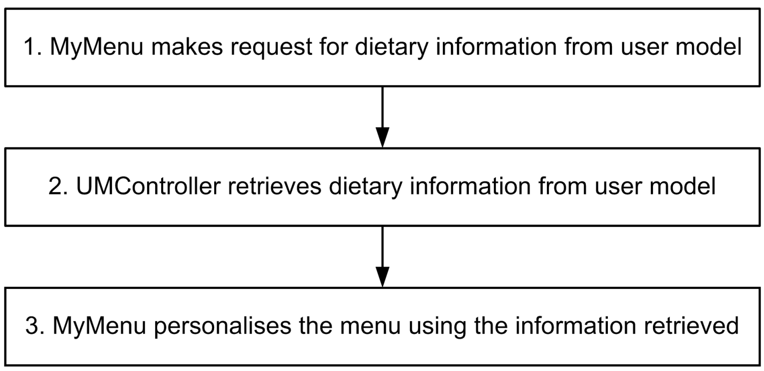


FIGURE 4.11. Steps outlining the personalisation process.

When a user drags their Persona onto a menu, MyMenu first asks UMController to look for dietary information in the user model (Step 1). UMController will then retrieve information from the dietary components that the user has indicated the tabletop is allowed to access and sends this to MyMenu (Step 2). Finally, MyMenu uses that information to personalise the menu, resulting in a menu that indicates dishes that are recommended for the user.

Essentially, it was the information that was retrieved from the user model that determined which menu items were recommended and hence, the reasoning for the recommendation was based off this information. At this point, it is only necessary to understand the type of information that was used in the recommendation process. The user model contained separate components for what users like to eat (Likes), what they do not like to eat (Dislikes) and also any special diets that they preferred, such as "low carb" or "low fat" foods (Specific Diet Measures). The user model also contained information about what users could not eat, such as food they were allergic to (Allergies). Further details of the user model ontology and the personalisation process overall are provided in Chapter 5. However, the components just described play a major role in enabling users to scrutinise how their user model was used, which will now be discussed.

4.2.4 Scrutiny Interface

The concept of scrutability refers to the ability of a user to examine how their information is used for various purposes, such as personalisation. In MyMenu, users have the ability to view the reasoning behind the recommendations on their personalised menu. To address the issue of user privacy at the shared tabletop (Section 2.2.2), MyMenu allows the user to view the reasoning with different levels of detail.

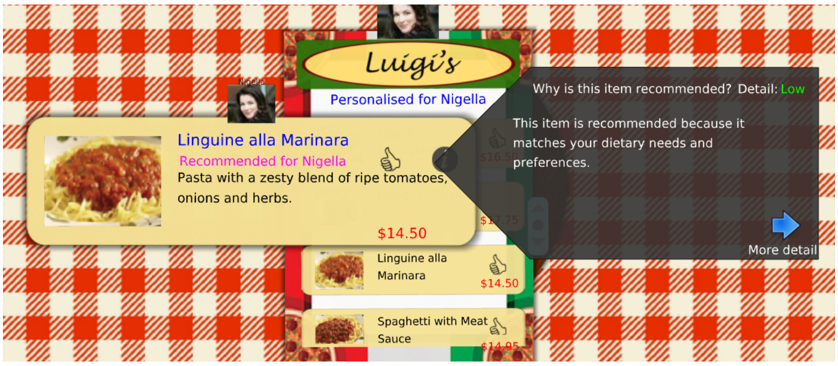
- Level 1 (Low): This level simply states that the dish is recommended because it matches the user's dietary preferences and requirements.
- Level 2 (Medium): The next level of detail reveals the *components* (Likes, Dislikes, etc.) in the user model to which the menu item matches.
- Level 3 (High): The final level of detail reveals actual *evidence* from the user model and how it matches the nutritional information in the menu item, such as the ingredients.

Please refer to Figure 4.12 for an example of the scrutiny interface and the different levels of detail in the recommendation reasoning.

For each recommended dish, the menu item card has an inspection button, indicating that the user can find out more about the recommendation. Upon pressing this button, a pop-out box appears, which is the scrutiny interface (Figure 4.12a). The first level of detail (Low) is shown to the user, which states that the menu item matches their dietary preferences (Figure 4.12b). When the user presses the "More detail" button in the lower right corner, the second level (Medium) is shown (Figure 4.12c). This level indicates that the nutritional content in the dish matches the user's likes and specific diet preferences, which are components of the user model. It also states that the dish does not contain any of their allergies. Upon pressing the "More detail" button again, the third level of detail is shown, which reveals the actual ingredients that match the user's likes (tomato, onion, garlic and seafood), the dietary information that matches the user's preferred specific diet measures (low fat) and also the user's allergy to nuts, to indicate that the dish does not contain this ingredient. Hence, actual evidence from the user model is displayed on the interface at the highest level of detail.

Having different levels of scrutiny, where the amount of detail in the reasoning gradually increases, allows the user to control how much of their personal information is revealed on the tabletop interface. This is important because they may prefer not to disclose sensitive personal information that might be seen by others at the tabletop.

Since group recommendations were essentially menu items recommended in common, the reasoning for the group recommendations would be that it matched the dietary needs and preferences of each user in a way that led to the same menu items being recommended for them. For example, it may turn out that a certain dish was recommended for Nigella because it did not contain nuts, which she is allergic to, while the same dish was recommended for Heston because it did not contain shellfish, which *he* is allergic to. However, it would defeat the purpose of the scrutiny interface to reveal this information to both users, since the notion of maintaining privacy would be lost. Although some users may feel indifferent to revealing their allergies, other users may prefer to keep this information private. Furthermore, other applications may use information that is highly sensitive, such as medical information, to provide group recommendations. In this situation, many users would probably prefer this information to remain hidden from others. For this reason, users were only able to see *who* the group menu items were recommended for and not why.



(A) Pressing the inspection button reveals the scrutiny interface.

(B) The first level of detail in the recommendation reasoning.

(C) The second level of detail in the recommendation reasoning.

(D) The third level of detail in the recommendation reasoning.

FIGURE 4.12. The scrutiny interface showing the three levels of detail in the explanation of the reasoning for recommendations.

4.3 Chapter Summary

This chapter has provided a walkthrough of both the mobile interface and the personalised tabletop interface in allowing users to personalise a restaurant menu. The key elements to note are the scrutiny interface, which allows users to examine how their personal information was used with different levels of privacy and the personalised group menu, which provided recommendations of menu items for multiple users. These interface elements aim to address the key challenges that were identified at the beginning of this thesis, namely the ability for users to scrutinise their user model and an interface that supports personalisation for groups of users. With the personalised tabletop interface complete, it was then necessary to evaluate its effectiveness in providing personalisation for users at a tabletop. However, before discussing details of the evaluation, an overview of the system implementation will be discussed in the next chapter, providing an explanation of the technical aspects of the personalised interface.

CHAPTER 5

System Overview

The system implementation involved developing a new tabletop application (MyMenu) that was able to present restaurant menus to users. This application was integrated with existing work from others in order to facilitate the personalisation process. Both the system and interface implementations of MyMenu were developed using Cruiser, which is a software framework for developing surface applications. Cruiser itself falls under the TabletopUM framework, which necessarily enables an interactive tabletop and mobile device to communicate with each other. Hence, this chapter begins by discussing the core elements of Cruiser and TabletopUM before explaining the details of the underlying processes of MyMenu.

5.1 Cruiser Framework and TabletopUM

Cruiser (Apted, 2008) is a software framework that contains the core elements for developing interactive surface applications, including those that may run on interactive tabletops. It is hardware and operating system agnostic, so may easily operate under many different system environments. Cruiser is implemented in C++ and follows an object-oriented paradigm in its design. There are many types of widgets that may be used within the interface, such as images, buttons and containers; these are defined as part of the core functionality of Cruiser, or built into libraries that may be reused and adapted by developers for new applications.

A Cruiser *plug-in* is where a discrete piece of functionality is coded. For example, there is an email plug-in and a browser plug-in built into Cruiser. A Cruiser *application* may combine the functionality of several plug-ins, which are able to communicate with each other, to create more sophisticated forms of functionality. Please refer to Figure 5.1 for an overview of the Cruiser Software Architecture. For this thesis, a user-developed plug-in called Restaurant was created, which contained classes defining various objects that would allow restaurant menus to be presented. This plug-in was bundled together with the

Persona plug-in, which is discussed below, into the MyMenu application that provided an interface for personalising restaurant menus. The Restaurant plug-in used the core functionality of Cruiser and some libraries to present user interface elements, such as images and buttons.

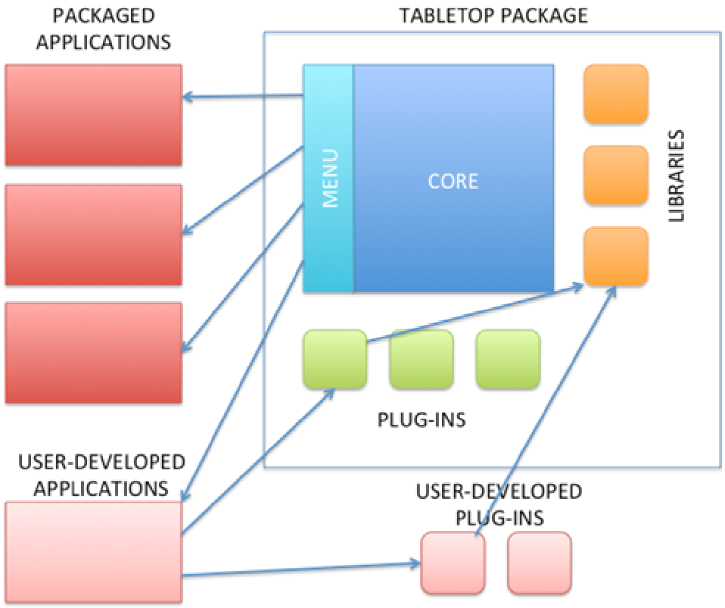


FIGURE 5.1. Cruiser Software Architecture (taken from the Cruiser Technology Architecture Overview by Smart Services CRC).

TabletopUM is a framework that provides the infrastructure for facilitating communication between a client side user model and a tabletop, whereby the user model is stored on a mobile device (Kim, 2011). This framework plays a key role in allowing the transfer of data between the user model and the tabletop as part of the personalisation process. Kim (2011) developed this framework with three key components in mind: the user model, the tabletop implementation of the framework and a mobile application, called *UMController*, that mediates between the user model and the tabletop.

The user model part of the framework was implemented using *PersonisJ* (Gerber et al., 2010), which is a client side user modelling tool for mobile devices. However, since PersonisJ was primarily designed for personalising applications within the mobile device itself, there was no means, at the time, of being able to access the user model outside of the mobile environment. Hence, Kim (2011) created UMController, which allowed the user model to be accessible from a location external to the mobile device. UMController is the mobile application that mediates data transfer between the client side user model and the tabletop. The tabletop implementation of TabletopUM was done using Cruiser and involved developing a plug-in called *Persona*. This plug-in enables UMController to connect to the tabletop (Kim,

2011) so that information may be obtained from the user model or written to the user model. This, in turn, allows for a tabletop application to personalise the interface with the user model information it can access. In summary, PersonisJ (user model), the Persona plug-in (tabletop) and UMController (mobile application mediator) together form the TabletopUM framework for allowing a tabletop to access a user model contained within a mobile device.

The implementation of TabletopUM has been reused in the work of this thesis to support the development of personalised interfaces at a tabletop. Since the core contribution of this thesis is in developing and evaluating the personalised tabletop interface and not the infrastructure required for personalisation, further details of TabletopUM will not be covered. For technical details on the implementation of TabletopUM, please refer to Kim (2011).

5.2 MyMenu Application

MyMenu is a tabletop application, developed using the Cruiser framework, that provides users with the ability to interact with a personalised restaurant menu. First, an explanation of the user interface elements will be given, followed by details of the application logic in the personalisation process.

5.2.1 Interface Elements

Before describing the interface elements specific to MyMenu, a brief overview of the existing elements of Cruiser will be given. A Cruiser *Resource* is essentially an object that may be shown on the screen by being added to the *Environment*, which handles the rendering of Resources and other processes. *Image* objects directly inherit from the Resource class and most of the other elements of the user interface inherit directly or indirectly from the Image class. In particular, some objects act as containers for other objects, such as *BrowseContainer*. BrowseContainers act as a storage mechanism by allowing objects to be placed into them. When these objects are needed again, they may be taken out of the container as well. Please refer to Figure 5.2 for an overview of the class hierarchy describing the relationships between the classes in MyMenu and the core elements of Cruiser.

Persona

The Persona class is part of TabletopUM (Kim, 2011) and was used in MyMenu to initiate the personalisation process. Persona objects identify a user by displaying their name and a chosen image. The IP

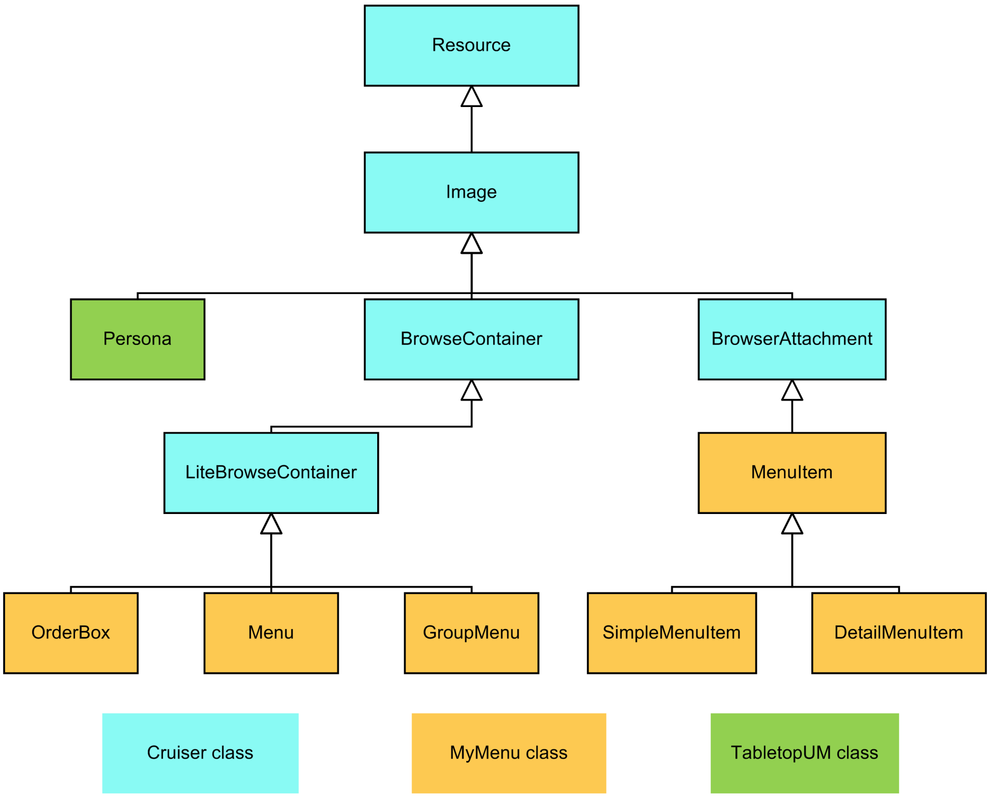


FIGURE 5.2. MyMenu class hierarchy.

address of the user's mobile device is also stored in the Persona object to facilitate the exchange of data with the user model.

Each interface element of MyMenu will now be briefly described. All of the elements used in MyMenu are inherited (not necessarily directly) from the Image class in Cruiser.

Menu (Individual)

The *Menu* class inherits from LiteBrowseContainer (which varies slightly in appearance from BrowseContainer) and acts as a container for other objects, so that menu items may be placed within the menu (See Figure 4.5). These items are the same for every Menu and are stored in a vector of MenuItem objects. Another important feature of Menu objects is that they may have a Persona object associated with them, which allows the application to know who it should be personalised for (See Figure 4.7).

MenuItem

The *MenuItem* class provides an abstract representation of a menu item. Attributes of a MenuItem include the title, description, price, ingredients, dietary information and an image of the item. Dietary information includes qualitative measures on certain nutritional information, such as "low fat" or "low carb". Together with the ingredients, this is used in the recommendation algorithm, which is described in Section 5.2.3.3. MenuItems also have a Persona attribute to indicate who it is recommended for (if it is recommended).

The subclasses *SimpleMenuItem* and *DetailMenuItem* allow for certain attributes of a MenuItem to be displayed. SimpleMenuItem shows the title, image and price of the item and are the objects that are actually appear on the menu (See Figure 4.5). DetailMenuItems display the title, price and description of the menu item and correspond to the "menu item card" that was described in Section 4.2.2 and shown in Figure 4.5, Label 2.

GroupMenuItem is another subclass of MenuItem and is used by the GroupMenu to display menu items recommended for the group (See Figure 4.9). GroupMenuItem also has a vector of Persona objects so that it knows who this item is recommended for.

Scrutiny Interface

The scrutiny interface allows the user to view the reasoning for recommendations of menu items. It was constructed by modifying the existing *BubbleNotification* class in Cruiser. BubbleNotification was designed as a visual cue to provide small hints or instructions for the user. For example, if the user was required to dwell on an object, the notification would pop up to indicate this, similar to a tool tip on existing desktop interfaces. Extensions to BubbleNotification for MyMenu included allowing for multiple lines of text to be displayed as well as adjusting the size of the pop-up area to accommodate the extra information (See Figure 4.12).

GroupMenu

As with the individual menu, *GroupMenu* also acts as a container for MenuItem objects. However, GroupMenuItems are displayed on the menu in a circular fashion (See Figure 4.8).

OrderBox

The *OrderBox* object acts as a container for the MenuItems that users would like to order (See Figure 4.10). When a user presses the "Place Order" button, the application will insert information into the corresponding user models. Further details of this process are described in Section 5.2.3.6.

5.2.2 User Model Ontology

Before describing the personalisation process, an overview of the user model ontology that the personalisation is derived from is provided. This ontology is required as part of the PersonisJ framework and its purpose is to allow information in the user model to be organised hierarchically, for easier retrieval of information when required. Within the hierarchy, *contexts* are defined, which may contain *components*. Each component may accrete *evidence*, which is essentially a value for that component, and may only be appended to the user model; that is, evidence cannot be deleted. For MyMenu, a Dietary context was created in the user model, which contains two child contexts: Inedible and Preferences. Each of these contexts had further components and descriptions of these components are summarised in Table 5.1.

TABLE 5.1. Description of User Model Ontology components.

Context	Sub Context	Components	Description	Example
Dietary	Inedible	Allergies	The user's allergies	nuts, shellfish
		Cannot Eat	Other foods the user cannot eat (due to religion, etc.)	beef
	Preferences	Likes	Foods that the user likes to eat	tomato, onion, garlic
		Dislikes	Foods that the user does not favour	chocolate, cheese
		Specific Diet Measures	Dietary measures the user is interested in	low fat, low carb, high protein
		Dining History	A history of dishes the user has ordered	Bruschetta

By analysing the information within the components, MyMenu is able to determine whether certain menu items are recommended for a particular user. The user model ontology described here is quite simple and was developed specifically for the evaluation of MyMenu. However, PersonisJ is able to support more complex user models. An area for future work would be to use such models for personalisation to determine the effectiveness of the personalised result.

5.2.3 Personalisation Process

This section introduces the key components of the personalisation process: menu creation, the request for information from the user model, the recommendation algorithm, the reasoning for recommendations, group recommendations and writing to the user model.

5.2.3.1 Menu Creation

All of the menu item data is read from a file in JSON[1] format. This file contains the attribute values of every item, including the title, category, price, description, ingredients, dietary information and image file name. For example, here is a listing for Mussels di Napoli:

```
"menu_item": {
    "category": "Appetisers",
    "description": "Mussels in the shell, simmered with wine, garlic-butter and onions.",
    "dietaryInfo": {
        "high_protein": "n",
        "low_carb": "y",
        "low_fat": "y"
    },
    "filename": "restaurant/menu_dataset/Mussels_di_Napoli.jpg",
    "ingredients": [
        "mussels",
        "wine",
        "garlic",
        "butter",
        "onions"
    ],
    "price": "12.5",
    "title": "Mussels di Napoli"

}
```

As indicated in the above listing, the dietary information is specified using boolean values for each type of dietary measure. The ingredients are encoded as an array of strings and the rest of the attributes are encoded as strings. The full list of menu items is provided in Appendix A. When creating a Menu object, MyMenu reads the data for each item, creates a MenuItem object using its values and adds it to the Menu. The data set may be interchanged easily by substituting the required file, so menus are not confined to a single data set. This would be useful in loading seasonal dishes or menus from different restaurants.

[1] http://www.json.org/

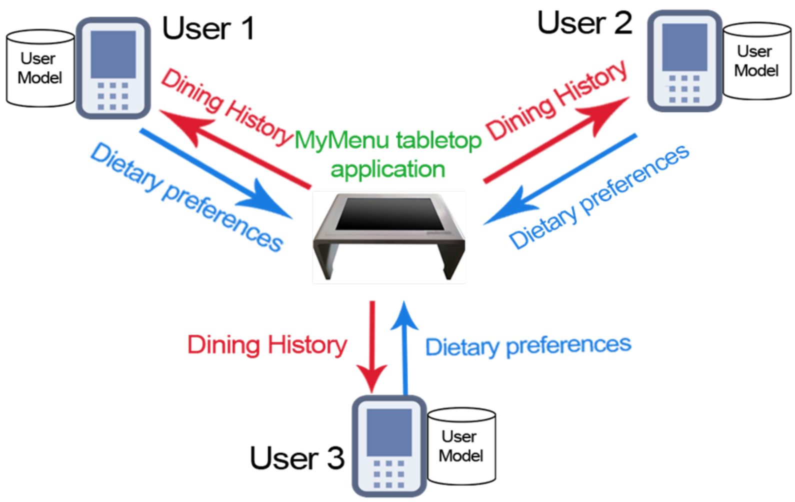


FIGURE 5.3. System architecture demonstrating the communication between the mobile devices and tabletop.

5.2.3.2 Request for Information

When a user drags their Persona onto a menu (as in Figure 4.6), MyMenu creates a request for information (evidence) from the Dietary context of the user model. This means that it will attempt to retrieve all the information from both the Inedible and Preferences contexts (and each of their components). Using the processes within the TabletopUM framework, the request is created and then sent to the UMController corresponding to the Persona. At this point, a callback is set up to listen for a response from UMController. UMController then checks whether the tabletop has access to each component. For each component that the tabletop has access to, UMController will perform an *ask* operation on PersonisJ to retrieve all evidence for that component. Once it has gathered all the evidence from each permissible component, UMController sends this information back to MyMenu (Figure 5.3)), which is captured by the callback that was set up earlier. MyMenu then proceeds to use that information to calculate which items should be recommended. In the event of an empty response, where evidence could not be retrieved (due to denied access to components or missing evidence in the components), MyMenu will not attempt to personalise the menu.

5.2.3.3 Recommendation algorithm

Once MyMenu has the necessary dietary information, it may then calculate which menu items are recommended for the user on their individual menu, using a simple recommendation algorithm.

The algorithm first determines whether the *MenuItem* contains anything the user cannot eat, using evidence from the *Allergies* and *Cannot Eat* components. If it finds any ingredients in the menu item that matches the evidence, the current item is immediately marked as NOT RECOMMENDED and the algorithm moves on to the next menu item. If there are no matches for foods the user cannot eat, then the user is able to eat this menu item (but may not necessarily prefer it). The algorithm proceeds to the next stage, which searches for matches in the user's *Likes* and *Dislikes*. It will also search for matches between the dietary measures in the menu item and the user's preferred *Specific Diet Measures*. A progressive score is maintained for the number of positives and the number of negatives.

The positive score is incremented by 1 for:

- Each ingredient in the menu item that matches the user's Likes.
- Each dietary measure in the menu item that matches the user's preferences for Specific Diet Measures.

The negative score is incremented by 1 for each ingredient that matches the user's Dislikes.

For example:

Bill has indicated that he likes potato and beef, dislikes carrot and would prefer low fat foods. For a steak dish that contained mash potato and vegetables as a side (which included carrots) and was indicated as low fat, the positive score would be 3 and the negative score would be 1.

When the search is finished, if the positive score is greater than the negative score, the menu item is marked as RECOMMENDED. Otherwise, it is marked as NOT RECOMMENDED. Since this recommendation algorithm is quite simple, it has limitations in its accuracy. However, it should be noted that the recommendation process is not a core contribution of this thesis and hence, a simple approach was chosen over one that yielded high accuracy. An area for future work would be to explore how more sophisticated methods of recommendation could be incorporated into the system to provide a personalised interface, which is discussed in Section 8.3.4.

5.2.3.4 Reasoning for Recommendations

Throughout the recommendation algorithm, MyMenu stores matches in the Allergies, Cannot Eat, Likes, Dislikes and Specific Diet Measures components so that the reasoning for the recommendations may be constructed. For recommended items, the result is displayed in the scrutiny interface, allowing the user to examine why the item was recommended for them. For the example above, Bill would be able to see that the steak dish was recommended for him because it matched his likes of beef and potato and also matched his low fat preference. It would also indicate that the dish contained carrot, which he doesn't like.

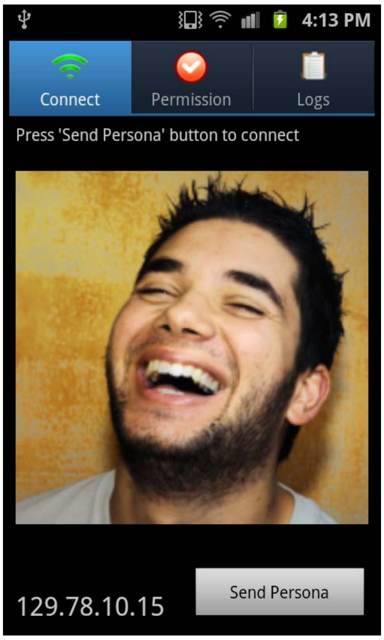
5.2.3.5 Group Recommendations

The group recommendation algorithm works by identifying the menu items that are recommended in common. For example, if Bruschetta was recommended for both Jane and Matthew on their individual menus, it would be marked as recommended for them on the group menu as well. However, the group menu only displays the top six group recommendations to avoid cluttering the user interface. To calculate which menu items to display, MyMenu keeps a count of how many users each menu item is recommended for and keeps them sorted in descending order. Hence, menu items that are recommended for the most number of people are given priority to be displayed. The reasoning for group recommendations indicates only who it is recommended for. It does not reveal each user's dietary preferences, since this could be seen by other users for whom the item is recommended for.

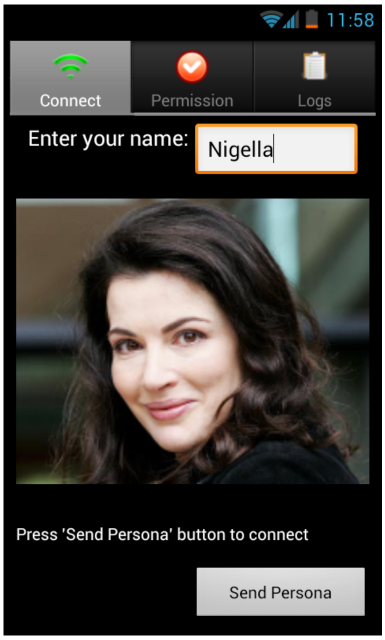
5.2.3.6 Writing to the User Model

In addition to requesting information to personalise menus, MyMenu also has the ability to insert information into the user model. The user model ontology has another component under the *Dietary -> Preferences* context called *Dining History*. When users press the "Place Order" button on the Order box object, MyMenu will send information to the mobile devices for each recommended item in the order. For each individually recommended menu item, which has an associated Persona, the title of that menu item will be sent to the corresponding UMController (Figure 5.3). UMController will then perform a *tell* operation on the Dining History component, which inserts the menu item's title as evidence. A similar process happens for group recommended items (which are associated with multiple Personas), except that the information is sent to *all* corresponding UMControllers. No information is sent for regular menu items, since there is no way of identifying who ordered them. It would be worthwhile to explore methods of doing this in future work, since the user's choice of menu items, recommended or not, forms a large part of their personal preferences.

The reason for writing information to the user model is so that the result of the user's interactions with the tabletop may be recorded and possibly used in subsequent interactions at other interactive surfaces. For



(A) Connect tab before modification.



(B) Connect tab after modification.

FIGURE 5.4. Modifications to the Connect tab.

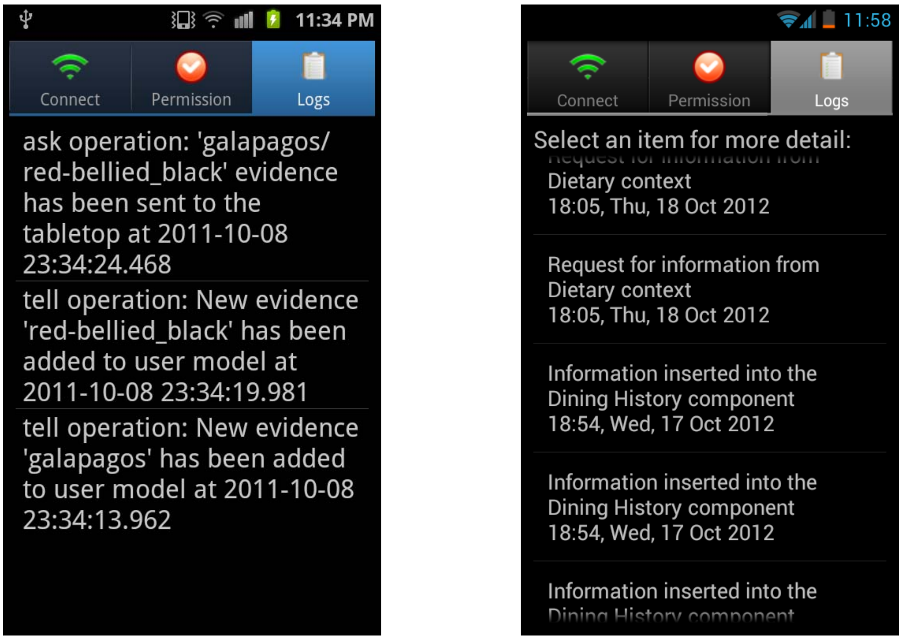
MyMenu, if the user were to return to the restaurant or visit a new restaurant, the information contained within the Dining History component could be used in addition to the other components to personalise a menu. An area for future work could be to explore how effective it would be to use evidence that is accreted over a period of time for personalisation.

5.3 UMController Application

Although the UMController mobile application was used with its implementation as described by Kim (2011), some minor changes were made to the user interface, which will now be briefly described.

The Connect tab was modified to include a text field where users could enter their name to associate themselves with their Persona. Also, the ability to hide the IP address field was added to reduce the cognitive load on users when examining the interface, as users might be confused by its purpose. The field may be toggled to be hidden and shown by pressing the menu button on the device and then selecting "Toggle IP address". Please refer to Figure 5.4 for modifications to the Connect tab.

The Logs tab was also modified to provide a more user friendly description of the operations that took place when using the application. Although the log messages did contain the necessary information that



(A) Logs tab before modification. (B) Logs tab after modification.

FIGURE 5.5. Modifications to the Logs tab.

might allow the user to understand what had happened, they did not clearly explain the contexts and components involved in the operation. They also lacked readability, which may impact on the user's experience with using the application, especially if multiple pieces of evidence were involved in the operation. Hence, descriptions of the log messages were reworded to indicate clearly which context or component was affected. To address the readability issue, each log item was made to be selectable, so that a new screen would appear when a user pressed on a log item (See Figure 4.2). Further details of the operation were displayed on this screen, such as each component that was affected and the corresponding evidence that was retrieved or inserted. This further improved the readability of the log messages as the evidence could now be omitted from them. Please refer to Figure 5.4 for modifications to the Logs tab.

5.4 Chapter Summary

This chapter has explained how the MyMenu tabletop application has been developed using the Cruiser software framework and the TabletopUM framework. Although MyMenu can only operate on Cruiser, many other types of applications may be built using the same principles that were described. The resulting implementation provides a foundational example of how to incorporate personalisation into a simple tabletop application. The key points to note include the personalisation process, including the request for information and then using the received data to personalise the application. As mentioned before, a simple recommendation algorithm was used as this was not a core contribution of this thesis. The next chapter explores elements of the evaluation design in determining the effectiveness of the personalised application.

CHAPTER 6

Evaluation Design

Evaluation of the personalised tabletop interface is critical in assessing its effectiveness at interactive surfaces and forms a key contribution of this thesis; a user study was chosen to understand the qualitative factors that influenced the value of the implemented mechanisms for personalisation. This chapter begins by presenting the goals of the evaluation, describing the specific aspects of the personalised interface that were to be evaluated, which led to the formulation of a set of hypotheses to be tested. The design of the experimental tasks and questions from the questionnaire and interview is justified in allowing for the evaluation goals to be achieved. This ultimately links back to the thesis goal of evaluating a tabletop interface to determine how effective it is in providing personalisation for small groups of users.

6.1 Evaluation Goals

Although the personalisation process involves using both the mobile and tabletop interfaces, the evaluation focused on the effectiveness of the personalised tabletop interface, which is the main contribution of this thesis. As such, the goals of the evaluation were formulated with regard only to the personalised tabletop interface and not the mobile interface. These goals enabled certain aspects of the tabletop interface to be measured. A description of each goal is provided for clarity on what was to be measured and the reason for doing so.

(G1) Assess the effectiveness of a personalised tabletop application for collaborative use.

This goal aimed to determine the degree of usability, learnability and understandability of the personalised tabletop interface. An interface that is simple to navigate, intuitive to use and easy to understand is important for providing a deeper interactive experience for the user. This allows the user to focus more on what the personalised result is showing them rather than how they should be obtaining it. Importantly, this goal relates to understanding how to personalise an interface when multiple users are present and are interacting independently of each other.

(G2) Assess the effectiveness of an interface for enabling scrutiny of a personalised interface within a tabletop application.

This goal was important for determining the effectiveness of the ability to control the level of personal information revealed in a shared environment. Although it is important to include the scrutiny interface as part of the resulting personalised interface, the overall effectiveness of the personalised interface would still be dependent on the user's perception of whether certain information would be too personal or private to reveal. Hence, the degree to which users understood the different levels of privacy was determined, followed by measuring how they felt about being able to control the information revealed in each level.

(G3) Determine the effectiveness of a tabletop interface that is personalised for the whole group to support a collaborative task.

The reason for evaluating the personalised group interface was to determine whether it provided users with support in carrying out tasks together as a group. For example, the personalised group interface may improve efficiency or facilitate better collaboration between users when carrying out a task. To achieve this goal, the degree to which users felt supported by the personalised group interface in making group decisions was measured.

It is emphasised that all goals were defined with the notion of evaluating a personalised interface for collaborative use rather than a single user at an interactive surface. Since interactive tabletops are used by multiple users, there is only minor value in determining how effective the personalised interface is for a single user. Hence, the evaluation was closely focused on assessing the usability and understandability aspects for small groups of users. This formed the basis for the formulation of the hypotheses and subsequently the design of the user study experiment, which are discussed in the following sections.

6.2 Hypotheses

As part of evaluating the personalised interface, the following hypotheses were formulated and were tested in the user study.

(H1) MyMenu provides an effective interface for personalised tabletop interaction.

(H2) MyMenu enables effective scrutiny over the personalised interface with indications of different levels of privacy.

(H3) MyMenu provides an effective tabletop interface with personalisation tailored to a whole group for a collaborative task.

The hypotheses (H1, H2 and H3) were respectively aligned with the evaluation goals (G1, G2 and G3). Although MyMenu was specifically used for the evaluation process, the results from the hypothesis testing can be generalised to any personalised interface that was structured in the same way as MyMenu (for example, in domains other than restaurant menus).

To test these hypotheses, user interaction with certain features of the personalised interface was explored. These features included:

- Individual personalisation: Users were assessed on following the procedure to personalise the interface to determine how intuitive this was (H1).
- Scrutiny: Users were assessed on the ability to examine how the user model was used in the personalisation process (H2).
- Group personalisation: Users were assessed on how usable the personalised group interface was and whether it supported them with a group task (H3).

The user study was designed to address the evaluation goals in terms of these interface features. Users were asked to complete a series of tasks that would involve using these features and were also asked to provide their feedback on their experience with using them.

6.3 Experimental Design

A user study was conducted in order to test the above hypotheses, which involved observing and recording how users interacted with the personalised interface. During the experiment, evidence was gathered primarily using qualitative methods. The approach consisted of using a combination of a modified *think-aloud* protocol and recording observations of user interaction. Participants were asked, verbally, to carry out some tasks that involved using the mobile and tabletop interfaces (further details on the tasks are provided in Section 6.3.3). While carrying out each task, the experimenter encouraged the participants to verbalise their thoughts and questioned them on their understanding of what the interface was showing them. Observations of participant actions were also noted as written evidence. Quantitative methods of measurement were also used in some parts of the data capture process, such as recording the number of errors that participants made during tasks. However, the experiment design did not measure quantitative efficiency, as the evaluation was weighted towards eliciting participants' thoughts on using and understanding the personalised interface in a group context.

The remainder of this section discusses aspects of the experimental design which allowed for capturing the necessary results. The scenario given to participants and the dataset used in the experiment are presented first. The experiment tasks are then discussed, including definitions of the outcomes of tasks and a description of each task. Finally, an overview of the design of the experiment questionnaire and the interview is provided.

6.3.1 Experiment Scenario

The experiment was conducted in groups of three in a laboratory setting, with each user seated at one tabletop. To provide a more realistic experience for the users, they were given a scenario where they were a group of friends out for dinner at an Italian restaurant called Luigi's. The table they were sitting at was the dining table and the menu dishes were themed for an Italian cuisine.

6.3.2 Restaurant Data Set

A requirement for the study (and the MyMenu application) was to have data that could be used to populate the menus. The menu data was obtained from the website of *Olive Garden Italian Restaurant*[1], due to the range of data that was readily available. This data included the names, descriptions, ingredients, prices and images of each menu item. Olive Garden also publishes nutritional information on their website, which was incorporated into the data set and used as part of the personalisation process when calculating the dietary measure qualifications (e.g. low fat or low carb). The data set consisted of 31 menu items grouped into various categories including Appetisers, Soups, Salads, Pastas, Chicken, Seafood, Beef, Pork and Dessert. It was important to obtain a data set that was authentic and suited to the domain to provide users with an experience that would simulate a real world scenario as much as possible.

[1] http://www.olivegarden.com/Menu/Dinner/

6.3.3 Experiment Tasks

The set of experiment tasks were designed to involve using various features of the tabletop and mobile interfaces. For each task, there were one or more steps to follow that would entail completion of that task. The tasks were specifically designed to exercise the features necessary to collect data for testing the hypotheses.

An **error** was defined as any action that did not advance towards the goal of the task or if the participant had experimented with many different actions and was still unsure of how to proceed.

Upon making an error, **recovery** was defined as either:

- taking an alternative action that advances towards the goal of the task; or
- completing the task after receiving hints from other participants or the experimenter

There were three possible outcomes regarding the completion of a task:

- **Success:** If a user followed every step without making any errors, this resulted in a Success outcome.
- **Did Not Finish (DNF):** If a user made an error and did not complete the task, this resulted in a Did Not Finish outcome.
- **Recovered:** If a user made an error, but recovered from that error and proceeded to finish the task, this resulted in a Recovered outcome.

The experiment was conducted in a manner such that every group performed the same tasks in the same order. This ensured that all participants would use each feature of the interface so that an outcome for each task would be able to be determined. Also, to assess learnability of the personalised interface, participants were not given a tutorial on using the MyMenu application (but received a tutorial on using the tabletop). This allowed for observing how participants would discover new features of the interface as they carried out each task. The resulting outcomes would then be used in a qualitative analysis on using the personalised interface.

Before commencing the tasks, it was necessary for participants to have information in their user model, to ensure that the personalisation process would be able to tailor the interface to each user. Hence, a preliminary *Data Entry Phase* was used to allow participants to do this. This phase is discussed further in Section 6.4.3.

The actual tasks involved exploring how to activate a personalised menu, use of the scrutiny interface and use of the group menu. As the process of personalising a menu involved both the mobile application (UMController) and the tabletop application (MyMenu), users were required to use the mobile device for some tasks and the tabletop for other tasks. The tasks that were asked of participants are reproduced below. Tasks T1, T2 and T6 were performed using UMController while tasks T3–T5 were performed using MyMenu. The hypotheses to which each task is linked to is given in parentheses.

- **T1.a Enter a name and choose a picture for your persona** (H1, H2).
  Users were required to enter a name in the text field and select an image to use as their Persona.
- **T1.b Indicate the dietary information that you want to allow the tabletop to access** (H1, H2).
  Users were required to tick the user model components on the Permissions tab that they would allow the tabletop to access. The users had entered information into the components in the preliminary data entry phase, ensuring some familiarity with the structure of the user model.
- **T2 Send your persona to the tabletop** (H1).
  Users were required to press the “Send Persona” button.
- **T3 Personalise your menu** (H1).
  Users were required to drag their Persona onto their menu.
- **T4 Find out why a menu item was recommended for you and examine each level of detail in the explanations** (H1, H2).
  Users were required to drag out a recommended menu item from their menu and then press the inspection button on the menu item card. After this, they needed to press the “More detail” button to reveal each level of detail.
- **T5 Now imagine that it is dinner time. Organise amongst yourselves what you would like to order for dinner and then place your order** (H1, H2, H3).
  This was an open ended task, so there was no set procedure to follow. Instead, observations of the users’ interaction with the group menu and individual menus were recorded including whether they ordered items from one or both of them.
- **T6 View the details of a log item** (H1, H2).
  Users were required to select a log item from the Logs tab and read the information presented to them.

It is emphasised that the core aim of the study was to evaluate the personalised tabletop interface. However, it was necessary to include tasks for UMController that would allow users to initiate the personalisation process. These tasks were not used in evaluating the mobile interface but still played a role in evaluating the understandability of the personalised tabletop interface in terms of the process of personalising it.

6.3.4 Experiment Questionnaire and Interview

The questions in the questionnaire and interview focused on three key areas closely aligned with the hypotheses:

- **Usability of the personalised interface** (H1)
  Participants were asked whether they thought MyMenu was intuitive to use and easy to navigate. They were also asked to give comments on which aspects of the tabletop interface they liked and disliked for carrying out the tasks and general comments on what they thought about the application.
- **Understanding the personalisation process** (H2)
  Participants were asked whether they understood that their menu had been personalised using their user model. There were also questions on the scrutiny interface, including their understanding of the different levels of scrutiny and how comfortable they felt about each level. This was also followed up in the interview with a similar question.
- **Group personalisation** (H3)
  It was important to determine how useful the group menu was as part of providing an interface for group personalisation. Hence, participants were asked whether it was effective in allowing them to make decisions as a group in both the questionnaire and the interview.

Most of the questionnaire questions required participants to indicate their level of agreement with a statement on a seven point Likert scale (1=strongly disagree, 7=strongly agree) and to explain their choice. The interview was conducted as a group to allow for participants to elaborate on their responses from the questionnaire and also to determine whether participants within a group disagreed on certain aspects of the personalised interface. Please see Appendix E for a copy of the experiment questionnaire and Appendix F for the interview questions.

6.4 Experiment Procedure

This section provides a comprehensive explanation of how each part of the user study experiment was carried out. As an aid to conducting the procedures for the procedures in the experiment, a user study task script was developed for the experimenter to follow. Please refer to Appendix H for a copy of this script.

6.4.1 Preparation

For the experiment, each of the three participants would be using a mobile device that contained their user model. In preparing for the experiment, it was necessary to ensure that all evidence from the *Dietary* context was erased, so that only the participants' information would exist in the user model. This was done using a mobile application called *User Model Data*, which is discussed further in Section 6.4.3.

6.4.2 Introduction

Each session began with the participants being seated at the tabletop and giving them the information statement (See Appendix B) about the study. After they read this, participants were informed of the confidentiality of their responses and procedures regarding withdrawal from the study. They were then asked to complete the consent form (See Appendix C). This was followed by an explanation of the procedure for the rest of the session and then completion of the background questionnaire (Appendix D). Once this was done, a brief verbal explanation of personalisation was given to the participants, including the role of the user model (for details, please see the User Study Script in Appendix H). This led to the data entry phase, where participants were asked to enter their dietary information into their user model.

6.4.3 Data Entry Phase

The data entry phase involved each participant using a mobile application, called User Model Data, to enter information about their dietary preferences. This application consisted of a sequence of screens that would ask participants for foods they could not eat (including allergies), as well as their likes, dislikes and whether they had any preference for specific diet measures, such as low fat or low carb. For each component (Allergies, Cannot Eat, Likes, Dislikes and Specific Diet Measures), participants were given a list of predefined ingredients or values. They indicated the values that applied to them by ticking the checkbox. Participants could also enter other ingredients or values in the text box provided. Screenshots of the User Model Data application are provided in Appendix I. Participants were given the option to enter fictitious information if they did not wish to disclose their own personal information.

6.4.4 Tutorial

Following the data entry phase was a tutorial on using the tabletop and the mobile device. Participants were given a demonstration of how to interact with Cruiser. They were shown how to move objects by dragging them to any location, how to rotate and resize objects using two finger gestures or by using the corner rotate and resize technique, and how to drag objects into and out of containers (such as the menus and the order list). The dwell operation was also demonstrated and the purpose of the black hole was explained and demonstrated by placing a few objects into it. For the mobile devices, which were all running the Android operating system, participants were shown how to use the back button for various functions, such as dismissing a keyboard or going back to a previous screen.

6.4.5 Main Experiment Task

After the tutorial, the main experiment task began. Participants were informed that they would be asked to complete a set of tasks. The experimenter guided the participants through the main task and had a task result sheet to record each participant's performance in tasks and to take down notes. (See Appendix G for a copy of the task result sheet). The first part of the experiment involved using the UMController mobile application, so each participant was given the same mobile device that they used in the data entry phase. This ensured that they would be using their own information to personalise the menu. Once they had completed Tasks T1–T2 using UMController, as outlined in Section 6.3.3, they were then asked to personalise their menu (Task T3). Upon doing this, the experimenter asked what the participants thought had happened to the tabletop interface and recorded their responses. Participants then completed Task T4 and were asked how they interpreted the different levels of detail in the recommendation. Their attention was then drawn to the group menu and they were questioned on what they thought it showed with their responses recorded. This was followed by Task T5 and T6, where participants ordered their chosen items, which concluded the main experiment task.

6.4.6 Post Experiment Questionnaire

When the main experiment task was finished, participants took a short break and were then asked to complete the post-experiment questionnaire individually. Each participant was given a questionnaire and completed it on separate tables. They were notified that they could revisit the tabletop or their mobile device to help them answer the questions if they had forgotten what they had done throughout the main experiment task.

6.4.7 Interview

After completion of the post-experiment questionnaire, the experimenter conducted the interview as a group. Participants were informed that it was an informal group discussion rather than a strict question and answering session. Following the interview question guide (See Appendix F), the experimenter asked participants about certain aspects of the personalised tabletop interface and encouraged them to reflect on the their experiences in the main experiment task. The interview concluded the session.

6.5 Apparatus and Data Capture

Various devices were used in the experiment to accommodate both the environments required to run the software applications as well as for capturing the actions and responses of participants.

The hardware used included a rectangular tabletop with a 46-inch, multi-touch display at (16:9) aspect ratio, 1920×1080 resolution and capable of detecting 32 concurrent touches[2]. This was placed roughly in the centre of the room. Two users were seated on one long side of the tabletop and the third user was seated on the opposite side.

Three Android[3] mobile devices were also used. For this user study, two smart phones (a Samsung Nexus S and HTC Nexus One) and a tablet (Samsung Galaxy Tab) were used, but any mobile device that is capable of running the UMController application will suffice. The mobile devices did not need to be in any particular position — they were given to the users when required. Prior to the experiment, each mobile device was configured to the same wireless network as the tabletop, which was required for them to communicate, as discussed in Section 5.1.

[2]http://multi-touch-screen.com/product_g3.html
[3]http://www.android.com/

Video and audio recordings were an integral part of the data capture for further analysis after the experiment. A high-definition video camera was set up on a tripod on the short side of the tabletop, such that there were two participants on the left of the camera and one participant on the right. The camera was raised and angled slightly downwards so that the whole surface of the tabletop could be seen as well as the participants from head to waist. The microphone on the camera was also tested to ensure that participants' speech would be captured.

In addition to the video recording for data capture, handwritten notes were also taken throughout the experiment. These notes were made on the task result sheet (Appendix G) and included information such as participant reactions, errors that participants made and how they recovered (if they did), general observations, answers to the experimenter's questions and other quotes from participants throughout the experiment.

6.6 Participants

The user study was conducted in groups of three. Recruitment of participants with different backgrounds was done intentionally to achieve a wide demographic, which is representative of potential users at a tabletop. As participants would be carrying out tasks that may require collaboration, it was also important to ensure that participants in each group were familiar with each other as much as possible. Please see Section 7.1 for a detailed discussion of participant backgrounds.

6.7 Chapter Summary

Foundations for the evaluation design were first presented including the evaluation goals and the hypotheses associated with them. In discussing the experimental design, it was emphasised that mainly qualitative methods of data capture would be used to test these hypotheses, which would lead to a qualitative analysis of the results. Another important point to note is that the evaluation focuses on assessing effectiveness of the personalised tabletop interface (and not the mobile interface), as this is one of the main goals of this thesis.

CHAPTER 7

Evaluation Results and Analysis

The goal of the evaluation was to determine the effectiveness of the personalised tabletop interface. As this was a first study of collaborative use of a personalised surface, our investigation aimed to assess usability of the interface by observing small groups of users as they interacted with it. Therefore, this chapter presents and analyses the gathered data to understand if the system and approach met its goals of providing an effective personalised interface for collaborative use.

7.1 Participants

Each session of the user study was conducted in groups of three with nine groups in total. Please refer to Table 7.1 for a summary of participant backgrounds. To maintain anonymity, each participant was identified by their participant code — either ‘a’, ‘b’ or ‘c’, preceded by the group number. There were ten male participants (17 female) and the ages of participants ranged from 18–61, with a mean of 26. There were 19 university students of various disciplines (physiotherapy, optometry, design computing, computer science, microbiology, software engineering, physiology, economics, business, solar engineering), three sales associates, two architects, a designer and a bookkeeper. Eleven participants indicated that they spent more than 41 hours per week using a computer, seven spent between 31-40 hours, three spent 21-30 hours and the rest spent 20 hours or less. One third of participants indicated that they had used a tabletop interface before, with five participants having used Cruiser before. Since the experiment was conducted in groups, it was important for participants to be familiar with each other so that they would feel comfortable interacting together. Seven out of the nine groups had at least two participants that had known each other for over a year. One group of participants had known each other for about one month and one group of participants had never met before the user study.

TABLE 7.1. Participant background information for groups 1–9. Note that PID is the participant identifier used for the experiments. Students are indicated with a *.

	PID	Age	Sex	Occupation	Partner 1 known	Partner 2 known	Computer usage hours/wk	Used table-top before	Smart phone/tablet experience
1	1a	18	M	Physiotherapy*	1 year+	1 year+	21-30	N	competent
	1b	20	F	Optometry*	1 year+	1 year+	11-20	N	competent
	1c	18	F	Commerce*	1 year+	1 year+	11-20	N	competent
2	2a	21	M	Design Computing*	1 year+	1 year+	41+	Y, Cruiser	competent
	2b	22	M	IT*	1 year+	1 year	41+	Y, Cruiser	limited
	2c	21	F	Computer Science*	1 year+	1 year+	41+	Y, Cruiser	advanced
3	3a	19	F	Design Computing*	1 week	1 week	1-10	N	competent
	3b	23	M	Computer Science*	1 year+	1 month	21-30	N	limited
	3c	22	M	Computer Science*	1 year+	1 month	41+	N	advanced
4	4a	21	F	Microbiology*	1 year+	1 week	31-40	N	competent
	4b	21	F	Hardware Retail	1 year+	1 week	1-10	N	advanced
	4c	21	F	Microbiology*	1 year+	1 year+	31-40	N	competent
5	5a	22	F	Software Eng	1 year+	1 year+	31-40	N	competent
	5b	22	F	Computer Science*	1 year+	1 year+	31-40	Y, Cruiser	advanced
	5c	21	F	Software Eng*	1 year+	1 year+	31-40	N	competent
6	6a	20	F	Physiology*	Never met	Never met	11-20	Y, Cruiser	competent
	6b	21	F	Economics*	Never met	Never met	31-40	N	advanced
	6c	21	F	Business*	Never met	Never met	41+	N	competent
7	7a	27	F	Designer	1 year+	Never met	41+	Y, museum	competent
	7b	31	M	Architect	1 year+	1 year+	41+	Y, shopping	advanced
	7c	28	F	Architect	1 year+	Never met	41+	Y, learning centre	limited
8	8a	24	M	Economics*	1 year+	1 year+	41+	N	advanced
	8b	22	M	Solar Eng*	1 year+	1 year+	41+	Y, photo album maker	advanced
	8c	24	M	Work Processor	1 year+	1 year+	21-30	N	advanced
9	9a	58	F	Merchant	1 year+	1 year+	31-40	N	limited
	9b	61	M	Shop Keeper	1 year+	1 year+	11-20	N	limited
	9c	46	F	Bookkeeper	1 year+	1 year+	41+	N	NEVER USED

7.2 High Level Results

As stated in Section 6.1, the evaluation goals considered the shared environment of interactive tabletops and were designed to evaluate usability of the personalised interface with regard to small groups of users rather than a single user. Hence, the results summarised here refer to the performance and responses of each group of participants.

While carrying out the experimental tasks, participants were only told what each task was and did not receive instructions on how to complete the task. Therefore, it was expected that participants would make a number of errors initially as they experimented with different parts of the interface. However, if participants could recover from their errors, this indicated that the user interface design was not necessarily poor, but on the contrary, easy to learn. For the task of personalising their menu, four out of the nine groups were immediately successful, another four were successful after recovering from initial errors and one group did not finish the task. When using the scrutiny interface, four groups out of nine were immediately successful, while the remaining groups were successful upon recovery from errors. Seven out of nine groups also used the group menu in the open ended task of selecting menu items to order and varying levels of collaboration were observed among the groups during this task.

The Likert scale responses from the questionnaire showed general agreement with the statements put forward to participants, such as “The Restaurant application was easy to navigate and intuitive to use” having a median rating of 6 (which evaluated to “Agree”), and “The group menu allowed my group to effectively discuss and decide what to order for the meal” also having a median rating of 6. This gave preliminary indications that the personalised interface was usable and understandable for the majority of participants. The free-form responses provided more detail on aspects of the interface that supported their scores (“Personalised menu is easy to navigate using scroll bar” — participant 5b), which further supported the evidence that the personalised interface was usable. The interview responses also demonstrated that it was clear to participants that the interface was personalised and that the group menu was effective in allowing them to make decisions together when ordering menu items for a meal. The following sections explain all of the above findings in detail.

7.3 Preliminary Tasks

Before describing the results of the task performance, a brief discussion of the necessary preparations for the tasks will be covered, including the data entry phase and the Persona connection phase. As described in Section 6.4.3, participants used the User Model Data mobile application to enter dietary information into their user model. During this data entry phase, all participants seemed to diligently enter the information, although it is emphasised that this information may have been fictitious. Please refer to Appendix I for a summary of the information that each participant entered into their user model.

Once participants had entered information into their user model, they used UMController to configure their Persona by entering a name and selecting an image. They then made their choice of which user model components to allow the tabletop to access, by ticking each one on the Permission tab. After this, each participant sent their Persona to the tabletop by pressing the "Send Persona" button. It is noted that the results from these phases were not part of the evaluation because they did not involve using the tabletop interface, which is what the evaluation was focused on assessing.

7.4 Task Performance

During the experiment, participants completed several tasks using the personalised tabletop interface. To assist with the data capture process, a task result sheet was used to record the outcome of each *step* of the task, which was indicated by ticking the applicable box or boxes — Success, Error and Recovery. The completed task sheet for group 9 is provided in Appendix G as an example of how this was done. It should be noted that the result sheets were augmented with additional notes after reviewing the video recordings of each group session.

The *task* outcome could be either Success, Did Not Finish or Recovered, as described in Section 6.3.3. This was calculated by taking the lowest *step* outcome of the task, where the order of the outcomes from low to high was Error, Recovery and Success. This was determined by the notion that if a participant made an error at any step of the task, that step was not intuitive to them on their first attempt. Hence, if they recovered from that error, this would produce a better outcome and if they completed the task on their first attempt, this would produce the best outcome. The chosen step outcome was then mapped to the task outcomes as follows — Error mapped to Did Not Finish, Recovery mapped to Recovered and Success (*step*) mapped to Success (*task*).

The task result sheet was used to record notes on participant reactions, errors that participants made, how they recovered from errors (if they did) and other general observations. Video recordings were also taken so that the actions of participants during the experiment could be confirmed. These recordings were reviewed later on to clarify observations of user actions during the experiment and also to extract data that may have been missed, including user actions as well as what was said while completing the tasks. A summary of the task performance results is provided below.

7.4.1 Personalising the Menu

Task T3: Personalise your menu.

At the beginning of this task, participants had an individual menu in front of them and each of their Personas was on the tabletop. To successfully complete the task, participants had to drag their Persona onto their menu. Table 7.2 shows the resulting outcomes for personalising the menu. The group result was taken as the majority result for the group.

TABLE 7.2. Performance results for personalising the menu (Task T3).

	Group								
Participant	1	2	3	4	5	6	7	8	9
a	✗	●	●*	●*	✔	●	●	●*	●*
b	✗	✔	✔	●*	✔	✔	●*	✔	✔
c	✗	✔	✔	●	✔	●	✔	●*	✔
Group result	✗	✔	✔	●	✔	●	●	●	✔
Legend: ✔= Success, ✗= Did Not Finish, ●= Recovered									
* indicates participant received assistance from group members									

Group 5 was especially proficient in this task, with no participants making any errors. They all dragged their Persona onto their menu immediately and they understood that their menu was personalised once they had done so. This could be due to their experience in computer usage as indicated by Table 7.1 (they are all software engineering or computer science students and spend 31-40 hours per week using a computer). Also, 5b had used Cruiser before, which may have contributed to how she knew what to do. Participants 2b and 2c had also used Cruiser before, which may have influenced their success in this task.

Errors

A consistent error that participants made was in personalising their menu, or someone else's menu, accidentally. Participants would often move different objects around to explore the interface. Hence, when they tried to drag their Persona across a menu, it would be "captured" by the menu rather than continue sliding with the participant's finger. This happened for participants 1c, 2a, 4c, 6a, 6c, 7a, 8a and 9a, who did not seem to expect their Persona to become attached to the menu. Some participants seemed to not notice this and consequently, were wondering where their Persona had gone. Participants seemed confused and did not fully understand what had happened to the user interface. This was apparent when participant 2a asked "What do you mean by personalise?" after personalising his menu accidentally.

Other errors included some participants trying to tap or dwell on the Persona (4b, 7b), dragging the menu onto the Persona (8c), dragging the Persona onto a menu *item* and vice versa (1b, 1c, 8a and 8c). Participant 8a specifically said "I thought I could personalise the individual menu item". Group 1 in particular seemed to have trouble in personalising their menu. Although they were given numerous hints about dragging one object onto another, none of the participants managed to drag their Persona onto their menu. This could be attributed to the fact that none of them had used a tabletop before (Table 7.1). Eventually, they were explicitly told to drag their Persona onto their menu so that they could continue. Some participants tried to use the mobile device to personalise their menu. Participants 1a and 4b examined UMController to see if there was a function to personalise. Participant 8c placed the mobile device on the tabletop and when he realised that nothing happened, he placed it specifically on his Persona.

Recovery from Errors

Participants were able to recover from errors in several ways. For those participants who had personalised their menu accidentally, some realised that it was personalised after receiving a hint from the experimenter to examine the interface more closely (7a, 9a) or doing this themselves (2a, 6a, 6c). Participants noticed that the menu was personalised due to a number of features, such as the textual notification ("Personalised for ..."), the Persona appearing on the menu, the thumbs up icons on the menu items or a combination thereof. Participant 7a said "*Now* I realise it's personalised" after the experimenter suggested to look at the interface more closely.

Other participants received assistance from their fellow group members. Although participant 4c had personalised her menu accidentally, she realised that it was personalised after collaborating with 4b. Meanwhile, 4b was having trouble with personalising her own menu, so 4c showed her how to drag the Persona onto it. 4a was also watching at the time, so she followed the same action to personalise her menu. Participant 9a received a hint from 9b about dragging the Persona onto her menu, while a similar situation occurred with 7a giving a hint to 7b. Participants 8a and 8c had their menus personalised by 8b after the experimenter hinted that 8b could assist them, since he had managed to do it. A similar observation was made with 3a receiving assistance from 3c. From these examples, it is clear that most participants recovered from errors by receiving assistance from other members in their group, suggesting that participants had no trouble performing the action after seeing or having it explained.

7.4.2 Using the Scrutiny Interface

Task T4: Find out why a menu item was recommended for you and examine each level of detail in the explanations.

After completing the previous task, each participant had a personalised menu presented to them with a number of recommended items. The steps involved in this task were:

(1) Drag out a recommended menu item from the menu.
(2) Press the inspection button to open the scrutiny interface, revealing the first level (Low) of detail (Figure 4.12).
(3) Press the “More detail” button to reveal the next level of detail (Medium) .
(4) Press the “More detail” button to reveal the final level of detail (High) .

It is emphasised that the experimenter only read out the task to participants and they were not told what the steps were. Table 7.3 shows the outcomes for using the scrutiny interface. As with the previous task of personalising the menu, the group result was taken as the majority result out of the whole group.

Sixteen participants (1a, 1b, 1c, 2a, 2b, 2c, 4a, 4b, 4c, 7a, 7b, 7c, 8a, 8c, 9b, 9c) began the task by scrolling through their personalised menu as if looking for an indication of something that would allow them to find the reasoning for recommendations. However, this could also be interpreted as the participants looking for a certain menu item that they would like to inspect. This resulted in participants taking a bit of time (about 15–20 seconds on average) to perform the first step of dragging out the

TABLE 7.3. Performance results for using the scrutiny interface to examine the reasoning for recommendations (Task T4).

	Group								
Participant	1	2	3	4	5	6	7	8	9
a	✔	✔	●	✔	●	✔	●	●*	●*
b	✔	●*	✔	●*	●	✔	●	✔	●
c	●	✔	●	✔	●	●*	●*	●*	✔
Group result	✔	✔	●	✔	●	✔	●	●	●

Legend: ✔= Success, ✗= Did Not Finish, ●= Recovered

* indicates participant received assistance from group members

menu item. Group 7 in particular spent a long time (90 seconds) before completing the first step. Once participants managed to drag out a recommended item, the rest of the task was done relatively quickly (approximately 5 seconds).

Errors

Instead of dragging out a recommended menu item, participants tried tapping on the menu item (1c, 3c, 4b) or dwelling on the menu item (3c, 4b 7a, 7b and 7c) within the menu. Participants 3c and 7b specifically tried to dwell on the thumbs up symbol.

Other participants were not sure of how to open the scrutiny interface. Instead of pressing the inspection button, Groups 4 and 5 and participant 9a thought that they were supposed give their own reason for why the menu item was recommended. Participant 4c asked the experimenter "Do we tell you why [it was recommended]?" and participants 5b and 9a gave their own account of why they thought it was recommended ("I guess because I chose I like tomato" — 5b, "I said I like seafood" — 9a). Also, participant 2b asked his fellow group members "Where'd you find that?" with reference to the scrutiny interface. He was in fact looking at a regular menu item, which did not have an inspection button, and later on realised that it only appeared for recommended items.

Some participants were also unsure of how to use the "More detail" button to view the different levels of detail. Participants 1c, 4b and 9a did not seem to notice the button at all and until they received assistance from their fellow group members with using it, they did not press it. From these resulting errors, it was apparent that participant 4b may have found this task rather challenging, which could be due to her inexperience with computer usage (1-10 hours per week, as shown in Table 7.1).

Recovery from Errors

As with personalising the menu, there were several ways in which participants recovered from their errors in this task. Some participants, who were unsure of what to do, looked at what their fellow group members had done and followed their actions. Participants 4b, 6c, 7c, 8a and 8c had seen that their fellow group members had dragged out the menu item and did the same. Some participants recovered after actually collaborating with their peers. Participant 2a hinted to 2b that there was an inspection button on the recommended menu items ("[use] the information icon"), which prompted 2b to drag a recommended item out of the menu and subsequently press the button. Participant 4b received assistance from 4c in pressing the "More detail" button and also, 9b told 9a that she could press the "More detail" button to view the different levels. Groups 4 and 5, who had not noticed the inspection button, received a hint from the experimenter about performing the action ("there is something else you can do [to view the reasoning]"). Upon receiving this hint, all participants immediately pressed the inspection button. All other participants who made errors (1c, 3a, 3c, 7a and 7b) were able to recover on their own by further experimentation. For example, when participants 3c and 7c realised that dwelling on the menu item had no effect, they dragged out the menu item.

7.4.3 Using the Group Menu

Task T5: Now imagine that it is dinner time. Organise amongst yourselves what you would like to order for dinner and then place your order.

This task was designed to examine and observe how participants interacted with the group menu. Before asking participants to perform this task, the experimenter asked what they thought the purpose of the group menu was to ensure that they understood it was an available feature for the ordering task (T5). Numerous responses indicated that participants quickly identified that it showed items that could be shared: "food for sharing" (2a), "things you can share" (8a) , "good for sharing in groups" (4c), "things that can be shared" (7a). Other responses included: "recommended for all three of us" (3a) and "recommended for all group" (1c). Every group's response was similar to those mentioned above, so it was clear that all participants could understand the purpose of the personalised group interface in providing recommendations for multiple users. It was interesting that some comments from participants included references to the user model ("what's recommended for all three of us, based on our dietary needs" (3c), "Common dishes considering what we like" (5b), "Shows things that matches everyone's preferences" (8a)), which suggests that these participants had a good understanding of the personalisation process.

At this point, all participants were familiar with the individually personalised interface; that is, their own personalised menu. Hence, this task was interesting as it allowed for observations of whether participants would continue to just use the individual interface or whether they would use the group interface as well. It was essentially a task that assessed the utility of the personalised group interface. Being an open ended task, there was no notion of success or failure. Instead, observations of how the group menu facilitated collaboration amongst the participants were made and whether items from the group menu were selected in the final order. The results are presented in Table 7.4.

The task result sheet had a different form of measurement to the previous two tasks. The experimenter observed how many participants placed group menu items onto the order list. If a participant placed a group menu item onto the order list, this would simply be marked as YES next to "User selects item/s from the group menu" for that participant.

TABLE 7.4. Usage of group menu during the collaborative task (Task T5).

	Group								
	1	2	3	4	5	6	7	8	9
Selected item/s from the group menu and placed on order list	✔	✔	✔	✔	✗	✔	✔	✔	✗
Number of participants who selected group menu item	1	2	1	2	0	1	2	2	0
Legend: ✔= Selected group items, ✗= Did not select group items									

Groups 1 and 6 displayed a moderate level of collaboration in using the group menu. Participant 1c had started selecting items from the group menu without much collaboration with the other participants. However, as the task went on, there was more collaboration amongst the group. Upon deciding whether to order a particular group menu item, participant 1a consulted the scrutiny interface on that same item from his individual menu before confirming with his group to order it. After selecting the group menu items, the group menu seemed to be disregarded as participants went on to examine their individual menus.

Participant 6c referred to the group menu and commented "I guess we can choose stuff from here if we also all like it". Participant 6a seemed to agree and collaborated with 6c on selecting group menu items. However, 6b did not seem to be interested in discussing what to order with the others and focused on her own menu. Her passiveness could be explained by the fact that she had only just met the other participants (Table 7.1). After selecting the group menu items, all participants then chose individual items to order.

Group 4 seemed to have decided to order menu items mostly for the group to share and exhibited much collaboration over the group menu in deciding what to order. They selected their menu items systematically, starting with entrees, then mains and finally dessert. Participants 4b and 4c selected items from the group menu and their own individual menus. Also, 4b seemed to compare the items in the group menu with her own individual menu, possibly to see which ones were in both. Participant 4a seemed to play a more passive role in using the interface, but still collaborated with her group members on the item selection.

Group 7 started off quietly, but displayed a high level of collaboration as the task went on. Participant 7c started choosing many items from the group menu without consulting her group members. However, the other two participants seemed to agree to this. Once 7c had finished placing group items onto the order list, the group checked which items they had already ordered and realised that they didn't have any desserts. There were no desserts on the group menu so they decided to order dessert from their individual menus.

Errors

It was observed that Groups 5 and 9 did not seem to know that the group menu was interactive and this was later confirmed in the interview. Although both groups realised that the purpose of the group menu was to provide recommended menu items for everyone, they thought that it was for display only and did not know that they could drag the items out of the group menu. Both groups did not attempt to determine which menu items would be suitable for all of them to share, so it was implied that they had decided to order items individually. As a consequence, there was no collaboration during the task and all participants selected menu items from their individual menus. The group menu was disregarded throughout the task.

Another error was that some participants (3c and group 8) had trouble placing the group menu items into the order list. To place these items into the order list, participants had to first drag the group menu item outside the boundary of the group menu to create a group menu item card. They then had to drag the group menu item card into the order list. Group 3 had placed the order list in the centre of the group menu. Hence, when participant 3c tried dragging group menu items directly into the order list (which would not work), he seemed confused. The same happened for participants in group 8, who had placed the order list close enough to the group menu so that group menu items would not leave the boundary before entering the order list. Participants 8a and 8c tried dragging group menu items (rather than the group menu item *card*) into the order list and as a result, did not seem to understand why it was not working.

Recovery from Errors

With regard to the issue of selecting group menu items to order, group 8 managed to recover when participant 8b suggested to his peers that the group menu item had to leave the boundary of the group menu first. This allowed participants 8a and 8c to understand how the group interface worked. Participant 3c was given a hint from the experimenter to drag the group menu item out of the group menu first. Upon doing this, he was able to place the item into the order list.

7.5 Questionnaire Responses

In the post experiment questionnaire, participants were asked to indicate the degree to which they agreed with several statements about using the personalised tabletop interface. A seven point Likert scale was used in collecting their opinions, ranging from *strongly disagree* to *strongly agree*. The responses are presented in Table 7.5. Please note that for statement 1 fo Table 7.5, the name Restaurant refers to the MyMenu application.

Participants were also asked to give a brief explanation of their responses in free-form, which are summarised below. The statements refer to those set out in Table 7.5.

Statement 1: The Restaurant application was easy to navigate and intuitive to use.

Participant 6c specifically commented on the personalise action, stating that “If I didn’t accidentally link the persona to menu it wouldn’t be clear how”, suggesting that this step may not have been intuitive. However, many comments were related to how participants could use the personalised interface after some experimentation. Participant 1a stated that “Once you got used to it, there would be no complications” and 4b stated “Not 100% straightforward, but with a little explanation and discussion with other

TABLE 7.5. Likert scale (1 = strongly disagree, 7 = strongly agree) responses for each group on using and understanding the personalised tabletop interface. The group scores are taken as the median of the participant scores for that group while the median and standard deviation shown are across all participant scores.

Statement		Group Media									Median	σ
		1	2	3	4	5	6	7	8	9		
1	The Restaurant application was easy to navigate and intuitive to use.	6	6	5	6	6	6	6	5	5	6	0.975
2	I understood that my menu was personalised using the information I had provided at the beginning of the session.	6	7	6	6	7	6	7	6	7	6	1.075
3	I understood the different levels of detail in the explanation of the reasoning behind the recommendations (using the inspection button).	7	6	5	6	6	5	6	7	6	6	0.808
4	The group menu allowed my group to effectively discuss and decide what to order for the meal.	5	6	6	6	5	7	6	7	6	6	1.091

participants, it was then easy to use and navigate". These comments portray the personalised interface as being easy to learn, since participants felt that they could use it easily after some initial experimentation. Hence, the resulting score for this statement (Median = 6, Table 7.5) could be attributed to the ease with which participants could learn how to use the interface. Some participants commented that it was easy to use due to their previous experience with touch interfaces. In particular, participant 7a thought that "basic manipulation of items on screen is similar to how you would use any other touch screen smart devices". Participant 8b stated that he knew how to use the interface "because of understanding how touch apps can work". Both participants had indicated a smart phone/tablet experience level of "competent" or higher (Table 7.1), which is consistent with their responses on the usability of MyMenu. Participant 2b also commented that "those [tasks] that weren't as straightforward had tool tips", which indicated that he found the hinting mechanism useful.

Statement 2: I understood that my menu was personalised using the information I had provided at the beginning of the session.

This statement referred to the understandability of the personalisation process. Many responses indicated that the scrutiny interface made this clear. Participant 8b understood because "the information bubbles explained source of recommendations", while 5a stated that she got the "explanation in details after touching the information icon (inspection button)". This implied that examining the scrutiny interface allowed users to understand how the user model was used in the personalisation process. However, participant 6b did not understand this until "someone had pointed it out", suggesting that it was not entirely clear.

Statement 3: I understood the different levels of detail in the explanation of the reasoning behind the recommendations (using the inspection button).

Some participants indicated that the differences in the content were clear in specifying more detail at higher levels. Participant 1c "recognised the information [she] put into the mobile and as the detail increased, info was more specific" and 4b stated "the higher the level, the more detailed the reasoning was". The use of colour on the top right of the interface was also helpful in distinguishing the levels, as indicated by participant 2a — "I saw the top right high/medium/low setting that was color coded". Participant 4a stated that "low and medium levels were similar" as did participant 5c, suggesting that there may not have been a clear difference between these two levels to all participants. Participant 2c also suggested that having one or two levels would be enough.

Statement 4: The group menu allowed my group to effectively discuss and decide what to order for the meal.

Responses to this statement were consistent with regard to sharing food for the meal. Participant 7a commented that "it's very handy to see the suggestions, especially at meal sharing situations" while 4c stated that "it helped us to narrow down on what we could all share". Participant 5c's response, "What if we don't want to share the food? In that case it isn't that useful", was consistent with her group's actions in the collaborative task because they did not use the group menu. There were comments regarding increased efficiency in deciding what to order from participants 8a ("Saves time for us") and 8c ("It showed us what we all like which can reduce time on deciding what we want"). Some participants indicated that the group menu was limited in the selection of items because there were "only 6 group items to choose from" (2c) and it "made it more restrictive on what we could order" (4c). Participant 4b also seemed to expect the group menu to recommend items from different categories (Appetisers, Mains, Desserts) as she stated "it did not suggest a desert even though we all had thumbs up for one of the choices". This indicated that group 4 had looked through their individual menus to find a dessert item that was recommended for all of them. Participant 6a also commented on the accessibility of the interface, stating that the "Lazy Susan allowed easy access to ... foods that were recommended for everyone".

General comments

Participants were also asked for general comments on using the tabletop interface. Aspects of the tabletop interface that participants liked included the ability to personalise the menu and to use the scrutiny interface to find more information about the recommended menu items ("I like the parts checking recommended dishes" (5a)). Many participants also indicated that they found the personalised group interface enjoyable to use ("[I liked] the tabletop interface, esp. the center table" (2b), "the shared meals among the group made group ordering easier" (4c)). Some participants mentioned that more user feedback and help functions would be useful in notifying the user that they had performed actions correctly ("Give some feedback or response after an action" (5c)). Participant 8c also suggested to "have more tool tips" for first time users as this would be helpful. Participant 6b commented that adding "instructions on the tabletop interface or a help button" would assist with explaining how to use the application.

7.6 Interview Responses

The interview was conducted as an informal group discussion about the tasks they performed and what they thought about using the personalised interface. It was conducted after the questionnaire so that responses in the questionnaire would be more reflective of the individual opinion of participants and not influenced by responses from the group interview. A summary of the responses to each question is provided below.

Question 1: When you personalised your individual menu, was it clear to you that it was personalised?

Participants generally agreed that it was clear that their menu was personalised for a number of reasons. For some participants, the Persona image that appeared on the menu made it clear ("because of the Persona image" (1c), "Persona picture was enough" (2a)), while for others, the textual notification that said "Personalised for *name*" allowed them to realise it was personalised ("Had your name, "personalised for ..." (5b)). The thumbs up icons also played a role in notifying participants that it was personalised as indicated by 4b — "thumbs up icons [made it clear]".

Participant 4b also suggested to use an alternative symbol, such as a green tick, to indicate that a menu item was recommended so that it stood out more from the menu. Some participants also said that it wasn't immediately clear that the menu was personalised either because "everything had a thumbs up" (2b and 6c), so it was hard to tell that it was personalised.

Question 2: (i) Did you feel uncomfortable with any of the information that was displayed on the tabletop interface? Would you prefer to have some information kept more private?
(ii) What if there was more sensitive and personal information, such as a medical condition you have?

All participants stated that they were comfortable with revealing their personal dietary information to a certain degree. They pointed out certain cases where they might be more cautious of revealing such information. Participants in group 1 responded that "it depends on who you're with", indicating that they were comfortable with revealing it around people they were familiar with, such as friends or family, but would perhaps be more cautious around strangers. They emphasised that if the nature of the information was more sensitive, they would definitely prefer to hide it "if dining with people you don't know well". A similar comment was made from participant 3c, who stated, "as long as the sensitive information is asked for [to enter into the user model] but definitely not displayed". This implied that he would still be willing to allow the application to access his deeply personal information, as long as it was not displayed on the tabletop. Group 8 also said it "depends on who you're eating with" and commented that more privacy would be needed when dining with strangers. Group 4 mentioned that "If you have allergies, you might be more concerned [about revealing those allergies]" and that the willingness to reveal the information depended on the user's actual dietary needs and preferences.

Group 7 made some interesting suggestions on how to provide an effective interface for scrutinising more sensitive information. They said that having "a warning on the inspection button" or somewhere on the interface would be helpful in alerting the user that sensitive personal information would be revealed. They also suggested to display this type of information on the mobile device, so that it would only be shown to the user.

Question 3: When you were using the group menu, was it helpful? What difference would it make if there was no group menu?

Participants commented that the group menu was useful because it made the decision making process easier. Group 8 commented that it "tells you quickly what everyone can eat", which made the process "more efficient". Group 7 also stated that it was "More efficient with the group menu" and that it was helpful because "it was easier to decide". Group 6 also agreed in saying that the group menu "provides a short cut to seeing what's recommended for everyone". Otherwise, they "would have to look through individual menus side by side to compare". Groups 4 and 5 indicated that it was helpful if the group decided to share food for the meal. They also commented that if the group was not sharing food, the group menu would not be useful ("if not sharing, not useful" (Group 5), "If you weren't sharing food it wouldn't matter if it wasn't there" (Group 4)). Group 2 also compared the group menu interface with the individual menu interface and said that it was "good for displaying what's recommended for everyone, better than scroll, because you can't see everything at once".

Other responses about the group menu were related to what participants thought could be improved. Group 1 stated that they would have liked to have seen alternative options on the group menu and perhaps "have them categorised". Group 2 had similar thoughts as they said "more items would be good". They also thought it would be more helpful "if it recommended for less than the maximum number of people [at the tabletop]", so that there could be recommendations for subgroups within the group. Participant 8b commented that the group menu interface "might discourage conversation" because it already presented menu item options for the group. He was referring to the fact that, in a social context where a group will typically engage in conversation, the group might have less to discuss when deciding what to order, since the application has already provided them with suggestions. This implies that, for groups who prefer to use the process of ordering a meal as a means for generating conversation, the group menu may take away some of the value in this.

7.7 Analysis

A key goal of an interactive tabletop is to support and enhance collaborative activities in small groups. As discussed in Section 6.1, the user study aimed to determine the effectiveness of the personalised interface for small groups of users rather than for a single user. Hence, the analysis was performed by examining the results at the *group* level rather than at the individual level. Also, the study was designed to be qualitative to understand how users interact with the system for an authentic task. The effectiveness of the personalised interface was measured more on whether participants found it easy to use and understand rather than the amount of time they spent performing tasks. Measurements of time could not be used reliably due to the extra time that participants had to spend in familiarising themselves with the interface. Each aspect of the results (task performance, questionnaire responses and interview responses) was linked to the hypotheses posited in Section 6.2. This section reflects on the combined set of gathered data, linking the emerging results to the experiment hypotheses.

(H1) MyMenu provides an effective interface for personalised tabletop interaction.

This hypothesis was related to the goal of assessing usability, learnability and understandability of the personalised tabletop interface in general. Although there were numerous errors made throughout the tasks, as indicated in Table 7.2 and Table 7.3, this did not necessarily reflect poorly on the personalised interface. Moreover, it was expected that errors would be made due to the intentional lack of instruction to participants. For the task of personalising the menu, four out of five groups who made errors were able to recover, while all groups who made errors while using the scrutiny interface were able to recover. This suggests that the interface was learnable but required some experimentation, highlighting the need for some additional interaction cues. This is supported by comments that the tool tips in the interface were useful (Statement 1, questionnaire) and that more user feedback would be helpful (General comments, questionnaire). Other responses to Statement 1 of the questionnaire that referred to how participants could easily use the interface after some experimentation ("Once you got used to it, there would be no complications" (1a)) also suggest that the interface was learnable. Hence, although errors were made while using the interface, participants still responded positively and were able to complete the tasks successfully.

While some features of the personalised interface were understandable to participants, others were not as obvious. With the exception of one participant, the personalisation process was clearly understood, as indicated by both the Likert and free-form responses to Statement 2 in the questionnaire. The personalised group interface was also very well understood, as discussed in Section 7.4.3. The scrutiny interface was moderately well understood, as shown by the mixed responses for Statement 3 of the questionnaire. However, as many participants accidentally personalised their menu, this caused problems with understanding that it was personalised. Overall, it may be concluded that most features of the personalised interface were understandable. For those features that were more difficult to understand, providing user feedback on the interface may help to overcome these problems.

In summary, the personalised interface is demonstrated to be usable and the ease of being able to recover from errors reveals that it has a high degree of learnability. Also, most features of the interface were well understood, with only one aspect requiring some minor enhancements. Hence, the combined results on usability, learnability and overall user satisfaction and enjoyment in the activity indicate that hypothesis H1 is well supported by the results.

(H2) MyMenu enables effective scrutiny over the personalised interface with indications of different levels of privacy.

This hypothesis mapped to the goal of assessing the effectiveness of the personalised interface in providing the ability for users to examine, with different levels of privacy, how their personal information was used on the tabletop. In testing this hypothesis, the degree to which participants understood the different levels of privacy was measured as well as usability of the scrutiny interface, including whether participants understood how to control it. As participants were given the option to use fictitious data, the degree to which participants felt comfortable with revealing this data is not analysed. Rather, the analysis concentrates on whether the interface was usable within a group setting.

In terms of understanding the information presented in the scrutiny interface, participants showed that they could understand the different levels of detail, as indicated by the Likert scale and free-form responses. In particular, the free-form responses confirmed that participants understood that higher levels of detail provided more specific information in the reasoning for the recommendations. One participant also mentioned that the label in the top right corner of the scrutiny interface helped to distinguish between the different levels, especially with the colour coding, suggesting that this was useful in allowing users to realise the differences. However, three participants commented that some levels of detail were either similar to each other or not required, which indicated that there were varying interpretations of what was "different". To address this, the content within each level could be altered so that the levels of detail may be clearly distinguished from each other.

Comments from group 7 in the interview also referred to how the scrutiny interface could be improved in terms of usability. They suggested that having warnings on the scrutiny interface, such as the inspection button, would be useful in notifying the user that their personal information would be revealed. This would give the user feedback on their actions, which is consistent with a response in the general comments from participant 5c — "Give some feedback or response after an action". The group also mentioned that rather than revealing deeper levels of detail on the tabletop, this could be done on the user's mobile device, so that sensitive personal information would only be seen by the user. This could be an area for future work and is further discussed in Section 8.3.2.

It is evident that the scrutiny interface was well understood by participants with regard to revealing different levels of detail in how the user model was used and also in terms of the information presented in the interface. Hence, it may be concluded that hypothesis H2 is supported. One point to address is how *useful* the scrutiny interface was in allowing users to reveal each level of detail. Although this evaluation did not focus on the usefulness of the scrutiny interface, it would be worthwhile to further investigate how this could be applied to a situation with real user data that is quite personal, so that users would be more cautious of revealing such information.

(H3) MyMenu provides an effective tabletop interface with personalisation tailored to a whole group for a collaborative task.

This hypothesis was linked to the goal of assessing the degree to which users felt supported by the personalised group interface in making group decisions. Indications from the results show that the personalised group interface was indeed effective in supporting a collaborative task. For the task of ordering dishes for a meal, seven groups selected one or more items from the group menu and placed it in the order list (Table 7.4), suggesting that it influenced their decision making in the ordering process. Participants stated that the reason for using the group menu included making the ordering process more efficient so that time was not wasted in trying to work out what was suitable for everyone. This was apparent in the interview responses where participants said that the group menu made it “easier to decide what to order” (7a) and “provided a short cut to seeing what’s recommended for everyone” (6a), and also in the questionnaire (“saves time for us” (8a), “reduces time on deciding what we want” (8c)).

The general sentiment towards the group menu was positive and participants thought it was useful, which is supported by the Likert scale response for Statement 4 in Table 7.5. Responses from the questionnaire and the interview included comments about the presentation of the interface. Groups could see what was recommended for everyone at a glance and the use of a circular object was also praised (”Lazy Susan allowed easy access to ... foods that were recommended for everyone” (6a)). Hence, it may be concluded that the presentation of the personalised group interface was effective in allowing users to view the personalised response or output. However, three participants made comments as to how the group menu could be improved, which included categorising the menu items (4b) and having a wider selection of menu items (2c and 4c). This suggests that structuring the interface better so that users can be more organised in carrying out their task and providing them with more information could improve the utility and usability of the personalised group interface.

To summarise, it has been shown that the group menu within the MyMenu application was utilised well and that all groups were able to understand it as an interface to provide personalisation for the group. Also, the way in which the personalised group interface displayed personalised information was demonstrated to be effective. Together, these conclusions indicate that hypothesis H3 is supported by the results.

Usability Enhancements

As discussed in the results, initial errors were made in each task, which suggests that there are features of the interface that require some enhancement to improve the initial learnability of the application. An overview of the most significant enhancements required is provided to illustrate how these errors may be avoided in the future.

As outlined in Section 7.4.1, personalising the menu *accidentally* was a common error. This occurred when participants moved objects around while experimenting with the interface and caused confusion and misunderstanding when it happened. Given that the personalised interface required participants to experiment in learning how to use it, as discussed above, the error of accidentally personalising the menu was closely linked to the learning process. It was the design of the interface that led to this error. The personalise action could be modified in several ways to prevent this error from occurring. One method would be to require the Persona to be dragged onto a certain location on the menu (within a marked area) before being personalised. Alternatively, the appearance of the Persona could change when touched. For example, a tool tip could be shown, notifying the user that dragging it onto a menu will personalise it.

As participants were experimenting with the interface, it appeared that they had some idea of the actions that were required to complete the tasks. However, the execution of these actions was often in the incorrect order or sequence. For example, for the task of personalising the menu, some participants dragged their Persona onto menu items, or dragged the menu (or menu items) onto their Persona. This suggests that participants had the idea of using the drag gesture to perform an action to personalise, which was correct, except that they were executing that action on the wrong sequence of objects (participants had to drag their Persona onto their menu). An interaction cue could be useful in this situation to notify the user of the sequence they should follow, so that they know exactly which objects they should be using and which one to drag.

Usability of the scrutiny interface was measured in terms of the errors that participants made. Eight participants from four different groups were unsure of how to open the scrutiny interface by pressing the inspection button. All of these participants had dragged out the menu item, which meant that the inspection button was visible. Also, as indicated in Section 7.4.2, three participants were prepared to give verbal accounts of their own understanding of why the menu item was recommended. This suggests that the inspection button may not have appeared intuitive to these participants as a means of finding out more information about the recommendation, even though the button had an “i” symbol on it. Providing a different label or some type of indication on the interface, such as “More information”, could possibly improve its usability in notifying the user that the inspection button was interactive.

A key error in using the group menu was that groups 5 and 9 did not understand that it was interactive, which consequently resulted in them not ordering any menu items from the group menu. Hence, it cannot be concluded that these two groups did not use the group menu because they did not elect to. However, since they did not realise it was interactive, this implies that the way in which the group menu was presented may not have been clear in indicating that they could drag menu items out of it. A way of improving this could be to include a tool tip, perhaps in the centre of the interface, to give users an indication that the items may be dragged out.

7.8 Experimental Considerations

As mentioned previously, the environment in which the user study was conducted was only a simulation of a real world scenario. The study took place in a laboratory, which was relatively small compared to the open space of an actual restaurant. Participant interactions were recorded (using video and written notes), which would have created a sense of unnaturalness for participants, especially if they did not know each other well. Also, the tasks that participants performed were closely scrutinised for erroneous actions and other observations. As such, one may argue that the conclusions put forward are quite specific to the conditions just mentioned, and hence may not be completely valid in a real world scenario. A counter argument would be that many aspects of the experiment were designed to create a scenario that was still reflective of how the application would be used in the real world.

First, the tabletop interface was designed to be what users would expect when dining at a restaurant. The various elements that make up the tabletop interface, such as the menus, the tablecloth background and the lazy Susan object, may all be found at an actual restaurant dining table. The realism of the interface was also reflected in the comments of some participants, who said that the menu was quite appetising. Second, the tasks that participants performed in the experiment were exactly the same as what they would do at a tabletop situated in a restaurant, such as personalising their menu and ordering items from the menu. Finally, it was ensured that each group of participants were reasonably familiar with each other to reduce the feeling of unnaturalness in using the tabletop interface and also to maintain the sense of a real world scenario (dining out with people you know).

Another caveat is the nature of the information that was shown in the scrutiny interface. Since MyMenu presented users with a personalised restaurant menu, the type of information that was required from the user included their dietary needs and preferences. From responses in the questionnaire and interview, all participants indicated that they were comfortable with revealing dietary information to varying degrees, with some feeling more comfortable than others. For this reason, the results analysed here may not be truly representative of a situation where users might actually consider using the scrutiny interface to hide more personal information. If the personalisation process required more sensitive information, the results may be different with regard to how users controlled each level of detail.

It was also observed during the study that many participants who had made errors during the tasks received assistance from their peers to recover from these errors. For this reason, it could be argued that the results would not be truly representative of how effective the personalised interface was, since some participants may not have recovered without the presence of others. However, it is emphasised that the analysis examined the results at a group level, which has its value in determining whether multiple users interacting together are able to overcome problems together and to learn from each other. It could also be argued that most usability problems would have been discovered with less users, as suggested by Nielsen (2000). As stated before, the value of conducting a user study with many users allows for observations of whether groups of users may collaborate to learn the interface and achieve their goals and also allows for an investigation for deeper issues of collaborative interaction beyond pure usability.

7.9 Chapter Summary

This chapter has presented the results of the user study in terms of the task performance of participants during the experiment and also their questionnaire and interview responses, which queried them on their experience with using the personalised interface. A qualitative analysis of the results indicated the each of the three hypotheses were supported overall. The following chapter concludes this thesis by revisiting the thesis goals and presenting a reflection on the generalisability of the results.

CHAPTER 8

Conclusions and Future Work

In concluding this thesis, the thesis goals are revisited to summarise what has been achieved. In considering how the outcome of these goals fit in to the larger vision of ubiquitous personalisation, it is shown that the generalisability of the personalised interface provides a foundation for further work on personalisation at interactive surfaces.

8.1 Conclusions

As part of the vision of ubiquitous personalisation at interactive surfaces, the first thesis goal was to develop a personalised tabletop application for collaborative use. The second goal was to evaluate this application to determine its effectiveness in presenting users with personalised information and in supporting a collaborative task.

In the approach to developing a personalised tabletop application, MyMenu was an application that allowed users to personalise a restaurant menu. In addressing the challenges that were identified at the beginning of this thesis (Section 1.4), MyMenu provided a group interface that was personalised for multiple users at once and also a scrutiny interface that enabled users to examine how the information from their user model was used in the personalisation process.

In evaluating the resulting personalised application, a user study was designed to assess the effectiveness of the personalised interface. Specifically, the goals of the study were to determine how effective the personalised interface was in general, how effective the scrutiny interface was in allowing users to scrutinise their user model and how effective the personalised group interface was in supporting a collaborative task. It was shown in the analysis of the results that all of these aspects of the personalised interface were effective. While some features, such as the personalised group interface were very effective, others were identified as requiring only minor adjustments in order to be more effective in enhancing the user's personalised experience.

To summarise, with the development of the MyMenu application and the evaluation of this application through a user study, it is clear that the goals of the thesis have been achieved.

8.2 Generalisability

Although this thesis focused on developing and evaluating a *tabletop* application, the core elements of the personalised interface may be generalised to other types of interactive surfaces. This is important in addressing the broader research question of how personalisation may be achieved ubiquitously in many different types of environments. As well, it is shown that generalisability to domains other than a restaurant dining scenario strengthens the assertion that the personalised interface, and the underlying conceptual framework itself, may be applied ubiquitously to a broad range of scenarios.

8.2.1 Interactive surfaces

In considering generalisability to interactive surfaces, two types of surfaces are considered: tabletops and walls. As described in Section 3.3, the *Single Purpose* tabletop was chosen as the context to develop the personalised application for. The reason for this was that this context required the highest level of security and scrutiny in the conceptual model design. Hence, applying the personalised interface to other contexts, which may require lower degrees of security and scrutiny, would only require minor adjustments to the current interface, such as redefining the levels of detail that are revealed in the scrutiny interface. Similarly, the notion of requiring minor adjustments to other features of the interface may be applied in generalising to other tabletop contexts. Essentially, the core elements of the personalised interface would remain the same, namely, the method of activating and presenting personalisation, the scrutiny interface and the personalised group interface. This justifies the generalisability of the personalised interface to tabletops overall.

Generalising to interactive walls should be straightforward, with some minor differences. Since all users face the same direction when interacting with a wall, the orientation of the display is the same to each user (in contrast to a tabletop). Hence, the developer would need to consider this when designing the personalised interface. Also, some interactive walls may support multi-touch interaction, while others may not. For those that do, the same principles of gestures and manipulating objects at tabletops apply.

Other interactive walls may require the use of motion gestures as a form of interaction, so this would also need to be taken into account when designing the interface. However, as stated above for tabletops, the core elements of the personalised interface would still remain the same, which is significant, as the evaluation focused on assessing the effectiveness of these elements. Therefore, generalisability to both interactive tabletops and walls is justified. As a result, it may be concluded that the personalised interface developed in this thesis forms a foundation for further work on personalisation at interactive surfaces.

8.2.2 Other domains

Given the presentation of the MyMenu application in Chapter 4, it can be clearly observed that the interface was designed to be similar to what would appear in an actual restaurant. The tabletop provides an ideal environment in which to present such an application; that is, an interactive table that doubles as a restaurant table, providing menus for users to browse through and a built in ordering system. This may lead one to assert that the evaluation of the personalised interface in MyMenu would only be restricted to applications that simulate a restaurant setting or similar.

It is true that MyMenu does incorporate many elements of a restaurant dining situation. However, in determining the generalisability of the application, it is the design of the personalised interface and how it provides user scrutability that must be examined rather than the design of the entire application. Let us first examine the nature of the user model data. The user model could contain a multitude of information about different aspects of a person, such as preferences in music, movies, books, sports, hobbies, games, favourite websites, diet, fitness and so on. While MyMenu only requires dietary information from the user, there may be many other types of applications that could utilise other data in the user model to personalise the interface. Furthermore, these applications may provide personalised services using methods other than recommendation, such as personalised search or personalised input. The scrutiny interface could then be used for each of these personalised applications to examine how it was personalised for the user.

For example, an information kiosk in a museum could provide a personalised tour to visitors, based on their interests in the subject matter of the exhibits. Users might drag their persona onto an interactive brochure, which would then produce a personalised map giving details of where to go. Users would then be able to use a scrutiny interface to examine why certain exhibits were included as part of the tour.

Another example would involve a personalised interface at a medical consultation. A doctor may have an interactive table in her surgery that allows both her and her patients to examine medical documents together. In instances where the patient has never seen the doctor before, personalisation would be especially useful in mitigating the doctor's problem of having no information about the patient. Upon releasing his personal medical information from his user model to the tabletop, documents specific to the patient's medical record and history could appear automatically, saving the doctor time in questioning the patient about past medical problems. The doctor could then examine the documents and work together collaboratively with her patient to discuss the specifics of diagnosis and treatment, for example. As the user model is likely to include sensitive medical information, the patient could use an interface to scrutinise how this information was used in presenting the specific medical documents.

8.3 Future Work

Within the resulting personalisation framework, there are many areas of future work that could be explored to enhance the effectiveness of the personalised interface. These are outlined below.

8.3.1 User Tracking

There has been previous work done on tracking users at a tabletop (Martinez et al., 2012), which may provide interesting results if integrated with the current personalisation framework. The ability to track user movements and actions would allow the application to identify who is interacting with certain parts of the interface. This could be applied to the scrutiny interface, where users would only be able to examine the interface that is personalised for them. For example, with MyMenu, it would be possible to allow users to press the inspection button only on menu items that are recommended for them, providing an extra layer of privacy.

8.3.2 Including a Scrutiny Interface on the Mobile Application

Some participants in the user study had indicated that they were somewhat uncomfortable with the revealing the highest level of detail in the scrutiny interface. Many participants also said that they would prefer to hide their personal information from the tabletop interface if it was very sensitive, such as medical information. One method of addressing this would be to provide a mobile interface that reveals the higher levels of detail in the scrutiny, while only revealing general details on the tabletop. This ensures that highly personal information stays on the user's own personal device so that only they may view it. In MyMenu, this could mean allowing users to reveal the Low and Medium level details on the tabletop, while the High detail level would be shown on their mobile device.

8.3.3 Familiar vs. Unfamiliar Groups in the Experiment

An interesting observation from the results of the experiment was that many participants stated that their willingness to use the scrutiny interface to reveal details of their user model was dependent on who was at the tabletop with them. They indicated that if they were with people they knew well, such as friends or family, they would generally feel comfortable with revealing their personal information on the scrutiny interface. However, if they were at the tabletop with people they were less familiar with, they might be more cautious when using the scrutiny interface. Therefore, it could be interesting to investigate how users utilise the control aspect of the scrutiny interface under two different conditions — one being with users who know each other well and the other being with users who have never met each other before. A comparison of the results for each condition may show that being able to control the level of scrutiny is indeed an effective way to maintain user privacy.

8.3.4 More Sophisticated Recommendation

As mentioned in Section 5.2.3.3, the recommendation algorithm used in MyMenu was quite simple and had limitations in its accuracy. Hence, it could be worthwhile to explore how a more sophisticated recommender system could be incorporated into the personalisation process. This would add more value to the user's personalised experience, since recommendations would match closer to their own mental model of what is personal to them. One aspect that could be improved is the process of collecting data that goes into the user model. Instead of requiring users to enter their personal preferences into the user model *explicitly*, which was utilised in the experiment, the user model data could be obtained *implicitly*, which may involve collecting this data over a certain period of time before conducting the experiment. This was already demonstrated with MyMenu, where the a history of the user's dining activity was recorded into the user model (after pressing the "Place Order" button on the order list interface). There may also be other mobile applications that might constantly record fitness information for the user, which would be inserted into the user model. This information could then be used in personalising a menu based on the user's activity for the past week, as an example.

8.4 Contributions

This thesis contributes the definition of a conceptual framework that specifies the core elements required to develop personalised surface applications. The approach included integrating the features of the existing TabletopUM architecture with a new personalised tabletop application, MyMenu. The MyMenu application is a key contribution in itself, being a tabletop application that demonstrates personalisation by providing users with the ability to personalise a restaurant menu. This provided a foundation for studying how personalisation can be achieved in a group context.

In reflecting on the evaluation of MyMenu, it has been shown that the personalised tabletop interface was effective in providing personalisation for small groups of users. Hence, another key contribution of this thesis is a tabletop interface that enables effective personalisation for both individuals and groups of users, and also effective scrutability for users in examining how their personal information is used for the purpose of personalisation.

It has also been shown how the personalised interface may be generalised to other interactive surfaces and other domains. This demonstrates that the resulting personalised interface developed in this thesis provides the foundation for further investigation and exploration of how personalisation may be achieved ubiquitously at interactive surfaces.

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Appendix A

Restaurant Menu Data Set

Appetisers				Low Carb	Low Fat	Hi Protein
Bruschetta	9.25	tomato, garlic, olive oil, basil leaves, wheat, salt, pepper	A traditional topping of roma tomatoes, fresh basil and extra-virgin olive oil. Served with toasted ciabatta bread.	n	y	n
Lasagna Fritta	10.75	cheese, butter, cream, garlic, parsley, olive oil, onion, garlic, white wine, tomato sauce, seafood	Parmesan-breaded lasagna pieces, fried and served over alfredo sauce, topped with parmesan cheese and marinara sauce.	n	n	n
Mussels di Napoli	12.5	mussels, wine, garlic, butter, onions	Mussels in the shell, simmered with wine, garlic-butter and onions.	y	y	n
Sicilian Scampi	14.25	shrimp, wine, oilive oil, garlic, tomatoes, bread, salt,	Large shrimp sauteed in white wine, extra-virgin olive oil, garlic and tomatoes. Served over ciabatta bread.	y	y	n
Stuffed Mushrooms	9.25	parmesan cheese, roman, mozzarella, clams, herbs, breadcrumbs, mushroom, olive oil, oregano, parsley, salt, pepper, egg	Parmesan, romano and mozzarella cheese, clams and herb breadcrumbs baked in mushroom caps.	y	n	n
Soups						
Chicken and Gnocchi	6.75	chicken, potato, semolina, flour, egg, cheese, cream, spinach,	A creamy soup made with roasted chicken, traditional Italian dumplings and spinach.	y	y	n
Minestrone	6.75	beans, pasta, tomato, vegetables, olive, capsicum, olive oil, tomato	Fresh vegetables, beans and pasta in a light tomato broth - a vegetarian classic.	n	y	n
Pasta e Fagioli	6.75	beef, tomato, pasta, cannellini beans, olive oil, garlic, onion, spices	White and red beans, ground beef, tomatoes and pasta in a savory broth.	n	y	y
Salads						
Garden-Fresh Salad	7.75	lettuce, cabbage, tomato, carrot, vinegar, olive oil, capsicum	Our famous house salad, tossed with our signature Italian dressing.	n	y	n
Grilled Chicken Caesar Salad	13.75	chicken, egg, bacon, lettuce, bread, white wine vinegar, dijon mustard, garlic, olive oil	Grilled chicken over romaine in a creamy Caesar dressing topped with parmesan cheese and croutons.	n	n	n
Pastas						
Capellini Pomodoro	14.5	tomato, garlic, basil, olive oil, capellini, onion, garlic, white wine, tomato sauce, seafood, parsley	Roma tomatoes, garlic, fresh basil, extra-virgin olive oil and marinara sauce tossed with capellini.	n	y	n
Eggplant Parmigiana	16.5	eggplant, bread, mozzarella cheese, parmesan, pasta, olive oil, onion, garlic, white wine, tomato sauce, seafood, parsley	Lightly breaded eggplant, fried and topped with marinara sauce, mozzarella and parmesan cheese. Served with spaghetti.	n	n	y

Lasagna Classico	17.75	pasta, meat, beef, sausage, mozzarella cheese, ricotta, parmesan, basil	Layers of pasta, meat sauce and mozzarella, ricotta, parmesan and romano cheese.	n	n	y
Linguine alla Marinara	14.5	pasta, tomato, onion, basil, oregano, olive oil, onion, garlic, white wine, tomato sauce, seafood, parsley	Pasta with a zesty blend of ripe tomatoes, onions and herbs.	n	y	n
Spaghetti with Meat Sauce	14.95	pasta, beef, sausage, basil, garlic	Traditional meat sauce seasoned with garlic and herbs over spaghetti.	n	n	n
Chicken						
Chicken & Shrimp Carbonara	22.5	chicken, shrimp, pasta, parmesan cheese, cream, pancetta, bacon, capsicum, breadcrumbs, egg	Chicken and shrimp with bucatini pasta in a parmesan cream sauce with pancetta bacon and roasted red peppers, baked and topped with seasoned breadcrumbs.	n	n	n
Chicken Alfredo	19.25	chicken, pasta, butter, cream, garlic, parmesan cheese, parsley	Grilled chicken tossed with fettuccine and fresh alfredo sauce.	n	n	n
Chicken Marsala	20.75	chicken, mushrooms, garlic, wine, potato, capsicum	Sauteed chicken breasts in a savory sauce of mushrooms, garlic and marsala wine. Served with Tuscan potatoes and bell peppers.	n	n	n
Chicken Scampi	19.5	chicken, capsicum, garlic, onions, cream, pasta	Chicken breast tenderloins sauteed with bell peppers, roasted garlic and onions in a garlic cream sauce over angel hair.	y	n	y
Seafood						
Capellini di Mare	22.5	shrimp, clams, mussels, wine, garlic, pasta, basil, olive oil, onion, garlic, white wine, tomato sauce, seafood, parsley	Shrimp, clams and mussels sauteed in white wine, garlic and a zesty marinara sauce. Served over capellini and topped with fresh basil.	n	n	n
Crispy Parmesan Shrimp	22.5	shrimp, parmesan cheese, pasta, olive oil, onion, garlic, white wine, tomato sauce, seafood, parsley	A dozen handcrafted parmesan crusted shrimp served with curly mafalda pasta tossed in a five cheese marinara sauce.	n	n	n
Herb-Grilled Salmon	23.95	salmon, basil, oregano, parsley, thyme, broccoli, olive oil	Salmon filet brushed with Italian herbs and extra-virgin olive oil. Served with seasoned broccoli.	n	y	n
Parmesan Crusted Tilapia	20.5	white fish, garlic, butter, breadcrumbs, cheese, lemon juice, salt, pepper, olive oil	Oven-baked delicate white fish crusted with parmesan cheese. Served with Italian vegetables over angel hair tossed in a light garlic-butter sauce.	n	n	y
Beef and Pork						

Chianti Braised Short Ribs	22.5	beef, wine, portobello mushroom, rice, beans, tomato, carrot	Tender boneless beef short ribs slow-cooked in a chianti wine sauce. Served with portobello mushroom risotto and steamed vegetables.	n	n	y
Grilled Sausage and Peppers Rustica	15.75	sausage, capsicum, mozzarella cheese, pasta, olive oil, onion, garlic, white wine, tomato sauce, seafood, parsley	Italian sausage, bell peppers and fresh mozzarella with penne in a zesty marinara sauce.	n	n	n
Parmesan Crusted Bistecca	22.5	beef, cheese, oregano, basil, thyme, potato, asparagus, vinegar	Grilled 8 oz center cut sirloin topped with parmesan-herb breading, baked golden brown. Served with garlic parmesan mashed potatoes and asparagus drizzled with balsamic glaze.	n	n	y
Steak Gorgonzola Alfredo	21.25	beef, balsamic vinegar, pasta, spinach, butter, cream, garlic, parmesan cheese, parsley	Grilled beef medallions drizzled with balsamic glaze, served over fettuccine tossed with spinach and gorgonzola-alfredo sauce.	n	y	y
Steak Toscano	26.5	beef, basil, oregano, rosemary, thyme, olive oil, potato, capsicum, marjoram	Grilled 12 oz choice center cut Strip steak brushed with Italian herbs and extra-virgin olive oil. Served with Tuscan potatoes and bell peppers.	n	y	n
Desserts						
Lemon Cream Cake	8.5	lemon, cream, vanilla, sugar, eggs, flour, butter, cream, salt	Delicate white cake and lemon cream filling with a vanilla crumb topping.	n	n	y
Tiramisu	8.25	custard, cream, sugar, coffee, mascarpone, flour	The classic Italian dessert. A layer of creamy custard set atop espresso-soaked ladyfingers.	y	n	y
White Chocolate Raspberry Cheesecake	8.5	raspberry, white chocolate, sugar, butter, sour cream, raspberries, icing sugar, egg	Raspberry-swirled white chocolate cheesecake topped with slivers of white chocolate.	n	n	n

Appendix B

Participant Information Sheet

THE UNIVERSITY OF SYDNEY

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PARTICIPANT INFORMATION STATEMENT
Research Project

Title: Ubiquitous Personalisation at Interactive Tabletops

(1) What is the study about?

The purpose of this study is to explore how personalisation may be achieved at interactive tabletops. Our approach involves the use of a mobile application to store information about the individual that is then used by the tabletop to present personalised information. We are studying groups of three people who use the tabletop at the same time and how we can allow all of them to receive personalised experiences.

(2) Who is carrying out the study?

The study is being conducted by Honours student Jeffrey Leung, and will form part of the basis for the degree of Bachelor of Science (Advanced) (Honours) at The University of Sydney under the supervision of Professor Judy Kay.

(3) What does the study involve?

The experiment will consist of the following procedure. After completing a background questionnaire (about your previous experience with computers), you will be asked to enter basic health information, such as food allergies, special dietary or nutritional requirements and any goals relating to your fitness, into a mobile application. If you prefer not to disclose your personal health information, you are welcome to enter fictitious data. You will then be taken through a short tutorial on using the tabletop. Following this, your group of three will be given a scenario and you will need to carry out a number of tasks as a group. For example, you may be told that you are at a restaurant with two friends and that your task is to work together to order a number of dishes. At the conclusion of the experiment, you will be asked to complete a short questionnaire, followed by a short group interview about your experiences in the experiment. An experimenter will be present throughout the session to assist with any problems or questions you might have. You will also be video and audio recorded while you complete the practical tasks.

(4) How much time will the study take?

The total session will last approximately 1 hour. The session will consist of approximately 20 minutes for the background/post-experiment questionnaires and interview and approximately 25 minutes to complete the practical tasks.

(5) Can I withdraw from the study?

Being in this study is completely voluntary - you are not under any obligation to consent and - if you do consent - you can withdraw at any time without affecting your relationship with the researchers or the University of Sydney.

You may stop the experiment at any time if you do not wish to continue. You are under no obligation to continue working with your group; you are free to withdraw from the group activity at any time (the experiment may continue without you). The video/audio recording of your group's session will be erased and the information that you provide will not be included in the study.

(6) Will anyone else know the results?

All aspects of the study, including results, will be strictly confidential and only the researchers will have access to information on participants. All recorded data and responses will not be associated with any name; instead, your name will be converted to a code number when the researchers store the data. A report of the study will be submitted for publication, but individual participants will not be identifiable in such a report.

The video and audio recordings of the experiment will remain strictly confidential (not viewed by anyone except the researchers), unless you optionally give permission for them (video and/or audio) to be used in future research publications and presentations (your name will not be revealed). Parts of your conversations may be quoted anonymously in publications/presentations resulting from the study. Video and audio recordings of you will not be published in public domains. The health information that you (optionally) provide may also be used in anonymised form in publications/presentations.

(7) Will the study benefit me?

You will receive a movie voucher as compensation for your time. You may also find using a tabletop novel and interesting if it is your first time doing so.

(8) Can I tell other people about the study?

You are free to tell others about the study.

(9) What if I require further information?

When you have read this information, Jeffrey Leung will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact Jeffrey Leung (e-mail: jleu3693@uni.sydney.edu.au, ph: 0404 536 437), or Professor Judy Kay (e-mail: judy.kay@sydney.edu.au, ph: 02 9351 4502).

(10) What if I have a complaint or concerns?

Any person with concerns or complaints about the conduct of a research study can contact the Deputy Manager, Human Ethics Administration, University of Sydney on (02) 8627 8176 (Telephone); (02) 8627 8177 (Facsimile) or human.ethics@usyd.edu.au (Email).

Appendix C

Participant Consent Form

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Judy Kay
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PARTICIPANT CONSENT FORM

I, ...[PRINT NAME], give consent to my participation in the research project

TITLE: Ubiquitous Personalisation at Interactive Tabletops

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my experiment group, my relationship with the researcher(s) or the University of Sydney now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity. I understand that I may optionally give permission for video and/or audio recordings of me to be used in future research publications and presentations arising from this study, and that my name will not be revealed in these publications and presentations.

5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

6. I understand that I can stop the study at any time if I do not wish to continue and that any audio/video recording of my group will be erased and the information provided by me will not be included in the study. The group activity may proceed without me.

7. I understand that I may be asked to provide personal health information for the purposes of the experiment and that this is completely optional. I understand that I may provide fictitious health information if I choose not to disclose my personal health information.

8. I consent to:

i) Audio and video-taping. YES ☐ NO ☐

(with the recording to be kept strictly confidential, only viewed by the researchers and not published in public domains)

I also consent to (optional):

ii) Use of my image in video (no audio) for research publications and presentations YES ☐ NO ☐

iii) Use of my recorded audio for research publications and presentations YES ☐ NO ☐

iv) Receiving feedback YES ☐ NO ☐

If you answered YES to the "Receiving Feedback Question" (iv), please provide your details i.e. mailing address, email address.

Feedback Option

Address: ____

____

Email: ____

Signed: ....

Name: ....

Date: ....

Appendix D

Background Questionnaire

Participant Code: _________

Background Questionnaire

Please complete the following questions about your background:

Age: ______ Occupation: ____

Gender: ☐ Male ☐ Female

1. Are you primarily right- or left-handed? (please tick one)

☐ Right-handed ☐ Left-handed ☐ Ambidextrous

2. How many hours do you typically use a computer each week? (please tick one)

☐ None ☐ 1 to 10 ☐ 11 to 20 ☐ 21 to 30 ☐ 31 to 40 ☐ 41 or more

3. Have you ever used a tabletop interface before? (If yes, please give details)

____

____

____

4. Have you ever used a smart phone or a tablet before?

☐ Yes ☐ No

4.1. If Yes, What would you rate your level of skill with using it?

☐ Expert ☐ Advanced ☐ Competent ☐ Limited ☐ None

5. What is your understanding of the term, *personalisation*?

____

____

____

6. What level of consciousness do you hold about maintaining a healthy diet?

☐ Very High ☐ High ☐ Medium ☐ Low ☐ Zero

7. How long have you known your experiment partners? (Please tick one for each partner)

Partner 1:

☐ Never met ☐ 1 week or less ☐ 1 month or less ☐ 1 year or less ☐ over 1 year

Partner 1 is my:

☐ Relative ☐ Friend ☐ Colleague

☐ Other, please describe ____

Partner 2:

☐ Never met ☐ 1 week or less ☐ 1 month or less ☐ 1 year or less ☐ over 1 year

Partner 2 is my:

☐ Relative ☐ Friend ☐ Colleague

☐ Other, please describe ____

Please tell the experimenter when you have finished completing the questionnaire.

Thank you for your participation in this study.

Appendix E

Post-Experiment Questionnaire

Participant Code: __________

Post-Experiment Questionnaire

Please complete the following questions about your experiences using the tabletop and the mobile interfaces. For each of the questions, please make the most appropriate selection in your opinion, and explain in further detail (give feedback) when indicated.

1. Using the Restaurant tabletop application

a) The Restaurant application was easy to navigate and intuitive to use.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
☐	☐	☐	☐	☐	☐	☐

Please explain:

____

____

____

____

b) I understood that my menu was personalised using the information I had provided at the beginning of the session.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
☐	☐	☐	☐	☐	☐	☐

Please explain:

____

____

____

____

c) I understood the different levels of detail in the explanation of the reasoning behind the recommendations (using the inspection button).

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
☐	☐	☐	☐	☐	☐	☐

Please explain:

d) For each level of reasoning for the recommendations (using the inspection button), how comfortable were you with the amount of detail shown (given that others at the tabletop may also see this)?

Level 1 (Low Detail)
Very uncomfortable 1…2…3…4…5…6…7…8…9…10 Very comfortable

Level 2 (Med Detail)
Very uncomfortable 1…2…3…4…5…6…7…8…9…10 Very comfortable

Level 3 (High Detail)
Very uncomfortable 1…2…3…4…5…6…7…8…9…10 Very comfortable

Please explain:

e) The group menu allowed my group to effectively discuss and decide what to order for the meal.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
☐	☐	☐	☐	☐	☐	☐

Please explain:

2. Using the Persona mobile application

a) The mobile application was easy to navigate and intuitive to use.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
☐	☐	☐	☐	☐	☐	☐

Please explain:

____

____

____

b) I understood how to control which parts of my dietary information the Restaurant application could access.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree	Didn't use
☐	☐	☐	☐	☐	☐	☐	☐

Please explain:

____

____

____

c) The information logs were helpful in letting me know how my user model was being used.

strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree	Didn't use
☐	☐	☐	☐	☐	☐	☐	☐

Please explain:

____

____

____

____

3. General feedback (Tabletop and mobile)

a) Which aspects (of the tabletop and/or mobile interfaces) did you like best for the tasks you were asked to complete?

d) Which aspects (of the tabletop and/or mobile interfaces) did you dislike for the tasks you were asked to complete?

f) Do you have any other general comments regarding either the tabletop or the mobile interfaces?

Please tell the experimenter when you have finished completing the questionnaire.

Thank you for your participation in this study – the comments you have provided here are extremely helpful and much appreciated.

Appendix F

Post-Experiment Interview Guide

Post-Experiment Interview Guide

The follow questions may be asked of participants, depending on observations made during the experiment.

1. When you personalised your individual menu, was it clear to you that it was personalised?

2. Did you feel uncomfortable with any of the information that was displayed on the tabletop interface? Would you prefer to have some information kept more private? What if there was more sensitive and personal information, such as a medical condition you have?

3. When you were using the group menu, was it helpful? What difference would it make if there was no group menu?

4. Did you view the logs in the logs tab before I drew your attention to it?

5. Do you think that the Restaurant application was easy to use?

6. Did you use the inspection button to find out more information about the recommendations? If so, was it intuitive to use?

7. Did you find any part of the using the tabletop or mobile application confusing or difficult to do? If so, which parts?

8. Were there any conflicts that arose when working as a group on the tabletop? If yes, why?

9. Do you have any general comments to make about the application overall?

Appendix G

Task Result Sheet
Completed Task Result Sheet Sample

Task result sheet

PRESS RECORD ON CAMERA PRIOR TO STARTING EXPERIMENT

Task T1(a): Enter a name and choose a picture for your persona.

Enters name correctly	UID:	UID:	UID:	Notes
Success				
Error				
Recovery				
Chooses a picture				
Success				
Error				
Recovery				

Task T1(b): Indicate the parts of your dietary information that you want to allow the tabletop to access.

Ticks relevant components				
Success				
Error				
Recovery				

Task T2: Send your persona to the tabletop.

Presses Send Persona				
Success				
Error				
Recovery				

Task T3: Personalise your menu.

Drags Persona onto menu				
Success				
Error				
Recovery				

Question Q1: What do you think has happened?

Observation O1: Users looked at mobile interface to examine the log.

	UID:	UID:	UID:	Notes
Looked at mobile interface				
YES				
NO				

Task T4: Find out why that menu item was recommended for you and examine each level of detail in the explanations.

Drags out a recommended item				
Success				
Error				
Recovery				
Presses inspection button (revealing Low)				
Success				
Error				
Recovery				
Presses next button (Med)				
Success				
Error				
Recovery				
Presses next button (High)				
Success				
Error				
Recovery				

Question Q2: What differences do you notice in each level of detail of the explanations?

Question Q3: What do you think this object shows?

Task T5: Now imagine that it is dinner time. Organise amongst yourselves what you would like to order for dinner and then place your order.

	UID:	UID:	UID:	Notes
User selects item/s from the **group** menu and place in order box				
YES				
NO				
User selects item/s from **individual** menu and place in order box				
Recommended				
Normal				
NO				
Press Place order button				
Success				
Error				
Recovery				

Observation O2: Users looked at mobile interface to examine the operation details.

Looked at mobile interface				
YES				
NO				

Task T6: View the details of a log item.

	UID:	UID:	UID:	Notes
Selects a log item				
Success				
Error				
Recovery				

Session No. 9
Date: 17/10/12

Task result sheet

PRESS RECORD ON CAMERA PRIOR TO STARTING EXPERIMENT

Task T1(a): Enter a name and choose a picture for your persona.

Enters name correctly	UID: 9a	UID: 9b	UID: 9c	
Success	✓	✓	✓	c created persona c ~~the~~ c shift knew how to using keyboard
Error				
Recovery				
Chooses a picture				
Success	✓	✓	✓	
Error				
Recovery				

Task T1(b): Indicate the dietary information that you want to allow the tabletop to access.

	9a	9b	9c	Notes
Ticks relevant components				c tried scrolling lots of scrolling needed
Success			✓	
Error	✓	✓		
Recovery	✓	✓		

Task T2: Send your persona to the tabletop.

Presses Send Persona	9a	9b	9c	
Success				~~a and b~~ everyone pressed back to exit persona
Error	✓	✓	✓	
Recovery				

realised after
didn't understand rules the card

Task T3: Personalise your menu.

Drags Persona onto menu	9a	9b	9c	
Success		✓	✓	a accidentally personalised menu didn't understand
Error	✓			
Recovery	✓			

until saw words
screen so wanted so
put the persona on
top of the ~~p~~ menu

Question Q1: What do you think has happened?

recommends you to have certain dish, her picture and name is middle got an i → information
recommendations, everyone's is the same.
didn't scroll initially, got them to unpersonalise

Observation O1: Users looked at mobile interface to examine the log.

	UID: 9a	UID: 9b	UID: 9c	Notes
Looked at mobile interface				
YES				
NO	✓	✓	✓	

Task T4: Find out why that menu item was recommended for you and examine each level of detail in the explanations.

	9a	9b	9c	
Drags out a recommended item				b and c scrolling a immediate ~~[illegible]~~ gave over
Success	✓		✓	
Error		✓		
Recovery		✓		
Presses inspection button (revealing Low)				took hinting realised i button after a while
Success	✓	✓	✓	
Error				
Recovery				
Presses next button (Med)				thought levels were the content took some time to find it
Success		✓	✓	
Error	✓			
Recovery	✓			
Presses next button (High)				
Success		✓	✓	
Error	✓			
Recovery	✓			

Question Q2: What differences do you notice in each level of detail of the explanations?

There's not much difference, the same low and med the same:
high: dishes say particular ingredients they like, more information about its recommended

Question Q3: What do you think this object shows?

Suitable for everyone / all of them trying to work out whether its categorised; different pressed ? button

Task T5: Now imagine that it is dinner time. Organise amongst yourselves what you would like to order for dinner and then place your order.

	UID:9a	UID:9b	UID:9c	Notes
User selects item/s from the **group** menu and place in order box				~~a~~ all start scrolling through individual menu
YES				
NO	✓	✓	✓	
User selects item/s from **individual** menu and place in order box				C said that she might not have pressed recommended ones
Recommended	✓	✓	✓	
Normal			✓	
NO				
Press Place order button				
Success	✓			
Error				
Recovery				

Observation O2: Users looked at mobile interface to examine the operation details.

Looked at mobile interface				
YES				
NO	✓	✓	✓	

Task T6: View the details of a log item.

	UID:9a	UID:9b	UID:9c	Notes
Selects a log item				
Success		✓		didn't seem to
Error	✓		✓	understand to
Recovery	✓		✓	press

it matches what you put it
noticed fall keyword
a doesn't understand

Appendix H

User Study Task Script

User study task script

*Intro **(5 min)***
Thank you for choosing to participate in this study. This study is designed to evaluate the personalisation framework that we have developed to verify whether it is easy for users to use and understand. You will be interacting with a tabletop and also a mobile device as part of the session.

Confidentiality
Your information is strictly confidential and will not be used beyond the experiment. All recorded data and responses will remain anonymous.

Video and audio recordings will be used as an aid to the evaluation process. Video and audio recordings of the experiment will remain strictly confidential and will only be used by researchers for the purpose of analysing the experimental results. However, you have the option to give permission for recordings of yourself to be used in future research publications while still remaining anonymous – names will not be revealed.

Withdrawal
If at any time during the session you feel uncomfortable or do not wish to continue, you may withdraw from the study. The audio/video recording of you will be erased and the information provided will not be included in the study. If you do withdraw, the session will continue without you. If you have any questions at all during the study, please feel free to ask me.

Do you have any questions?

Fill out consent forms (2 min).
Could you please fill out the consent form now.

Fill in background questionnaire numbers.

Thank you. I will now go through the procedure for the rest of the session.

Explain procedure for the session

1. First, you will complete a background questionnaire that contains some general questions. **(5 min)**

2. Then I will give you some more details about what this project is about and what we're aiming to achieve with this study. This will be followed by the data entry phase, which I will talk more about when we get to it. **(5 min)**

3. After this, I will take you through a tutorial of the tabletop and the mobile application. **(2 min)**

4. This will be followed by the actual experiment, where you will carry out some pre-set tasks. I will help you during the experiment if you get stuck or have any difficulties. **(10-15min)**

5. Once the experiment is finished, you can take a break and then I'll ask you to fill in a post experiment questionnaire, which has questions on what you thought about the experiment and the tasks. **(10 min)**

6. This will be followed by a short group interview, which will conclude the session. **(3 min)**

The whole session should take less than one hour.

Do you have any questions?

Hand out background questionnaires. (5 min)

If you are a student, please indicate your study discipline.

Fill in user IDs on User Study Task Result sheet

Make sure Logs tab works on Persona.
Make sure all Wifi is on and connected to sitrg0.

Brief explanation of project. (3 min)
Personalisation is the process of adapting a user interface to the person who is using it. Use ebay as an example. We are looking at how we can personalise a tabletop application. An important part of personalisation is to have information about the person's interests and preferences so that we can arrange the interface to suit that person. This information is stored in a *user model*, similar to a user profile. With the ebay example, ebay might have a record of a person's purchase history so that they can recommend products for them the next time they visit.

You will now use the mobile device to enter data into your user model. You just need to follow the instructions on the app. **You may enter fictitious data if you do not wish to disclose your personal information.** Please note that this phase is not part of the experiment.

Data entry (2 min)
Start UserModelData on each device. Make sure data is deleted. Hand out phones/tablets.

1 – Nexus S
2 – Galaxy Tab
3 – Nexus One

Start restaurant application.

Let me know when you have finished.

Get mobile devices back.

Thank you. I will now go through the tutorial of the tabletop application and then the mobile app that you will use.

Tutorial (2 min)

<u>Demonstration of tabletop interactivity.</u>
Start Restaurant application. Feel free to copy what I am doing.

- Move an object: *move menu*
- Rosize and object: *rosize menu*

- Drag an object out of a container: *drag out menu item*
- Drag an object into a container: *drag menu item into order box*
- Dwell operation: *dwell on menu app icon*
- Demonstrate black hole: *put a menu item inside black hole*

Mobile app tutorial
- Explain Android back button

Ok, that's the end of the tutorial.

Do you have any questions?

We will now start the experiment. I will be asking you to perform some tasks. As you complete each task, please await my instruction for the next task. Thanks.

<u>PRESS RECORD ON CAMERA</u>

ENSURE THAT CAMERA IS RECORDING PRIOR TO STARTING EXPERIMENT

Experiment tasks (10 – 15 min)

Start Persona application on each device. Hand out each device to the same person as before.

This is the Persona application. It lets you link your personal identity, or Persona, to the tabletop. Your first task has two parts.

Using the Persona mobile application:

Task T1(a): Enter a name and choose a picture for your persona.

Task T1(b): Indicate the dietary information that you want to allow the tabletop to access.

Call me over when you are done. I will give you further instructions after you have done this.

Check.

Task T2: Send your persona to the tabletop; and

Task T3: Personalise your menu.

Question Q1: What do you think has happened?

(Check for Observation O1: Users looked at mobile interface to examine log)

Look through the menu and find an item that is recommended for you.

Task T4: Find out why that menu item was recommended for you and examine each level of detail in the explanations.

Now do the same for some other menu items that are recommended for you.

Take note of the differences in the level of detail and the nature of the information that each level reveals.

Question Q2: What differences do you notice in each level of detail of the explanations?

Take note of the circular object in the middle.

Question Q3: What do you think this object shows?

Task T5: Now imagine that it is dinner time. Organise amongst yourselves what you would like to order for dinner and then place your order.

(Check for Observation O2: Users looked at mobile interface to examine the operation details.)

Did anyone look at the logs tab on the Persona application?

Task T6: View the details of a log item.

Take note of the information it provides you.

That concludes the experiment.

PRESS STOP RECORD ON CAMERA

Fill in post experiment questionnaire. (10 min)
Take a break. When you are ready, please fill out the post experiment questionnaire. Feel free to go back and use the tabletop or mobile device.

PRESS RECORD ON CAMERA

Thank you. The final stage of the session is a short interview about the experiment you just did.

Conduct interview (3 min).

Thank you. This concludes the session.

STOP CAMERA RECORDING AFTER INTERVIEW

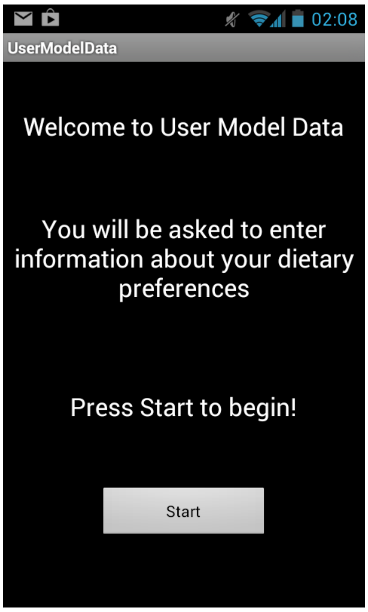
Give out movie vouchers.

Appendix I

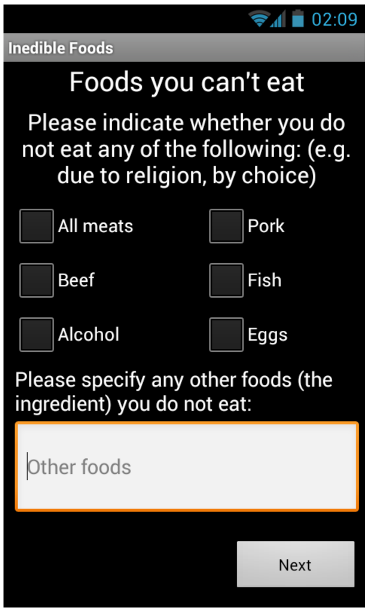
User Model Data Application

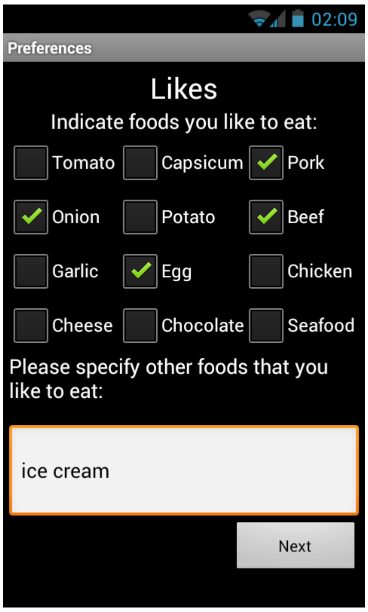
Screenshots

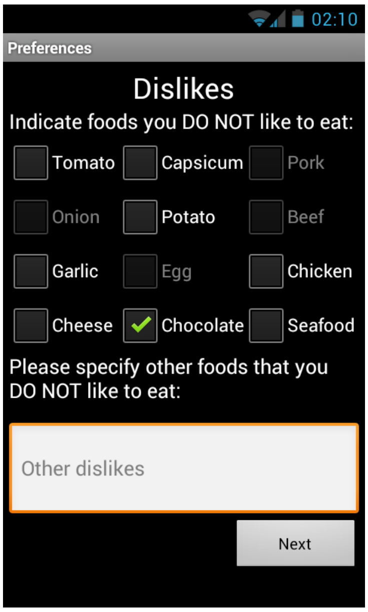
Participant user model data

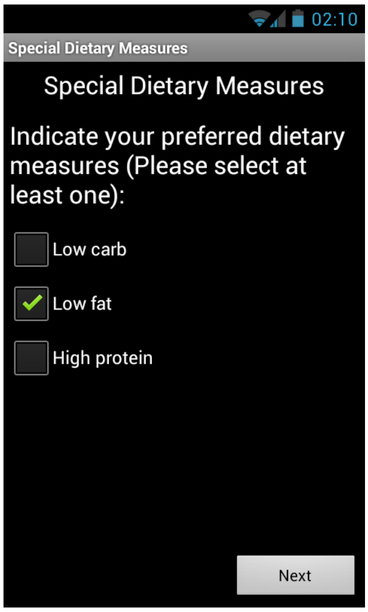

02:08
UserModelData
Welcome to User Model Data
You will be asked to enter information about your dietary preferences
Press Start to begin!
Start


02:09
Allergies
Allergies
Are you allergic to any of the following foods?
Nuts
Shellfish
Soy
Wheat/Gluten
Fish
Milk
Eggs
Tree nuts
Please specify any other allergies you have:
Other allergies
Next


02:09
Inedible Foods
Foods you can't eat
Please indicate whether you do not eat any of the following: (e.g. due to religion, by choice)
All meats
Pork
Beef
Fish
Alcohol
Eggs
Please specify any other foods (the ingredient) you do not eat:
Other foods
Next


02:09
Preferences
Likes
Indicate foods you like to eat:
Tomato
Capsicum
Pork
Onion
Potato
Beef
Garlic
Egg
Chicken
Cheese
Chocolate
Seafood
Please specify other foods that you like to eat:
ice cream
Next


02:10
Preferences
Dislikes
Indicate foods you DO NOT like to eat:
Tomato
Capsicum
Pork
Onion
Potato
Beef
Garlic
Egg
Chicken
Cheese
Chocolate
Seafood
Please specify other foods that you DO NOT like to eat:
Other dislikes
Next


02:10
Special Dietary Measures
Special Dietary Measures
Indicate your preferred dietary measures (Please select at least one):
Low carb
Low fat
High protein
Next

PID	Allergies	Cannot Eat	Likes	Dislikes	Specific Diet Measures
1a	None	None	tomato, onion, potato, egg, beef, seafood	cheese, pork	low fat
1b	None	None	potato, egg, beef, pork, chicken, seafood	None	high protein
1c	None	None	tomato, onion, garlic, potato, egg, pork, chicken	chocolate	low carb
2a	cocoa	None	tomato, onion, garlic, potato, egg, pork, beef, chicken, seafood	cheese, chocolate	low carb
2b	None	None	onion, garlic, egg, chocolate, pork, beef, chicken, seafood	capsicum	low fat
2c	None	fish, seafood	tomato, potato, egg, pork, beef, chicken	seafood	low carb, low fat
3a	None	None	tomato, onion, potato, egg, pork, beef, chicken, seafood	None	None
3b	None	pork, alcohol	tomato, onion, garlic, cheese, capsicum, potato, egg, beef, chicken, seafood	chocolate, pork	low carb, high protein
3c	None	None	None	None	low fat
4a	None	None	cheese, egg, chocolate, beef	celery	low fat
4b	shellfish, milk	alcohol	tomato, onion, garlic, capsicum, potato, egg, pork, beef, chocolate, chicken, seafood	cheese	low fat
4c	None	fish	tomato, onion, garlic, chese, capsicum, potato, egg, chocolate, beef, chicken	seafood	low fat, high protein
5a	None	alcohol	tomato, potato, beef, chicken, seafood	onion, garlic	high protein
5b	None	None	tomato, cheese, capsicum, potato, egg, chocolate, pork, beef, chicken, seafood	onion	high protein
5c	None	alcohol	tomato, chese, chocolate, beef, chicken, seafood, watermelon	onion	low fat, high protein
6a	None	all meats	tomato, onion, garlic, potato	pumpkin	low fat
6b	None	None	tomato, onion, garlic, chese, capsicum, potato, egg, chocolate, beef, chicken seafood	None	high protein
6c	None	alcohol	cheese, potato, egg, chocolate, pork, beef, chicken, seafood, candy, chips, ice cream	onion, capsicum, pickles	high protein
7a	shellfish, red wine	None	garlic, cheese, potato, egg, chocolate, pork, beef, chicken	capsicum, seafood	low fat
7b	shellfish, apricots	None	tomato, garlic, potato, egg, chicken	None	None

Participant User Model Data

7c	nuts, shellfish, treenuts	pork, alcohol	tomato, capsicum, seafood, duck	onion, cheese, pork	low fat
8a	milk	None	tomato, onion, cheese, capsicum, potato, egg, chocolate, pork, beef, chicken, seafood	garlic	None
8b	None	None	tomato, onion, garlic, cheese, capsicum, potato, egg, chocolate, beef, pork, chicken, seafood	None	low fat
8c	None	None	tomato, garlic, cheese, potato, egg, beef, chicken, seafood	None	None
9a	None	internal organs	tomato, onion, garlic, capsicum, potato, egg, pork, beef, chicken, seafood	None	low fat
9b	None	None	tomato, onion, garlic, cheese, capsicum, potato, egg, pork, beef, chicken, seafood	chocolate	None
9c	None	alcohol	tomato, onion, garlic, capsicum, egg, beef, chicken, seafood	chocolate	None