Communicating with Your E-memory: Finding and Refinding in Personal Lifelogs

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Declaration

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Abstract

The rapid development of technology enables the digital capture and storage of our life experiences in an “E-Memory” (electronic–memory) or personal lifelog (PLL). This offers the potential for people to store the details of their life in a permanent archive, so that the information is still available even when its physical existence has vanished and when memory traces of it have faded away. A major challenge for PLLs is enabling people to access information when it is needed. Many people may also want to share or transfer some of their memory to their friends and descendants, so that their experiences can be appreciated and their knowledge can be kept even after they have passed away.

This thesis further explores people’s potential needs from their own PLLs, discuss the possible methods people may use and potential problems that they may encounter while accessing their PLLs, and hypothesize that better support of users’ own memory can provide better user experience and improved efficiency for accessing their E-memories (or PLLs). As part of a larger project, three lifeloggers collected their own prototype lifelog collection for about 20 months’ time. To complete this study, the author developed a prototype PLL system, called the *iCLIPS Lifelog Archive Browser (LAB)*, based on the author’s theoretical exploration and empirical studies, and evaluated it using our prototype lifelog collections through a user study with the three lifeloggers. The results of this study provide promising evidence which support the hypothesis. The end of this thesis also discusses the issues that the lifeloggers encountered in using their lifelogs and future technologies that are desirable based the studies in this thesis.

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Chapter 1
Introduction

Memory is the cognitive system that enables us to store and use our knowledge of the world, of our past, and emotions relating to our experiences. Of course, our memories do not always last forever. They are prone to fading, distortion or blocking. Memories are inside an individual's brain, not directly accessible, and vanish when the person passes away. Therefore, it is desirable that what a person has experienced and encountered can be captured and stored for them or others, so that these experiences can be reconstructed, transferred, and some of the encountered information can be re-used.

In the past, people attempted to share their experiences by writing autobiographies for themselves, and preserve their memory by maintaining diaries. One particularly powerful means of preserving a record of past experiences are photos that can vividly record what one has seen. However, until recently the cost of film and printing meant that not many people could afford to construct photo archives of sufficient size to tell detailed life stories. Apart from this, physical objects can also be associated with memories of past moments or people encountered. However, these embedded "memories" are not visible or transferrable. The development of digital technologies enabling large scale capture and storage is introducing a new realm of possibilities for storing a person's experiences permanently and electronically as "Electronic-memories" or "E-memories". A key question which arises in relation to the capture and storage of human experiences in E-memories is, how can the content of these E-memories be most efficiently and effectively accessed to make their creation and preservation worthwhile?

Personal information space (PIS) or personal archives refers to a collection of files or information which relates to or belongs to an individual. An electronic PIS is a collection of files and information in electronic form. Examples of typical electronic personal archives include one's email inbox, documents, digital photo collection, music library, and all the other files on a person's hard drive. Advances in computing technology mean that the typical contents of personal archives are rapidly changing, becoming bigger, richer and ever more heterogeneous. The average portion of traditional information items such as emails and text documents in a person's electronic personal archive is being reduced due to the emergence of new types of digital media that many people spend increasing time working with. For example, with the prevalence of digital cameras, MP3 players and smart phones, ever-increasing numbers of photos, and audio and video files are being captured which relate to a person's life. These types of data now play an increasingly important part in many people's personal archives. One of the most radical changes in this regard is the introduction of wearable, automatic image capturing devices such as Eye Tap (Mann, 2004) and photographical devices embedded with sensors such as Microsoft SenseCam (Gemmell et. al., 2004). Using such devices people can almost effortlessly capture what they see, as well as environmental context about the moment of capture. Even a person's actions and emotional status can be captured or inferred using sensors such as accelerometers and biometric devices (e.g. heart rate monitor, Galvanic Skin Response (GSR)). The term *Personal Lifelog* (PLL) is used to describe this special type of electronic personal archive which can potentially capture and store all of the above types of information and others, with the term *lifelogger*s referring to those who carry out lifelogging of their lives.

This thesis explores how people might best be supported in accessing the "memory" that is embedded in these electronic lifelogs. To do this I explore the topics of lifelogging, information seeking behaviour and human memory, and examined how these can be brought together to deliver effective PLL access technologies.

1.1 What Are Lifelogs?

The idea of PLLs can be traced back to the 1940s when Vannevar Bush proposed this idea in "As We May Think" (Bush, 1945). He suggested storing all of a person's media throughout a lifetime with stereo cameras mounted on eyeglasses and a device called "Memex". Bush's original vision is remarkably like a more physical version of a digital PLL. The recent rapid developments in electronic capturing techniques and computing technologies have seen an increasing number of researchers beginning to try to realize Bush's vision. The pioneers include Steve Mann, who has devoted much effort to the development of wearable cameras (Mann, 2004), and Gordon Bell who has digitalized almost all his physical collections (paper documents, CDs, sculptures) and is exploring tracking his life with many newly developed technologies as they emerge (e.g. auto-capturing cameras, GPS)). According to Gordon Bell, current research in lifelogs is not aimed at bringing about a single product, but to learn about benefits, fall-backs, and user requirements of personal lifelogging techniques, and to gradually make PLLs as commonplace as mobile phones and personal computers.

Lifelogging has been predicted to have many promising future applications, for example, transmitting professional knowledge (Bush, 1945), re-telling life stories e.g. (Byrne & Jones, 2008; Helmes, Hummels, & Sellen, 2009), summarizing life patterns to help human well-being, and supporting the data owner's memory e.g. (Berry et al., 2007; Sellen et al., 2007). Of course, there may be many other unforeseen and yet to be discovered ways in which lifelogs may be exploited, since users can be unexpectedly creative in utilizing things in novel and surprising ways. A detailed review of potential applications for lifelogs is included in Chapter 2.

This thesis focuses on the functions that serve the purposes of accessing a lifelog by data owner themselves, including: retrieval (retrieving archived electronic items such as documents), recollecting (recalling facts from the past), reminiscing (mentally re-living the past for emotional comfort), and reflecting (learn about oneself or things related to oneself in the past). For any of these applications, it is important that corresponding information in the lifelog can be accessible when needed. For retrieving functions, it is important that the digital items required by the users can be found. For recollecting and reminiscing functions, things that act as memory cues should be retrieved to help people retrieve further details from their own memories to elaborate their activities. For example, to support reflecting, some sort of summarized pattern for certain periods of the person's past might be provided rather than low level individual items or records.

For any of these functions, it is necessary that the lifelogger is able to access the appropriate information when needed. This thesis seeks to address the question of how to find information in a lifelog archive most efficiently and effectively.

1.2 Challenges of access from personal lifelogs

There are many challenges for accessing information from PLLs, beyond locating information relevant to the user's needs. e.g., how to collect data seamlessly, how to access the data securely, or how to prevent the users' traumatic memories from being evoked. Of course, solutions for many of these challenges are beyond the scope of this thesis, which aims to investigate ways to enable users to EASILY find needed information from their lifelogs. The ideal scenario is that a lifelog-access system can automatically detect the user's needs, and provide information to them immediately when needed. However, at this stage, technologies are still not advanced enough to automatically detect thoughts in the human mind, and information systems need humans to manually interact with them, e.g. to tell the system what they need, or to navigate from place to place to locate their target. There are many challenges for accessing information with these methods. Rest of this section briefly reviews some challenges for information accessing from PLLs with current technologies from the user's perspective.

1.2.1 Challenges for managing a PLL

Traditionally, people keep things that they believe will be useful to them in the future, for example, they save them to certain directories on their computer and come to find them again later in the place where they saved them. However, the keeping, organizing and finding of information is usually problematic. In the past, due to the small size of hard drive storage, people usually had to remove some less important things from their hard drive to save space for more important things. The decision of what to keep and where to keep it bothered people for many years. By contrast, the recent rapid increase in the storage capacity of personal hard drives make it possible to keep everything in a personal archive without the effort of deciding which items to keep. Lifelogging extends this freedom to not having to delete items from a hard disk to a situation where personal archives can have much greater volume and variety than most current typical personal data collections. These archives retain more information related to what a person has encountered or experienced than any traditional personal datasets. However, the amount of information stored in such personal archives makes it almost impossible to find things by scanning them one by one. The speed at which content can be added to a PLL makes it almost impossible to manually organize everyday data, not to mention the difficulties in categorizing them. Besides, it cannot even be guaranteed that people can easily find what they need within well-organized archives. In fact, it is not unusual for people to forget the directories (categories) under which they placed their stuff. It was claimed by (Lamming & Newman, 1992) that personal archives should not require manual management by the user. This problem can be solved from two aspects: i) creating a system that assists the lifelogger to manage their lifelog by doing most of the "organizing" work automatically, or ii) leaving all the problems to the information finding stage when people need some information from their PLL. Unfortunately, little work has been done to address the question from either approach. This thesis focuses on the latter approach, that is: *helping people find what they want from an "un-organized" (not manually organized) PLL collection.*

1.2.2 Challenges for finding within a PLL

Information retrieval (IR) generally refers to the science of retrieving documents from a collection of documents or information within documents in order to satisfy an information need. IR systems are developed based on the idea that people can rely on a digital assistant to fetch the information that they need from a messy corpus by telling this digital assistant what is needed. One of the main problems in search is the barrier in communication, that is, the difficulty of letting the IR system understand exactly what information the searcher wants. This problem is not just a matter of transferring human natural language to digital symbols that the information system can understand. In fact, a significant problem is that the user cannot express their needs precisely. This problem may be even greater for searching in PLLs, due to the diverse types of data and the lack of textual content in many of them. For example, a user may want to find “that” specific photo in which “there is a really beautiful lake (visual image in mind)”. However, such descriptions may not be clear enough for an electronic information system to automatically identify the qualifying items. There are gaps between what a user knows and what he or she tells to an information system. Such gaps pose a big challenge to current IR (including multimedia IR) techniques.

Work in this thesis seeks to relieve this problem from the user’s aspect, by helping them provide clearer and better queries. Therefore, it is important to understand what and how they tend to tell a system about their needs, the factors that influence this process and the problems or difficulties in such a process. Another approach that people often employ to locate items in a PIS is the location-based technique, such as navigation or browsing. It has been found that people tend to prefer location-based approaches to searching with an IR system, e.g. (Alvarado, et. al., 2003; Bergman et. al., 2008; Teevan, et. al., 2004). Yet, it is unknown at present whether people would have the same preference when looking for things in their PLL archive.

1.3 Memory and finding in PLL archives

Several authors have highlighted the importance of a user’s memory in finding his or her previously encountered information (e.g. (Lansdale, 1988)). I believe that better support to a user’s memory can be a effective approach to help users to access relevant information in their lifelogs easily. As I will frequently mention memory in this thesis, I introduce some of the main concepts about memory in this section, and gives a brief outlook of some scenarios in which memory influences information finding in PLLs.

1.3.1 What is Memory?

Memory is the cognitive ability to retain and utilize information. However, it cannot copy the original physical existence of this information. There are three processes of memory: *encoding, storing and retrieving*. *Encoding* is the process of converting external stimuli received by human sensors such as the eyes and ears into signals, which the neuron system in the brain can interpret, and then selectively processing these neural signals to absorb them into *long term* *memory* (LTM). *Storing* refers to the long-term storage of the information in the brain. *Retrieval* is the process of bringing back information from the LTM storage. The two main approaches of explicit memory retrieval are *recall* and *recognition*. Recall refers to the retrieval of specific pieces of information detail from memory. We usually need to recall specific information (e.g. the name of a file or contact) for searching, or to recall the directory or path of electronic items to locate them. *Recognition* is a judgment of whether the currently presented item is the specific one that was encountered in a certain previous context. It is involved when browsing for target items which the user has encountered before, or navigating in a previously visited environment. More details about human memory theories and the involvement of memory in information finding processes in PLLs are described in Chapter 4. The next two sub-sections present some sample scenarios and explain how user's memory is involved in the finding process.

1.3.2 Memory in searching

Since the items in PLLs are usually what the person has encountered before, or related to his or her experiences, when searching in PLLs, the searcher usually needs to tell the IR system some information about the target based on what she remembers about the searcher for information. However, people cannot always obtain the answers to the questions that the search interface asks (e.g. the filename of the image) from their memory, although the system expects them to have seen, and therefore to know the answers, since they have interacted with the items previously. For example, when looking for an article one read some time ago, one may recall some interesting findings it reported, its author, and probably some rough memory of visual elements, yet one may be unable to describe the target sufficiently to a typical IR system which only accepts queries based on the filename, or related keywords.

Due to the rich types of data in PLLs, the problem can be even more serious. For example, Jack wants to find the recorded episode in which he saw an object (suppose that he was a lifelogger at that time). What he remembers about the scene can be some rough visual features of the background and of course, the object itself. Since Jack may not have seen the electronic capture of the scene before, he can hardly know which parts of the scene have been captured. And as he has not visited the file before, he is unlikely to know the filename or URL of the item. What he has experienced and encountered is the event and its physical existence in the physical world, but as indicated above, he may have little knowledge about the electronic capture of the event. What matches his knowledge about the target record with the electronic capture may not even be the content of the image, but some metadata, such as the time he saw the scene and the time the photos and other lifelog data were captured. Apart from this, some other metadata may have been captured at the same time, e.g. the name of the location. In order to let him communicate with an information system which holds the data in PLLs, the system should at least provide an interface with search fields that accept one of the things that he does remember, and that matches the electronic records. In this case, it can be the date time and location. But of course, a person does not always remember the location or date and time for an event, and so general solutions to the PLL search problem are not simple.

In order to make it possible for a person to search for what they want from their lifelogs, it is important to understand the types of things that they can remember for different types of the target. Since almost no study has explored information behaviour relating to an individual's own lifelogs, some exploration, either theoretical or empirical has to be done to address this question before further exploration could be carried out for the role of the user's memory during information finding tasks in PLLs.

1.3.3 Memory in locating results

Lifelogs can contain various forms of content, e.g., texts, images, or multimedia streams (e.g. video and audio). When an information system finds some items which it "thinks" are relevant to what the user asked for, it presents them in certain forms, with some extracted or summarized features to represent the "items" to the users. It is then up to the user to recognize and determine the utility of these presented things. For example, a file is usually represented by an icon indicating its type, and text for the filename; time is usually presented as exact number in a certain date and time format (e.g. 2007-01-01 10:30am), or the distance from now (e.g. 3 minutes ago, 2 days ago); and location can be presented in exact latitude and longitude, by the address name (21, Collins Avenue), or visually presented on a map. Although people are likely to understand the information which is presented in their language (e.g. English), it is not necessarily true that searchers can recognize them as the specific items they are looking for, e.g. "this is the document that I read before". As for more abstract "things" such as events, their presentation can be even trickier. Yet, there is no definition of the best form of presentation. Indeed, any form that can allow people recognize an item is acceptable. In order to present the data in a form that users can easily recognize and make use of (e.g. reminiscing or reflecting), it is also important to understand how people recognize things. This topic is explored in Chapter 4 (based on cognitive theories about memory) and in Chapter 7 (based on empirical investigation).

1.4 **Hypothesis and Research Questions**

To summarize from above, the user's memory plays a very important role in finding information from lifelog archives. In this thesis, I hypothesize that:

Better support for the user's memory will bring improved usability and efficiency for accessing their own PLL archives.

To test this hypothesis, it is necessary to have or build a system which can support the user's memory when they access their PLLs, so as to test the hypothesis through user studies with this system, and test whether the memory-supporting features in this system improve the usability and efficiency for accessing needed information in PLLs.

Before the prototype system can be developed, a number of questions must be investigated:

1) *What types of memory support should the system provide?*

   Since there is not currently any relevant literature on this topic, either theoretical or empirical, that directly answers this question, we need to answer this question from the fundamentals based on a better understanding of the second question:

2) *How is memory involved in information finding tasks related to accessing information from personal lifelogs?*

   Only with a better understanding of the involvement of human memory in the information finding process, as well as insight into the mechanisms of human memory, can I further explore the potential problems people may encounter, and possible solutions for relieving them from such problems. Therefore, it is essential to answer the following question:

3) *What is the information finding process in PLLs?*

   Since PLLs are a brand new type of highly heterogeneous information corpus, little literature is available which is relevant to addressing this question. As the information finding process may vary according to different types of targets and other factors, there is another question that needs to be solved:

4) *What might people look for in their lifelogs?*

   This question is not just about the type of data people may look for, e.g. a photo, an email, a video record, but higher level composite information types, e.g. an event. This question is not only important for exploring question 3 and designing the prototype system, but also for evaluating the prototype system. The results of such evaluations will be more generalizable if the usability of the system is tested under different task types.

Before developing a system that supports a user's memory for accessing information from their own lifelogs, answers need to be found for the above four questions in a bottom up order. The main challenge is that there is little in the way of ready-to-use theories or literature which answers these questions, nor are there any existing tools that allows users to access information from their PLLs. Therefore, it is difficult to directly explore these questions through empirical studies which could observe the behaviour of PLL users when accessing their PLLs.

In this thesis, I develop a theoretical basis deducted from relevant higher-level theories of information seeking and cognitive psychology, e.g. how people look for things in typical information spaces, or what do people tend to remember. I then conduct empirical explorations to supplement to this purely theoretical guideline, and use this to generate by providing more concrete parameters for developing a prototype PLL information access system.

In addressing question 4, the potential types of targets are mainly explored based on related literature and empirical studies. Both my theoretical and empirical explorations seek to maximally collect potential types of information finding targets and tasks. For example, in Chapter 2, the outlooks from experts and models of human needs are reviewed, to infer the potential information needs that can be satisfied by PLLs; and in Chapter 3 I proposed a knowledge-based information-seeking model, based on which I predicted types of scenarios that people may seek for information in their lifelogs. From the empirical perspective, an online survey was conducted to directly explore the general-public's desirable functions and information needs from PLLs. This study is reported in the end of Chapter 2. Apart from these, types of information finding tasks and targets in PLLs were also explored as part of a diary studies and an online survey, which are reported in Chapter 6.

For question 3, I deduce the potential process from models and findings on general information finding behaviour. Based on which I discuss the steps in which a user's memory should be involved, e.g. need to recall some information to generate a search query.

Question 2 is explored theoretically from cognitive theories of human memory (in Chapter 4), as well as information finding models which I review and propose in Chapter 3.

Finally for question 1, based on question 2 and theories of memory from psychology, overviewed in Chapter 4), I proposed guidelines for how to support user's memory during information finding tasks in PLLs. Of course, guidelines are not sufficient to determine the exact features and algorithm for an information accessing system for PLLs. For example, although psychological theories can tell us what features makes things memorable, they can not directly inform us regarding the types of information in potential users of PLLs that are likely to be remember for search targets. Nor can they tell us what types of data or which information tend to be efficient in representing events, computer items, or other types of data collections, which a user may need to recognize to browse within their PLL. Therefore, I explore these detailed questions empirically with diary studies, surveys and experiments, and report these in Chapter 6 and Chapter 7.

Only after all the above four questions have been answered, could I proceed to design and develop a prototype system and evaluate the main hypothesis.

1.5 Thesis Outline

This thesis is composed with three parts. The first two parts explore the four pre-development questions introduced in the previous section from theoretical and empirical perspectives. The third part describes the prototype system and the final evaluation of the hypothesis. The structure of each part is as follows:

Part 1: Theoretical explorations

Since different information needs and types of task can lead to different information behaviour, it is essential to understand the most likely potential applications, information needs and types of support that are needed for each application. In Chapter 2, I review the literature describing current work on lifelogs and, based on the these current findings, summarize a list of functions that people are most likely to want from their own lifelogs, the types of data they like to capture and the types of information that they want to see. This chapter mainly seeks to collect answers for question 4, that is, what might people look for in their lifelogs.

In Chapter 3, I review literature relating information behaviour, including general models in information seeking about how a information seeker (searcher) interacts with the information world (information, information system, and the information needs); and models of the process and strategies people use when looking for information. Based on these theories and models, I propose a *knowledge-based framework* for information finding, and apply this model to information finding behaviour in lifelog archives. This framework seeks to describe the role that the user's memory plays during the process of information finding in lifelog archives. This chapter provides answers to questions 3 and 2, that is, what are the information finding processes, and how is a user's memory involved in these processes.

In chapter 4, I review the psychology literature about human memory mechanisms, and studies on memory in refinding. I further investigate the interaction between the user's memory and the process of the accessing their PLLs. Finally, I propose solutions to supporting the user's memory when they are accessing their PLLs. This chapter also provides further insight into questions 2 and 1, that is, how is a user's memory involved in the information finding process, and how to support the user's memory in this process. It also leads to two questions that are resolved by empirical studies, which are reported in Part 2.

Part 2: Empirical investigation

The second part empirically explores potential approaches to supporting the user's memory information finding tasks in PLL. Chapter 5 introduces the main test data set and test subjects: the prototype long-term PLLs used in most of my main empirical investigations and their data owners. Chapter 6 report my studies exploring people's memory of encountered information, and the items in lifelogs which serve as good memory cues in Chapter 7.

Part 3: Evaluation and pilot investigation of a prototype PLL search system

The last part of the thesis describes the development of a prototype system based on theories and attributes, and algorithms that are derived from Part 1 and Part 2, and tests its ability to satisfy the hypothesis.

Chapter 8 describes the prototype system that I developed to test the hypothesis, including the data collections, pre-processing, background algorithms and the interface functions. The system is expected to support the user's memory when accessing their lifelog archives. Chapter 9 reports the evaluation of the prototype system with three lifeloggers who collected 20 months of diverse lifelog data. The evaluation compares the PLL interface with advanced functions which support the user's memory in different refinding strategies against baseline interfaces with basic search and navigation functions. During the evaluation experiments, I also collected suggestions and comments from the participants, regarding the functions and reflect on other types of tasks they would like the lifelog system to provide.

This thesis seeks to make the following contributions:

- Provide a systematic understanding the role of the user's memory in refinding processes in PLLs based on both theoretical and empirical evidence, taking into consideration factors such as task types.
- A pioneering trial to build a full featured information finding system for PLLs, and to explore the requirements of features and functions for future PLL system development.
- A direct exploration of the potential applications and information needs from personal lifelogs for the wider population.

Part 1

Theoretical Explorations

Chapter 2
LifeLogging

2.1 Overview

The personal lifelog (PLL) is a special case of a Personal Information Space (PIS). A PLL aims at recording certain aspects of a person's life. It contains not just information that the person has encountered or is interested in, but also information about what he or she has done. The concept of events or episodes is a feature of a lifelog that distinguishes it from traditional PISs. Lifelogs can include a large portion of automatically (passively) captured information, which the lifelogger may never have viewed. Currently, most of lifelog research focuses on the stage of capturing information in one's everyday life. However, given the wealth of gathered personal information, it has yet become mainstream to develop applications that utilise these lifelogs. The main applications of lifelog nowadays are in the medical domain to help users with compromised memory functions. Yet, few applications have been developed for the public to make good use of their own PLLs. This chapter reviews the history and research relating to lifelogging, and discusses the possible applications or functions that lifelogs could provide to benefit their owners within the general population.

2.1.1 Types of lifelog collections

PLLs and the process of lifelogging do not have unique definitions. There are a wide range of collections that could or have been called lifelogs or given related labels. This section gives an overview of the main categories of lifelogs that have been introduced to date.

2.1.1.1 *Total capture vs. Situation-specific captures*

Total capture lifelogging aims to capture as many aspects of a person's life as possible. In total capture lifelogs, multi-modal methods (e.g. a combination of visual, audio, textual) are usually used to capture many aspects of a person life as possible. *Situation-specific lifelogging* captures certain aspects or specific moments of a person's life. Examples include meeting video recording, diet monitoring, sport or exercise monitoring, and the monitoring of work or project progress in the office to improve work efficiency. Situation-specific lifelogging is limited in scope comparing the total capture type, although people also try to make the capturing process as automatic and complete as possible for these specific aspect or situations. In the context of this thesis, I use the term *lifelogging* to refer to *total-capture* type of lifelogging. *Lifelogging* thus refers to the activity of electronically capturing and storing every possible piece of information that a person (lifelogger) has encountered during the capturing period, and details of context of their experiences.

2.1.1.2 ***Passive vs. Active***

Most of current lifelogging activities involve passive, continuous, and non-intrusive capture. This type of logging is usually carried out by using small-sized, wearable devices attached to the lifelogger and software running on computing devices. Actively captured "lifelogs" can be traced back to ancient times when the "diary" was invented about 2000 years ago. In a traditional diary, people record their experiences and thoughts through writing. In the current age, although many people still write regular diaries, they are not the main forms of "active lifelog". At present, the prevalence of digital cameras, camcorders and micro blogs such as twitter are making the active form of lifelogging increasingly popular. In the prototypes described later in this thesis, both passive and active capture methods are employed.

2.1.1.3 ***First person vs. third person***

Lifelogs can be recorded or generated from the first-person's perspective, e.g. recording what is in front of a person's view (assuming that the recording is what the person sees) or what one hears, as a copy of the information one encounters in the physical world. Third-person perspective recording captures scenes where the lifelogger is present. For example, this type may include photos taken by others which include the lifelogger, and CCTV recordings containing images of the lifelogs.

2.1.1.4 ***Temporal dimensions***

Since lifelogging can last for many years, there are three temporal stages of lifelog data:

1) Information that has just been captured: this type of information is particularly useful for context-based event detection and processing, e.g. by detecting the wearer's current context or what one is doing, providing the lifelogger or a third party with instant feedback for real-time assistance, or as reminders to help people to remember to do things;

2) *Active collection* contains information that is captured recently: they may still be frequently used for current work or directly related to the main themes of current life;

3) *Lifelog archives*: information that has been captured a considerable long time ago and is seldom accessed. The longer the lifelog lasts, the more content and the greater proportion of it will belong to the third category.

In the context of this thesis, I use the term "lifelog" to refer to total capture type lifelogging which include both passively and actively captured contents, from both first person perspective and third person perspective, and across all temporal stages. However, the issues and questions that this thesis focuses on mainly concern the archive type data. This is because the archive part is often the greatest proportion of a long term PLL collection. In addition, as the research that I conducted was a pioneer exploration, there is a considerable time gap between capturing, processing and using the data with our prototype system.

2.2 The history and state of art of Lifelogs

2.2.1 The Memex vision

The idea of electronic lifelogging can be dated back to 1945, when Vannevar Bush proposed in his paper "As we my think" (Bush, 1945), that all of a person's media throughout a lifetime can be captured with stereo cameras mounted on eyeglasses, and a system called "Memex". The Memex system could potentially store an individual's lifetime media, including all of his or her books, records, and communications such as letters. It could also support full-text search, annotations and hyperlinks to enable easy access and transmission of professional knowledge. Current technologies for media-capture, storage, sensor and computing have progressed to a point which is already beyond Bush's vision, where nearly all of what a person sees or hears can be captured and stored digitally.

2.2.2 Early researches of lifelogging

2.2.2.1 *Pioneers of wearable computing devices for lifelogs*

Early research on lifelogging started in the 1980s, with pioneers such as Steve Mann (Mann, 2004) and Kiyoharu Aizawa (Aizawa, Tancharoen, Kawasaki, & Yamasaki, 2004) concentrating on making ever-smaller recording devices with increasing battery capacity. Most of this research was in the hardware domain, and focused on "copying" the visual world that one sees.

Steve Mann was described as "the world's first cyborg" and inventor of wearable computers. One of the wearable computer devices he built was the Cyborg "Eyetap". It is worn in front of an eye of the user and acts as both a camera to capture the world around the eye and as a display to show the user captured images and augmented information (Mann, 2004). Figure 2.1 shows the evolution of Mann's lifelogging (wearable computing) devices in the 1980s and 1990s.

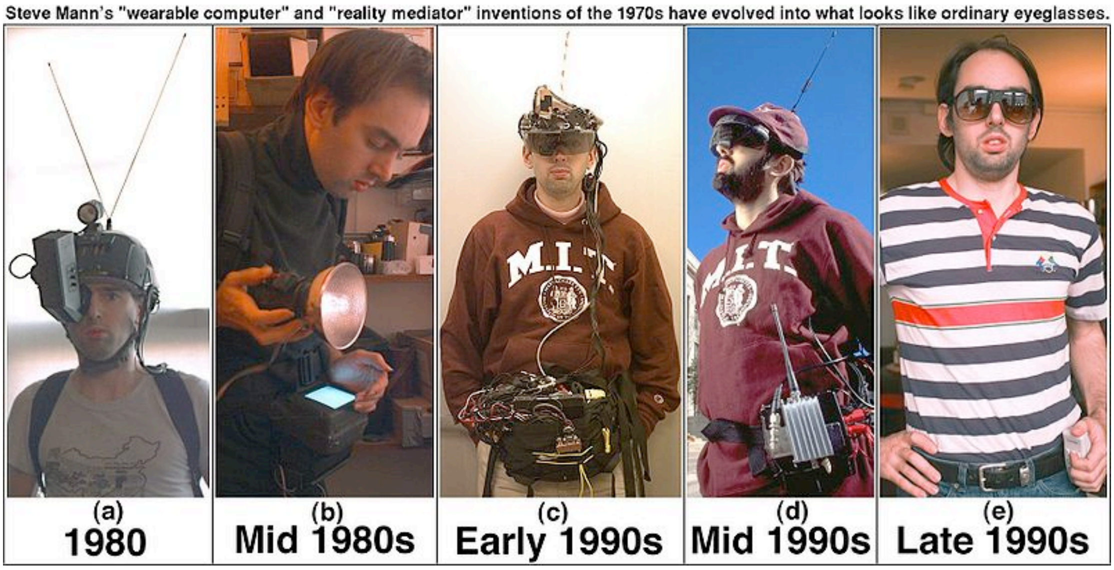

Figure 2.1 The evolution of wearable lifelogging devices by Steve Mann

In addition to visual information, later researchers such as Kiyoharu Aizawa also tried to capture diverse types of "context" information, which were primarily used as a type of metadata for information retrieval purpose. Another example is Cathal Gurrin, who has collected visual lifelogs using a Microsoft SenseCam for more than 6 years up to the time of writing this thesis and various other information from his life. His data has been used to conduct various research studies, such as health and memory (e.g., Doherty et. al., 2012).

2.2.2.2 *Mylifebits and "Total recall"*

The Mylifebits project at Microsoft Research fulfilled much of Bush's vision (Bush, 1945) of capturing, storing and indexing documents and even other types of information in the physical world. As one of the pioneering lifeloggers, Gordon Bell has explored the topic of "e-memories" and "Total Recall" technologies related to his own experiences of digitizing his life (Bell, et.al., 2010) . His lifelogging has two stages:

1) **Paperless office—collections of electronic files**

Bell started his lifelogging by digitalizing all his paper documents (book, papers), to create a "paperless office". He was inspired by the advantages of digital documents over paper documents. For example, digital copies can save much physical space and are much easier to organize and find via searching. He decided to go beyond the office, and "digitalize" his memorabilia, such as his collections of mugs and eagle sculptures. One of his important reasons for digitizing these items is to keep pleasant "remembrances" of his valuable collections in case the original physical objects are destroyed or gone. At this stage, his main purpose for "lifelogging" was to "digitalize" physical objects to preserve them and make it easier for information management, and his lifelog is no more than an extended personal information archive with scanned copies of physical objects.

2) Passive capture of the dynamic physical world

As capturing technologies develop, Bell started to collect more real-time data related to his daily activities, e.g. what he sees (with Microsoft SenseCam), where he is (with GPS). At this stage, his lifelog went beyond digital copies of objects he owned, and become digital collections of records for his life experiences. Bell initially tried to categorize this data manually, but had difficulty not only in categorizing information but also in finding information in these categories (directories) afterwards. The development of the early version of Windows desktop search[1] was inspired by Bell's need of search functions to cope with this problem, that is, to enable him to find items or information in his lifelog without the effort to categorizing them or remembering where he stored them.

Bell's example has the following implications for research in lifelogging:

1) Both the contents and potential applications of the lifelog are evolving with usage over time and benefitting from development of technologies.
2) Lifelog research can create new user needs and potentially bring in new technologies. For example, Bell had the need of a search tool to find things in his ever-increasing digital collection, and this led to the requirement of developing a desktop search system, which is installed on Microsoft Windows systems and used by millions of people.

2.2.3 Current research on lifelogging

2.2.3.1 *Visual lifelogs*

Current research effort on lifelogging continues to improve the electronic recording of what people see or hear in the physical world. The data gathered from lifelogging usually includes images, video clips, and audios. The Microsoft SenseCam[2] (now called Vicon Revue) is one of

[1]http://en.wikipedia.org/wiki/Windows_Desktop_Search

[2]http://en.wikipedia.org/wiki/Microsoft_SenseCam

the passive visual capturing devices used by lifeloggers. It can automatically take photos at a pre-set time interval (a minimum of 5 seconds depends on the processing speed) or when the environment changes (triggered via built-in sensors e.g. change of light status, or when a human approaches). Images captured by SenseCams have been demonstrated to be very helpful in supporting people's memory by providing good memory cues to trigger episodic memory (e.g.(Sellen et al., 2007)), even for people with severe episodic memory problems (e.g.(Berry et al., 2007)). Visual lifelogs like this have mainly been used to assist the quality of life of elderly people or for people with memory problems (amnesia) to recall or re-build memory of their recent experiences.

2.2.3.2 ***Logging the context***

Context information such as location has also captured by many lifelog researchers, together with visual data, to annotate the photos or videos and make sense of them. In fact, the context data is so useful that many of the consumer digital cameras nowadays have the built-in Geo-tagging function. Many smart phones manufacturers have also equipped their products with a GPS or assisted-GPS module. Real-time detection of context is also helpful in discovering user needs, in order to provide instant appropriate feedback or support. This type of application and techniques has been discussed extensively in the ubiquitous computing literature (e.g. (Harter et al, 1999; Schilit et al, 1994)).

2.2.3.3 ***Desktop logs***

The personal computer has become an increasingly popular platform that users spend increasing amount of time interacting with and using which they acquire large amounts of information on a daily basis. Therefore, a "total capture" type lifelog should include information that a lifelogger receives and exchanges on his or her computing devices, as well as their interaction with these devices and corresponding digital items. While desktop lifelogs are usually neglected in mainstream lifelog research, much related work has been done in the personal information management (PIM) and human computer interaction areas. Most current research in the area aims to help people get better organized in their work settings and to improve their work efficiency. Examples of this type of application include desktop search or personal information management systems (e.g. Google desktop, email clients), and desktop task detection or support systems such as TaskTracer (Dragunov et al., 2005) and others (e.g. (Bardram et al, 2006; Shen, Li, Dietterich, & Herlocker, 2006)).

2.2.3.4 ***Data mining of lifelog data***

Many researchers have noticed the problems of effectively utilizing the massive amount of less-structured data in lifelogs, and have tried to filter the data through various grouping or clustering methods for better visualization. For example, PIM researchers have built prototype systems for people to manage and search information items in their personal desktop data collection. In the domain of lifelog research, a lot of effort has been made to group passively captured images into an "event" unit (e.g. (Doherty & Smeaton, 2008)). Further data mining of these unit events has also been explored. For example, researchers have tried to detect the themes of events, and show the pattern of a lifelogger's life style (Byrne, et. al, 2010)). I believe that a better understanding of the information needs relating to PLLs, that is, what people want from their lifelogs, could guide the research of corresponding techniques, including data capture and multimedia or textual content processing techniques.

2.3 **Applications of lifelogging**

While most of early studies of lifelogging focused on improving capture, less effort has been spent to exploit lifelog data that has been collected, to benefit people's lives. This section reviews some possible applications of lifelogs, and discusses that the information people may need to retrieve from their PLLs.

So far, lifelogging data has been used in several domains, such as marketing (e.g., Hughes et. al, 2012), physical well-being (e.g., Doherty, 2012), and mental health, in particular, supporting the episodic memory of the data owners (lifeloggers). Digital records such as photos may help people to reminisce about their past experiences more vividly, as supported by several studies such as (Berry et al., 2007; Sellen et al., 2007), or to help people recall specific activities, e.g. where they left their keys or a document. Currently, the most well explored application of lifelogging techniques is to use streams of passively captured first-person perspective photos to support mentally impaired people, specifically for people who have severe mnemonic problems (Berry et al., 2007). Yet, the use of PLLs as memory cues has not expanded to other potential applications, such as helping normal people with their daily tasks. Some of the few new applications which have been explored include: re-telling life stories (Byrne & Jones, 2008; Harper et al., 2008; Helmes, Hummels, & Sellen, 2009), and summarizing life patterns to assist human well-being (e.g. (Kelly et al., 2011)). I believe there can be many more potential applications.

This section briefly reviews the applications of PLLs proposed by experts from the computer science and psychology communities (section 2.3.1), discusses potential applications that are inspired by basic human needs (section 2.3.2), related work on physical mementos (section 2.3.3.1), and suggestions from the general public collected from an online survey (section 2.3.3.2).

2.3.1 Proposed applications from the experts

Applications that have been proposed by experts to utilise lifelogs have been suggested to have a number of functions summarised as follows.

Sellen and Whittaker (2010) suggested five functions that lifelogs can potentially support, mainly from the lifeloggers' perspective, and referred to as the 5 'R's:

1) *Recollecting*: recalling specific experiences or pieces of information encountered in the past.
2) *Reminiscing*: to help users re-live past experiences (recalling) for emotional or sentimental reasons. They suggest that people may reminisce by themselves or socially in groups, by watching videos and flipping through photo albums with friends and family.
3) *Retrieving*: retrieving digital items or information that has been encountered over the years (such as created documents, received email, and visited web pages) for re-use.
4) *Reflecting*: they suggest that Lifelogs might support "a more abstract representation of personal data to facilitate reflection on, and reviewing of, past experience". For example, it could present summary data for users to examine patterns of past experiences (such as about one's behaviour over time). They suggested that the value of reflecting is not about memory per se, but learning about self-identity.
5) *Remembering intentions:* helping people to remember prospective events in one's life ("prospective memory"), as opposed to the things that have happened in the past. Examples include remembering to show up for appointments.

The first three functions can be considered as different forms of *memory supports*. The *retrieving* function corresponds to what Spärck Jones called "deposit", that is, storing currently less important stuff for potential later use.

Spärck Jones suggested five possible applications of PLLs (as summarized in (O'Hara et al., 2006)):

1) *"Super me":* using digital records of a person's history to amplify one's memory. It is similar to the "recall" or "recollection" function suggested by Sellen and Whittaker (2010).
2) *"Deposit":* capturing and storing of currently less important stuff for future use. The "retrieval" function suggested by Sellen and Whittaker (2010) is the key to realizing the value of the deposit.
3) *"Persona":* enabling lifeloggers to present and share their lifelog data with others on their own initiative.
4) *"Assembly":* referring to having certain aspect of one's lifelog being used by someone else, e.g. a doctor's medical record of me.
5) *"Collective":* different individuals sharing their lifelog records in social networks.

These applications include usage of lifelogs not only by the lifeloggers themselves, but also by others. In particular, "assembly" concerns the use of lifelog data that is not under the control of "lifelogger". Of course, this function of a lifelog can potentially be useful in a wide range of domains. For example, E-commerce companies or commercial search engines can provide recommendation to a person through machine learning of the person's previous personal activities in similar contexts; automated marketing research can also be conducted from multiple individual's lifelog data through image analysing (Hughes et. al, 2012); monitoring and assist healthier living (Doherty, 2013). Although experts usually have a better outlook than people who are not familiar with the frontiers of technologies, experts' ideas may not cover all the potential applications of lifelogs. For this reason, I decided to expand lifelog applications from two additional aspects: 1) a theoretical exploration from the perspective of human's needs to discuss the applications that lifelogs could potentially offer to meets these general human needs, and 2) empirical studies to explore desired information that the general public may want from their "lifelogs".

2.3.2 Implications from human needs

Firstly, I try the top-down approach to imply the potential function that lifelogs could offer from models of general human needs. One of the most popular models of human needs was proposed by Maslow (1970). In his model, there are five hierarchical levels of needs, including: 1) physical needs, e.g. food, water which we need to survive, 2) safety, 3) love and belonging, e.g. family, friends, intimacy, 4) esteem, that is, to be respected and to have self-esteem and self-respect, 5) and finally, self-actualization, that is, to realize a person's full potential. The first three levels of needs are called "Deficiency needs" or D-needs, meaning that these are needs that arise due to the lack of something which human nature requires, the deprivation of these things makes the person uncomfortable or unhealthy. Esteem and self-actualization belong to a higher-level category, which they call "Being-needs" (B-needs) or "growth-needs", which stem from a desire to grow as a "person" rather than the lack of something. Max-Neef (1992) classifies the fundamental human needs as: subsistence, protection, affection, understanding, participation, recreation (in the sense of leisure, time to reflect, or idleness), creation, identity and freedom.

The question is: how PLLs can be used to support these basic human needs? Of course, PLLs cannot serve all the basic human needs, e.g., providing food. However, some content in PLLs can be used to support higher-level needs, e.g. subjective well-being (SWB). SWB is the sensation of satisfaction in life, and is sometimes labelled as "happiness". People tend to experience abundant SWB when they feel (remember) having more pleasant experiences in contrary to unpleasant ones, when they are engaged in activities that are interesting to them (Diener, 2000). To bring higher subjective satisfaction of life, PLLs could present users with more information that reminds them of pleasant experiences, or things they are interested in looking at. Similarly, positive information could also be provided to help people reinforce the memory of experiences of which they feel self–esteem or self-actualization. As for *safety needs*, lifelogs are like a double-sided blade: lifelogging provides a means of storing all encountered information even when the memory of it is lost; however, the capture and storage of unwanted information, shameful or unpleasant incidents from the past makes one worry about the leaking of this data, and may bring them negative emotions.

2.3.3 What do general public want from lifelogs?

Up to this point, I have only reviewed the opinions of some experts and made inferences from basic human needs. I believe that an exploration from a wider population, that is, the general public, can provide us with more detail and potentially interesting applications of PLLs that might not otherwise be suggested. The following sections give a summary of findings from two studies: an exploration of user needs from physical mementos, and an online survey, which required participants to imagine the potential needs from PLLs after the concepts and possibilities of PLLs had been introduced to them.

2.3.3.1 ***Implications from Physical mementos***

Although not many people store their memory in digital PLLs, numerous people attach their memories to physical objects, such as photos and souvenirs. These physical objects, which are attached to their memory can be called *mementos*. I believe that the user's needs from their physical collections can at least partially, reflect their potential needs from personal lifelogs. Petrelli and colleagues (2008; 2009) conducted a series of experiments that investigated the types of things that people want to keep and the applications they want from physical mementos. The participants of one experiment (10 families) were required to pick items in their homes to store in a plastic box called a "time capsule" to trigger their memory in the remote future, and asked to report the reasons for keeping these items. They found that the objects people choose to store are usually what could reflect experiences about oneself, about certain people, events or places, and things reflecting contemporary features, so that they can compare them with things they encounter in the future. The participants' reasons for keeping these items include:

- certain objects recorded aspects of one's life;
- items may help reminiscing (e.g. for nostalgia or for fun), contain unique characteristics of the time that could distinguish them from the future;
- items that preserve value or bear special meanings to the owner (because they are valuable or embedded with great personal meaning).

Due to the way that the examiners proposed the questions, participants may have biased their selection of 'mementos' towards physical objects. For example, since "time capsule" is a physical entity, digital items are less convenient to be stored and used in it. If one wants to preserve an email, one may need to print it out on paper, or store it in a USB key and plug the key into a computer to view the email. Compared to this, a physical object such as pen can be stored directly in the capsule and is directly tangible. Thus, while interesting, the results from these studies are not directly applicable to electronic lifelogs because of the difference between objects in the physical world and those in the digital world. Besides, since physical storage ("time capsule") only has limited space, their participants are unlikely to select and store all the potentially interesting items. I believe that a direct exploration of electronic lifelogs can provide further guidance to developing lifelogging systems.

2.3.3.2 *Opinions from general public for personal lifelogs*

In an online questionnaire conducted in 2009 (Chen & Jones, 2012), the authors explored the types of information that people want to record and to be provided with by a lifelog management system. This study recruited 414 participants mainly from the questionnaire hosting website which paid the participants credits. The participants included 182 males and 232 females, with age varying from 15-50 (73.8% in the age range of 20-30). Since none of them had ever carried out any lifelogging, it was difficult to ask people to answer questions based on their imagination of technologies that do not currently exist or that they may not even have heard of previously. It was also difficult to provide the right amount of information, so that participants could generate feasible suggestions. In order to avoid the biasing and restricting the participants' imagination of potential functions of PLLs, the questions in this questionnaire were carefully designed to gradually explain the idea of lifelogging without giving too much information to the participants. For example, the questionnaire started by asking each participant to recall (instead of imagine) any physical objects or memory they wished had been captured in the past 10 years of their life, and why they wished that these things had been captured. In the next stage, the questionnaire provided the participants with some options to vote for their preferred capturing methods and applications of the captured data, followed by an open-ended question asking for more ideas. Finally, a prototype system that provides functions to retrieve digitised items in one's lifelog was introduced to them and they were asked to provide further suggestions of applications or functions. For more details of the questionnaire, please refer to the (Chen & Jones, 2012).

Many of the functions and applications that are suggested by these participants were similar to what I discussed earlier in section 2.3.1. For example, many participants wanted to "backup" information or "memory" in case they wished to use it in the future or use it as evidence. Interestingly, quite a few participants mentioned that they wish to record their thoughts and motivations.

Consistent with the scenarios that experts had predicted (e.g. (O'Hara et al., 2006; Sellen & Whittaker, 2010)), the participants generally wanted to preserve happy or precious moments of life, similar to the findings of the physical memento study (see section 2.3.3.1), or for reminiscing (see section 2.3.1,2)). For example, they wanted to keep track of emotional, cheerful, funny or touching moments, when they were with loved ones, or when they were playing their favourite games. The purpose of reminiscing is usually casual and/or emotional, e.g. to re-enjoy a happy time, for fun ("laugh at my stupid stories in the past"). Some participants expected to leave out their unhappy emotions through reviewing events that had happened. Many participants mentioned that they wished that these moments could have been captured as "photos", and some participants wished that the voice of people speaking could have been recorded, as they believe that human language is more emotional. Some participants also wished their childhood or infanthood could have been captured so that they could see what they were like in times which they have little memory of. Some participants also expressed the wish to easily share some of their lifelog data, and to be able to pass their life experiences to their descendants. In my opinion, the function of generating stories is suitable for sharing life experience among generations.

Some participants wanted to see their relatively recent past. Instead of reminiscing or watching for fun, they were interested in knowing how they had become what they are now, or how they developed certain behaviour. Supporting wellbeing and being better organized were also a desired function for some participants, e.g. "help me understand what I did and how I spent my time online", "how I put on weight", "how I spend my money", "how many calories I consumed today", etc.

One interesting finding is that some people intend to make electronic records unique by "stamping" them. For example, they wished that timestamps and context such as location could be captured.

2.3.4 **Section Summary: Potential application of PLLs**

To summarize the opinions of experts and the general public, there are at least the following potential functions that lifelogs should support:

1) Reminiscing

Support for reminiscing is one of most frequently mentioned functions of lifelogs. Events that people might be reminisce about included: moments, specific episodes (e.g. a party, a sport match), a series of events related to certain aspects of a person's life (e.g. the development of a relationship and thereafter), or any events which have certain properties, e.g. happiness, events with a certain person, events in certain places. In order to cater for the needs of reminiscing, an information system should have the ability to show users "moments", "events", or a series or group of "moments" or "events" based on targeted properties, e.g. emotions and the people in present in the event.

2) Recollecting

As suggested by Sellen and Whittaker (2010) and the findings in our survey (Chen & Jones, 2012), people also want to "backup" the past, in the case of "I forget it". In this requirement, people usually want to recollect a fact or a facet of an event (e.g. the date) that they used to know. Usually, if the fact is recordable (e.g. if it is visually presented or could be captured electronically), the exact fact could be retrieved. For example, the numbers that a person saw on a notice board or a sound that they heard. Sometimes ideas themselves may not be easily recorded (e.g. one's thoughts or intentions). In such cases, relevant information could be presented as *memory cues,* to help lifeloggers recollect the ideas from their long-term memory (more details of memory are given in Chapter 4). To support the reminiscing functions, it is worth spending effort not only on the technical side, but also in psychological research to explore the types of information that could be representative and remindful for triggering "memories".

3) Retrieval and Re-using

One important function of lifelogs is to act as a personal information archive which stores the electronic items that one has encountered or used before. In this case, information systems of lifelogs should present the users with individual electronic items, e.g. files, or information embedded in the electronic items, e.g. phone number (information) of a person that was mentioned in an email (item).

4) Learning and reflecting

Lifelogs can be used to learn about the lifelog him or herself. This function should provide information such as a summary or pattern of certain aspects of a person's life (during a certain period of time). Information in lifelogs may need to be presented at different levels of detail and be structured in various ways for people to learn about multiple sides of the behaviour. For example, if one just wants to know how he spent his time in the last week or how his weight has changed over the last couple of years, he may not want to view detailed stories, but rather some relevant statistics.

5) Storytelling

The storytelling function is both important for people to learn about themselves and to share their experiences with others. Examples of the former case include the story of "how I grew up", "how I came to the world", "things that happened when I was an infant". The latter case could include stories ranging from recent holidays, to one's entire childhood or life. It could let one's child know "what was my father's life like before I was born" or allow descendants to learn about the life of their forefathers. Ideally, the stories could be automatically generated to cater for requirements of different types of audience. Multiple types of information or structures may be needed to implement these ideas.

6) Reminding

This function is similar to what Sellen & Whittaker (2010) describe as "remembering intentions". It does not just record what one plans to do, and give alarms when the time comes, but can also be used as reminders of intermediate or long term goals. According to one of the participants in the survey (Chen & Jones, 2012), it would be easier for him to find what else is left for him to do by knowing what he has done.

In short, a lifelogger can use his or her lifelog data for at least six functions. This thesis focuses on the first three functions: reminiscing, recalling, and retrieving electronic items for re-use. To support these functions, a lifelog system should be able to provide users with information or items, and "moments" or "events", as well as items or information that act as memory cues for reminiscing. In order to be able to provide these functions, essential data should have been captured and stored, and the system should be able to identify which data is appropriate for the user's current needs.

2.4 Implications for lifelogging techniques

2.4.1 What to capture?

In order to realize the functions described above, some types of data are essential to be captured in a lifelog. These data should include as much information as possible that one "receives" as a "backup" to support a recollection function. This section lists the types of information that should be captured and explains their importance.

1) Visual: The majority of individuals receive information with their eyes. Therefore it is important that encountered visual information should be captured. Ideally, the captured visual information should be as close to what the lifelogger saw as possible.

2) *Voice:* Audio information, in particular conversations, is another important source of our information input. However, audio recording in lifelogging has been argued is controversial with surrounding people finding it to intrusive. In the online survey mentioned in section

2.3.3.2, several participants claimed that they would never record voice, though some others were fond of original voice recordings as they evoke vivid emotional memories. I suggest that voice recording should be selectively when it might be important for the event and participants are comfortable with recording taking place.

3) *Texts:* Nowadays, since people communicate more and more via digital messages (email, instant message, text message), an increasing portion of the information, which used to come from vocal conversations, now comes from these digital sources. People communicate and transfer information in the form of plain text, not only during online chatting, but also through reading and posting (e.g. blogging, tweeting). Textual data is not only an important part of the information in everyday life, but also light and easy to manipulate. It can be used to narrate events and represent computer activities to trigger related episodic memory, e.g. (Lamming & Flynn, 1994) .

4) *Original or copies of electronic item:* To act as a deposit and provide retrieval function, it is essential that the queried electronic items or copies of them should be captured, and that copies of original files can be opened and viewed in the same way as the original file. For example, storing the filename and metadata of an executable file or a multimedia file is almost useless for the "re-use" function.

5) *Context*: Contextual information such as location and the people present are important memory cues for events, and they should be captured to support the retrieval and recollection of the information, as well as to help users identify the events. They can also be utilized to annotate or index events for later selective retrieval. For example, if a user wants to find events that he/she participated in Dublin, the function of searching or filtering events with location would be very helpful.

6) *Timestamps*: Time is an important attribute of activities. Timestamps can also be used to manage massive unstructured data collections into orderly and meaningful entities such as episodes, activities or events. For example, one may want to see not only the image taken during an event, but also the conversations, the exact name of location, who was there, what happened shortly before it, etc. Organizing data by timestamps can allow people to review all the related information easily in a timely order. For this reason, all the data in lifelogs should be time-stamped.

7) *Others:* There are other types of information which may also be useful in supporting undiscovered functions. For example, biometric measurements could be used to record a person's physiological status which can be used to estimate exercise taken and calories consumed, health condition, arousal level, and reflect a person's mood. Evidence has been found that the skin conductance, heart rate and facial expressions could reflect a person's emotion, e.g. (Damasio, et. al, 1996).

Of course, these are only some of the types of information that can be in included in lifelogs. New technologies are becoming available almost every day, and some of them may bring new lifelogging methods, and create other user needs.

2.4.2 Requirements for a lifelog information system

Since the major portion of a lifelog collection is archived data, I aim to explore applications of this type of data, and focus on supporting the following functions:

1) Recollecting: helping people to recall specific information, and details of information encountered or experienced in the past, e.g. the date of an event.
2) Reminiscing: enabling users (lifeloggers) to reminisce about events which happened during the lifelogging period.
3) Retrieval and Re-use: as an archive, one of the most important functions is to store infrequently used pieces of information items so that they are available for potential needs in the future. Therefore, the system should allow users to easily find and open items in their "deposit".
4) Learning and reflecting: this function could be regarded as a by-product of Retrieval and Re-use. When accessing lifelog data, as the user is browsing events and detail information, he/she may also encounter some captured scenes or data that he/she was not able to remember or had no recollection of. These things may include details that one did not attend to (e.g. perhaps one was not interested in that type of thing when encountering them previously, but is interested in them now), or things that were presented in another way that the user had never seen or thought of before (e.g. different ways of summarizing the user's life patterns).

To support these functions, a lifelog information system should be able to provide users with: i) events, ii) facts about events (such as date, location, and other types of information), iii) electronic-native items (such as watched videos, documents, software), and iv) patterns in life during certain periods of time for people to reflect on. Ideally, an intelligent lifelog information system could detect a person's needs automatically and promptly present relevant information to him or her automatically. Yet, of course, even with the rapid development of context-aware, ubiquitous computing techniques and research in recommendation systems, it is still far from possible for an information system to understand a users' mind accurately, unless, the needs are explicitly given to the information system, in a 'language' it understands. For example, if the system provides a search function (e.g. like Google) for users to communicate with it, users can tell the machine what they want by filling in the search fields, e.g. date: 2008-10-05. Of course, users may not always know the answers to each of the search fields, and a communication problem occurs. The next chapter moves on to explore how people interact with information systems. Based on an understanding of users' information behaviour, I will discuss how to cope with the problems that people might encounter when looking for relevant information in their own PLLs.

Chapter 3
Information Seeking and Refinding

As discussed in Chapter 2, a personal lifelog (PLL) can potentially enable a person to "re-live" their past through reminiscing or recollecting information that he or she has forgotten, to learn about him or herself by re-examining their past, and to store things that are currently less useful away for retrieval when they are needed in the future. In order to support these functions, a PLL system should be able to provide users with required information in appropriate forms, e.g. evocable items for reminiscing or recollecting, and electronic files for re-use. To develop a system which can make it easier for users to acquire or find information to serve various purposes, it is essential to understand how people interact with information systems, the problems they tend to have while looking for information and their requirements for the functions to be supported by information systems. Since few systems are currently available for people to access their PLLs, (in fact, few people have ever had a long term PLL collection to use), I could not start with empirical studies to explore these question from real users of existing PLL systems. However, I believe that information finding behaviours in PLL should share some common principles with other information finding behaviours. Therefore, a better understanding of information finding behaviours in general can help us to find some answers to the above questions specifically for lifelogs.

This chapter reviews information seeking behaviour in electronic environments, as well as well finding and refinding in Personal Information Spaces (PISs). I also propose a framework to predict how people will tend to find their information in PLL according to different types of tasks and their knowledge.

3.1 Some concepts related to this chapter

Before I start discussing information behaviour, I first introduce some concepts that are important for understanding the rest of this chapter.

3.1.1 Information

First of all, a clear definition of the concept of "information" itself is needed. There have been several definitions of "information". Much of the traditional literature considers information to be a "process" or media for transferring knowledge, e.g. (Ingwersen, 1996). Information has also been defined as "any informatics *things*", which includes: data (records or files stored in a computer), documents (e.g., text-bearing objects, images, sounds), objects (e.g., things in the physical world and their electronic representations of references, e.g. a person, a building, a film, a photo), and even events since people can also learn from them (Buckland, 1991). However, according to the DIKW (data-information-knowledge-wisdom) hierarchy (e.g. (Alavi & Leidner, 2001; Zins, 2007)), information is different from data or knowledge. *Data*, at the lowest level, refers to meaningless digits, signals and symbols, or simply, units of facts. Information is the meaning inferred from processed, structured and organized data, while knowledge is the information when processed in the mind. In this sense, information can also be defined as the explicit symbolic presentation of knowledge. The DIKW model perfectly fits into the cognitive model of information processing, that the sensors in a person's eyes, ears and skins receive stimuli (square, cold, etc.) and transform them into neuron signals which are decoded and processed by higher level structures and give the human being a "perception" of the information (e.g. an ice cube). As the perceived information accumulates, meanings can be extracted from them and stored or used as the person's "knowledge", more details of this cognitive process are described in Chapter 4. In the context of this thesis, I define information as:

Any informative things a person can seek for, including data, files, objects, electronic resources, events, and any temporary knowledge acquired (inferred, extracted, or perceived) from the data.

3.1.2 **Personal information**

According to Jones and Teevan (2007), there are four types of personal information items:

1) Information items that a person keeps, and are under the person's control;
2) Information about a person, but is not kept or under control of the person, e.g. health records, bank statements;
3) Information experienced by a person, but may not necessarily be under the person's control, e.g. books one reads in the library;
4) Information received by a person, e.g. emails. The information itself may not be of personal interest.

We categorize personal information on two dimensions: 1) ownership, that is, if it is owned and under control of the person, and 2) past encounters, that is, how much of it has been experienced by the person. The first dimension is useful from the technical or user interaction perspective in determining how the information can be re-accessed. The second dimension is important for discussing the involvement of a user's memory when retrieving the information. Each dimension can have many levels. Table 3-1 shows some examples of personal information that belongs to each of level on the two dimensions.

We define the levels of ownership or control as the extent to which the user can manage the item, e.g. move it to another place, access it, or even delete it. Partial control is that the user can control only part of the information. For example, they can edit their web browsing history or favourites list, that is, the links to the information objects, but they are unlikely to be able to change the items (web pages) themselves. For items that are out of the user's control, one example is a person's police records, which are held by the police or revenue commissioners. Therefore one can only query for information from them indirectly without the ability to make any changes.

Table 3-1 Examples for different types of personal information

	Directly experienced	In-directly experienced	Not experienced
Fully controlled	Created or used files, emails, web pages, local digital copies of online articles or photocopy of borrowed books	Passive captured information, e.g. SenseCam images, Location names	e.g. received emails which has never been read. Applications or files pre-installed, but never used by the person,
Partially under control	Online playlist, e.g. favourites of YouTube videos	Facebook Photos of a person, taken and posted by others	Health records
Not under control	Visited online articles which were not stored locally, books in library, information on a notice board	Bank statement	Police records

The experience level describes how much and how directly the user has previously been exposed to the information itself. "Directly experienced" refers to the situation where users have visited or edited the digital object themselves, e.g. the documents one has read, a web page one has visited. "In-directly experienced" information contains content or represents the data that a person has experienced, but the information itself has not been exposed to the person. For this type of information, the data owner can only infer the possible content of the digital items, but may not know what exactly the digital item contains. Examples of this situation include passively captured images from a first-person perspective, and video or audio records of a person, given that these records have not been viewed or played by the person. Further down the line of experience levels, there are items which the person has not experienced at all, but that either belong to the person or are about certain aspects of the person's life. Examples of this level include received but unread emails, files or applications that pre-exist on a person's digital devices, but were never used by the person, and a person's health records, which contain a person's health information which the data owner may never have had the chance to view.

In the context of lifelogging, all these types of information can be included. However, only those under control can be kept and managed by the lifeloggers and personal lifelogging information systems. For example, the PLL can record a user activity of watching an online video (e.g. on YouTube), including the URL of the video, but the lifelogger, if he has no administration right of the video, cannot remove or edit the video, nor can he guarantee that the video is still there when he wants to watch it again. In this sense, a PLL cannot store everything a person encounters to enable the lifeloggers to see or use it again if the external information space changes.

In conclusion, in the context of this thesis, I define personal information as:

Personal information is any information that belongs to a person or is related to the person's past experiences, including all the information that the person possesses and/or with which they have interacted.

3.1.3 **Temporal dimension of personal information and PLLs**

Barreau (1995) described three types of electronic personal information in working space:

- *Ephemeral information* has a short shelf life and includes items such as recent electronic mail messages, "to do" lists, note pads, memos, calendars. According to Barreau's (1995) view, *ephemeral information* is about what has just been done, what one is working on, and what one will do shortly afterwards.
- *Working information* is frequently-used information that is relevant to the user's current work needs and that has a shelf life of weeks or months. Examples include files related to a current project.
- *Archived information* can have a shelf life of months or years, but is only indirectly relevant to the user's current life and work, and is infrequently accessed. Most archived information represents completed work.

As one type of PIS, information in lifelogs can also contain data in different temporal categories. Unlike most of the data in a traditional PIS, such as documents that one has created or received in their workspace, most data in lifelogs is passively captured. This means that much of it may have not been seen or used by the lifelogger. Most data is archived straight away, waiting to come to the surface someday in the future. Of course, a small portion of the data is captured recently, and is still related and useful for the owner's current work and life.

3.1.4 Information behaviour

Information behaviour refers to actions taken to interact with information, including defining of information needs, finding and using or transferring of information (Wilson, 1999). *Information seeking* is the activity of attempting to obtain information from both physical and digital resources. There are several terms regarding information behaviour which have multiple definitions. For example, the terms *information search* and *information retrieval (IR)* are usually used interchangeably, to describe a unit activity of using information retrieval systems to find a specific piece of information. It is generally regarded as a micro step of an information seeking behaviour (Wilson, 1999). However, information search has also been used as an alias for information seeking in some literature (e.g. (Kuhlthau, 1991; Kuhlthau, 2004)). To avoid ambiguity, I use the term "information search" to describe the activity of searching in an information retrieval system with queries, and use "information retrieval" (IR) to describe the computing side process which fetches information from an electronic information system using an IR algorithm. Since one can take multiple approaches in finding specific information, I use the term *information finding* (IF) to refer to the activity of looking for information from within an electronic environment, regardless of the approach. In the rest of this chapter, I use "information seeker" (ISKer) to refer to people who look for information in either a digital or physical environment, "information searcher" (ISer) for people who look for information in the digital world when the information channel is undefined, and the term "users" to refer to people who seek for information in specific information systems.

Refinding is the action of finding information that has been encountered before. It is different from other types of IF tasks with regard to the types of targets and the involvement of memory (Capra, et. al., 2005). Refinding is actually a predominant (although not the only) type of IF task in PISs, since most of the targets are what the user has already encountered directly or indirectly, looking for any of these items is a refinding task. Of course, there can be a considerable amount of information that was not exposed to the person previously. For example, finding information in emails which a person received but has never read is not a refinding task. Besides, even if the target information is something a person has encountered before, the ISKer can turn to other sources to find a solution. For example, when looking for example source code which was seen previously to solve a programming problem, the ISKer may try to find the exact piece of code that they encountered, but they may also search on Google for any piece of example code that serves the same function. This task is a refinding task only if they choose the former approach.

Accessing one's PLL is a case of information behaviour. It includes the seeking or finding of information in it and use of the information found. Since a PLL can contain content that has been viewed or has not been viewed by the lifelogger (who can also be called "user" when they are interacting with the lifelog data afterwards), finding in lifelogs is not necessarily a refinding behaviour. The relations of the information behaviours introduced above are depicted diagrammatically in Figure 3.1

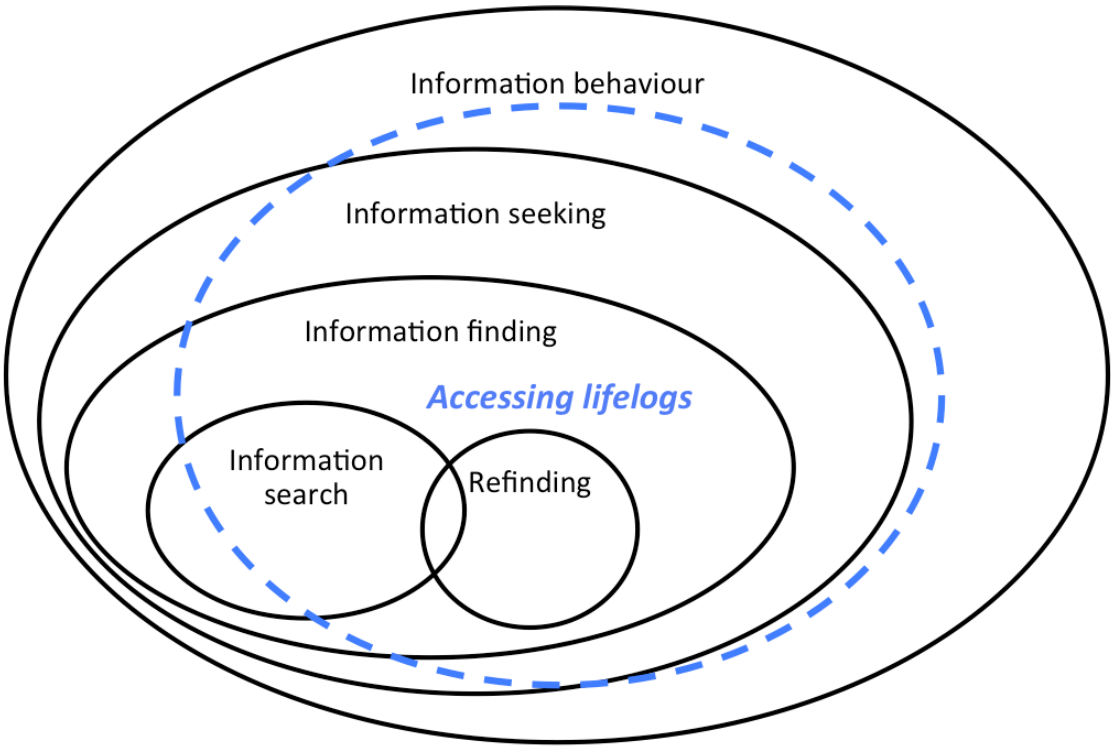

Figure 3.1 Relationship of information behaviours

3.1.5 Information needs, target, and relevance

Information needs refer to the gap between the ISKer's knowledge about a problem or topic, and what he or she needs to know in order to solve the problem (Ingwersen & Järvelin, 2005). *Information targets* are pieces of information or sources of information (e.g. a document which contains such information) that can satisfy the user's information needs. The targets can be either an open answer (anything related to the topic) or closed (look up a specific piece of information, e.g. opening hours, look up a specific item, e.g. a specific file). *Relevance* is the assessment of "perceived topicality, pertinence, usefulness or utility, with reference to an information situation at a given point in time" (Cosijn & Ingwersen, 2000). It can change dynamically during a single IF task from the same ISKer.

3.2 Models of information behaviour

With an understanding of the concepts and definitions of terms related to information behaviour, we are almost ready to discuss how people might interact with the information in their PLLs and how their corresponding IF tasks can be supported. Unfortunately, there is little existing literature about information behaviour specifically in lifelogs. Although there have been many studies and several models describing how people find information in general electronic information spaces, such as the World Wide Web or electronic libraries, most of the information they looked for is unknown, that is, not related to the searchers past experiences. Therefore, the findings from these studies may not be fully applicable for tasks that require finding in lifelogs, which have their own special issues such as the involvement of the user's memory. Yet, I believe that accessing lifelogs shares many common features with the behaviour of information seeking from other electronic information spaces. This section reviews information behaviour models regarding how people look for information in the electronic world (in general), including findings from empirical studies of IF in traditional PISs, and discusses how these models and findings can be tailored to IF in PLLs.

3.2.1 Traditional information retrieval models

Traditional information search models describe the information finding process as an isolated sequence of actions, as illustrated in Figure 3.2. The information searcher (user), motivated by a need of certain information in the task that they are currently working on, expresses their need in a verbal form to transform it to a search query and send it to an IR system. The IR system finds the documents which best match with the query (text), and provides the user with some potential relevant documents. If no relevant item is found, the user can revise the wording of the IR query and send it to the search engine again.

Belkin (1993) pointed out that classic IR models have two fundamental assumptions which are not necessarily true:

1) A user has a single static information need in each search.

2) The most appropriate way to address this need is to *search* for the relevant item(s).

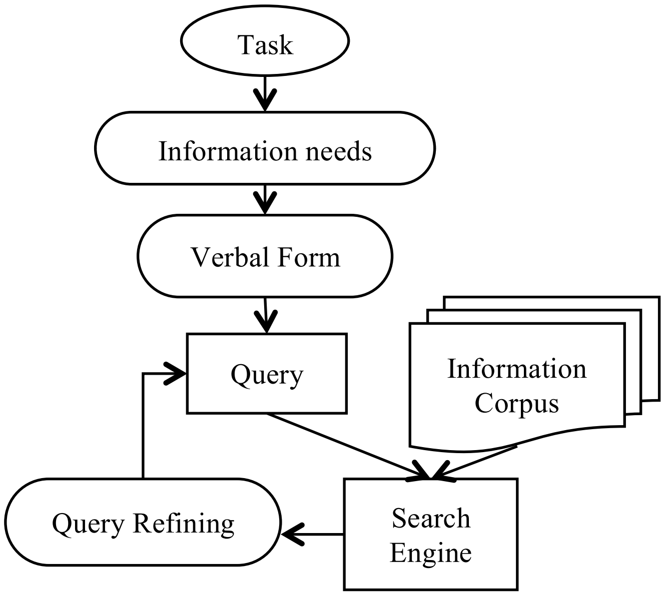

Figure 3.2 Classic information search model (Broder, 2002)

Therefore, most classic IR systems only provide support for a single form of information-finding behaviour, which is, using queries to search for some well-specified information items. Belkin suggested that it is desirable for IR systems to support the uncertainty or changeability of a user's information needs and search tasks. According to the berry picking model proposed by Bates (1989), the search query is satisfied not by a single final retrieved document set, but by a series of bits of information from each stage of an ever-modifying information need during the search process.

In short, information finding is usually a more complex and diverse process than that described by the traditional information search model. It is suggested that people's interaction with IR systems should be modelled as information seeking, e.g. (Belkin et al, 1982; Ingwersen, 1992). The following sections first review the literature on information seeking, in particular, how it is modelled as a problem solving process, so that I can apply these theories from the problem solving domain to information finding and refinding behaviour in PLLs. Then it explores the elements and factors that influence information finding behaviour in general, and discusses the approaches, potential problems users may encounter in the tasks and solutions for these problems.

3.2.2 **Information seeking and problem solving**

Information seeking has been considered as a special case of problem solving which is aimed at solving the "uncertainty" problem, e.g. (Belkin et al, 1982; Bystrom & Jarvelin, 1995; Dervin, 1992; T. D. Wilson, 1999), that is, the uncertainty of the target information or the information needs. It consists of a series of problem solving tasks, where information seeking itself is usually one step in solving a larger problem. According to Machionini (1997), information seeking is driven by the need for information so that a human can interact with the environment. In my opinion, information seeking is a reaction or strategy to deal with a problematic situation where resources are absent for solving the problem (task). Wilson considered information seeking as a series of problem solving tasks, including four stages (Wilson et. al., 2002): problem identification ("where do I have problems"), problem definition ("what the nature, what exactly is the problem"), problem resolution ("how can I solve this problem"), and problem statement ("this is the answer"). They believed that each stage could have an uncertainty problem to solve. The above literature suggests that an understanding of problem solving can provide a better guide for the understanding of information finding processes. The rest of this section reviews literature on problem solving, and applies corresponding theories to information seeking and finding tasks.

3.2.2.1 ***Problem Solving***

Problem solving usually starts with recognizing or finding that there is a problem. After a problem is recognized, one needs to define it, that is, to make clear the goal of the problem and represent it mentally, regarding its initial state (current state), goal state, allowable operators and a set of constraints. According to sense-making theories (Dervin, 1992), information seeking behaviour is aimed at closing the gap between the goal state and the outcome (current state). For example, people may feel unhappy or bored sometimes, but the feeling may not be recognized as a problem that needs to be solved. If they realized their unsettled mental status, and want to solve this problem, they may think of possible solutions based on their past experiences, e.g. how they coped with such a situation before, or a source from which they can learn about the solution.

There are *well-defined* problems and *ill-defined* problems. In a well-defined problem, all aspects of the problem, including the current states, the goal, and even the range of possible strategies are clearly specified. Therefore, the evaluation criteria are clear and straightforward. For example, deducting a variable's value from a mathematical equation is a well-defined problem. In contrast, ill-defined problems are underspecified. These problems may not have a single clear goal, or there may not be a fixed set of strategies to solve the problem. Most of our everyday problems are ill-defined problems, e.g. how to save time, how to look good, how to be rich. Ill-defined problems do not always have a set of fixed evaluation criteria. These three steps are interactive rather than discrete and sequential. For example, change in the presentation of a problem may lead to a change of its definition. This indicates that the knowledge of potential approaches and constraints can change the goals.

In developing solution strategies, people usually need to allocate their mental and physical recourses to plan and organize a set of steps to form a workable strategy to solve the problem. When there are not adequate resources available, people usually seek the missing resources, or try other strategies based on the knowledge and resources that they do have, e.g. if a person lacks knowledge in dealing with the problem, he would seek information to bridge the gap in knowledge and the problem situation. When there is more than one potentially feasible strategy for solving a problem, one needs to make a choice. This selecting step is also called decision-making. There are several theories or principles about how people make decisions. One of them is the *law of least effort*, which states, "each individual will adopt a course of action that will involve the expenditure of the probable least average of his work" (Zipf, 1949). For example, people tend to ask the closest person, grab the nearest tool, etc. Another well-established theory that has been applied to information behaviour is the *risk-gain paradigm*. It was found that ISKers tend to minimize the effort required to obtain information, even if it means accepting a lower quality or quantity of information. For example, people generally tend to make small steps and get instant feedback before moving on, rather than making all possible effort in one-go and waiting for an answer which may not be guaranteed to be provided by the information system (Teevan et. al., 2004). Apart from these, decision-making for strategies is also influenced by emotion, such as the anticipated feeling for each outcome after choosing the strategy and the feeling at the time of making the decision (Loewenstein, 2003).

Knowledge, social context, and other personal differences are all important factors that influence people in representing planning and solving problems. For example, one usually makes assumptions of the conditions of ill-defined problems based on their common sense. For instance, in (Davidson & Sternberg, 2003), there is a puzzle-solving problem: There was a cup of lemon tea and a cup of ice, which they cannot mix when they are both emptied into a vat. If you can think of a reason, you may have assumed that the lemon tea is in liquid state, as many people would do. In fact, the lemon tea can be and is iced in his puzzle. Similarly, in our daily life, we generally assume that some approaches are not feasible, so we do not even consider them when planning strategies. Instead, we immediately ignore these "infeasible approaches" without serious considerations. For this reason, it is difficult for people to have creative ideas for imagining the potential application of PLLs without existing knowledge of potentially feasible techniques or functions. Therefore, it is extremely worthwhile to build up some prototype systems for a group of first users to further explore the potential of lifelog technology. Similarly, when using an information system, it can be helpful if users are reminded of all the possible solutions. For example, if they only know what they can search with keywords, they will not be able to reach the target if they cannot think of the keyword, as they are unlikely to be able to plan any other strategies. If a user does not know that a PLL system is available to show them "events", and they only know that the system can enable them to find individual files (including photos, documents, emails, etc.) by filename and date, they would probably not use it for reminiscing. This mechanism suggests the importance of making users aware of all the possible functions that a PLL system can provide, so that they can be more likely to consider using a lifelog information system to solve their problems.

In summary, how people solve problems depends on how they define the problem. The definition and representation of the problems, which depends on the person's knowledge of the world (e.g. how things work) directs the user's planning of solution strategies. Several strategies may be tried mentally before any action is taken. In an information system, the user may not try to get information with methods that they do not know about. In the rest of this chapter, an IF task is considered as a step and an instance of problem solving, and the process of solving an IF problem is discussed.

3.2.2.2 ***Problem definition: Uncertainty in information seeking***

It is now generally believed that information-seeking tasks are ill-defined problems, with an uncertain definition of the goal state at the beginning. It has been suggested by many researchers in information seeking and retrieval (ISR) domains, that problems (information needs) can change during the course of information seeking, e.g. (Bates, 1989; Belkin, 1993; Dervin, 1992). This is because that the ISKer's knowledge is modified and their understanding of the problem changes, which may lead to a change in the goal and the current status.

In Belkin's ASK (anomalous states of knowledge) model of information search (Belkin, Oddy, & Brooks, 1982), he assumes that information search is a process towards solving a problem which is not well understood (defined) at the beginning. This means that the information searcher does not know exactly what he needs (or what can meet his needs) when starting the search, and gradually makes the problem information need clearer during the course of information seeking. Such changes may be more frequent and likely to happen in the case of an exploratory type of information finding task such as a subject or topic search, in which the ISKer gradually learns about the topic, and narrows down the question, or to put it in another way, the expected outcome changes.

Kuhlthau (1993) proposed an Information Search Process (ISP) model which differentiates the information-seeking process into six stages according to the searchers familiarity with the topic. The stages in the ISP model are: task initiation (corresponding to the problem recognition stage, when the person first comes to be aware of the problem), selection exploration (similar to the problem definition stage, when a general topic or problem is identified), exploration (explore the general field of the target), formulation (formulize a personalized construction of the topic from the general information gathered), collection (set out to look for some specific information or topic) and presentation (use the information to solve the problem). According to Kuhlthau, the centre of information seeking behaviour is uncertainty, which she called the *principle of uncertainty* for information seeking (Kuhlthau, 1993). During the course of information seeking, thoughts change from uncertain, vague, and ambiguous to clearer, more focused, and specific. This model includes not only actions, but also the affective (feelings), and the cognitive (thoughts) states associated with each stage. She suggested that the level of certainty could influence relevance judgement of items that have been retrieved.

Most of the above information-seeking models originate from the study of library users seeking information for understanding something. This type of IF tasks is called *subject search* or *topic search*. It is one of the most common search tasks when people search on the web. Yet, it is not the only type. This means the principle of uncertainty may not apply to every finding task. When people know what exactly to look for, they may not go through all the stages in Kulthau's ISP model. Indeed, people with different levels of knowledge (certainty) for the information needs may just jump to certain stages.

3.2.3 **Strategies and methods in information finding behaviour**

Once the information need or target is defined, one can set out to find it with certain strategies. This section reviews relevant literature in information finding and refinding strategies. Based on this review, I will discuss potential choice of strategies when finding information in PLLs.

3.2.3.1 ***Strategies and tactics in finding***

In the information-seeking and search literature, researchers have studied and listed several sets of strategies and tactics (a sub-action of strategy):

Belkin and colleagues (1993) proposed an episodic model which defined the flow of interactions in the course of information seeking. They used the term "scripts" to define the typical steps of interaction between a user and an information system. Each script consists of four elements or dimensions: method (search, scan), goal (learn, select), mode (specify, recognize), and resource (information, meta-information). By pairing every two dimensions they obtained a list of 16 information-seeking strategies (ISSs). This model underlines the process of refining of a query through learning from current search results, which are called "meta-information" if they are not the search targets.

Bates postulated the terms *search strategies* and *tactics* (Bates, 1979): strategy deals with overall planning, while tactics deals with short-term goals and manoeuvres. She later proposed a model containing four levels of search strategy (Bates, 1990): "move," "tactic", "stratagem," and "strategy" (Bates, 1990). A "move" is the lowest level of action, described as a single action performed by users, either physically or mentally, e.g. reading, deciding. A "tactic" is a combination of moves. It is the lowest level that involves strategic considerations, that is, the selection and order of "moves". Bates defined 32 information search tactics falling into 5 categories: monitoring tactics (check, weigh, pattern, correct, record), file structure tactics (bible, select, survey, cut, stretch, scaffold, cleave), search formulation tactics (specify, exhaust, reduce, parallel, pinpoint, block), term tactics (super, sub, relate, neighbour, trace, vary, fix, rearrange, contrary, respell, respace) and idea tactics (rescue, breach, focus). "Stratagem" is a combination of individual moves and tactics, and "strategies" are at the highest level which involves a combination of moves, tactics and stratagems.

Orienteering and teleporting are two strategies people use in both finding new information and previously encountered information. *Orienteering* is the approach of using current location and context to decide where to go next (Alvarado, 2003). It usually takes many small steps to narrow in to the target (Teevan, 2004). *Teleporting* is to take a direct jump to the information (target) they are looking for. When finding by orienteering, people rely on a large amount of contextual information (Alvarado, 2003). According to Teevan (2004), "Orienteering involves using both prior and contextual information to narrow in on the actual information target, often in a series of steps, without specifying the entire information need up front". They suggest that orienteering tends to lessen people's cognitive burden during their searches. The orienteering approach does this by "saving them from having to articulate exactly what they were looking for and by allowing them to rely on established habits for getting within the vicinity of their information need, thus narrowing the space they needed to explore" (Teevan, 2004).

With reference to refinding, orienteering methods tend to be equally or even more preferred. Capra & Perez-Quinones (2003) found an iterative two-stage pattern for their participants refinding behaviour on the web. Their participants usually started by locating the information source, and explored further to locate the detailed information. This is congruent with what was found by Teevan et al. (2004) that people tend to start finding by getting into "the vicinity of the information in question" by making a "large step to get to the correct area". Once there, "the participants used local exploration to find the information target."

3.2.3.2 *Searching, navigation and browsing*

Searching, navigation and browsing are the approaches (moves or tactics) people usually employ when finding information in the electronic world. *Search* is a method of finding and refinding things from an information system, usually an IR system. With the search approach, a new collection is generated from the chaos of an information corpus. The terms "navigation" and "browsing" are usually used interchangeably. In fact, they are not always the same. In this thesis, I define *navigation* as the activity of moving from one source to another source, and *browsing* as the activity of scanning within a single source. *Browsing* involves scanning in and learning about an information collection (in a single view space), usually in order to locate some specific items one is interested in. Navigation is about switching between collections (or view spaces) in a structured information space. Navigation usually follows and is followed by browsing. Of course, a single source is not always equivalent to a single page. For example, jumping from folder to folder is navigation, scanning in a folder, in a document or in a paper is browsing. Navigation is usually a top-down (hierarchical) process, in which the information finder usually knows where they are in a larger context. Since search behaviour has been discussed above, in the rest of this subsection, I review literature about user behaviour in navigation, browsing, and faceted browsing.

1. Navigation

Most IS and IR models consider searching as the main approach of finding information, and there have been many models for information search behaviours from IR systems. Yet, very few models have addressed the process of browsing and navigation. In fact, it has been found that people tend to prefer navigation and browsing approaches over search when they look for things in their own information archives (Bergman, 2008). There are several advantages of a navigational approach over search, including constant supporting and reminding from contextual cues, instant feedback, location-based finding (which fits well with peoples' storage habits), and lower cognitive load. Despite the general easiness of the navigational approach, it does not mean that users need no support at all during navigation. To do this, I need to have a better understanding of how navigation behaviour works.

Spence (1999) developed a cognitive framework for navigation behaviour in unknown information spaces. In this framework, he defines navigation as "learning about the information space", while search and other activities make use of the space, and browsing is one step in navigation. According to this framework, people learn about the space through browsing, which he defines as "the registration of the content". People generate a mental (internal) model of the information space based on browsing. The internal model of the space contains the entities, as well as the locations of the entities and the relation of these items, e.g. item A is shortly after item B. The navigator then generates a browsing strategy to browse the current information space.

2. Browsing

Unlike navigation, during browsing the user stays in one collection regardless of how the collection is organized (a cluster can be created, but the items belonging to each cluster should still be directly visible, the same as before they were clustered.). Spence (1999) believes that browsing is not really random. In fact, according to the theory of human attention (which I will talk about in Chapter 4), browsing is either a top-down process during which readers are guided by knowledge of the browsing space which he or she is browsing, or adopt a "bottom-up" strategy directed by attractive objects. In a known space (e.g. your email inbox), the stages of learning about the space may be partially completed by retrieving knowledge from the navigator's own memory, e.g. what types of files are in the folder, and where approximately certain files are located (spatially). For example, if the user knows the system displays the directories by time, and that events inside the directories are named by corresponding month, they can quickly jump to the end of the list if they want to find records of an event that happened in December. While browsing purposelessly, they may be attracted by interesting photos and browse to that area of the page (window). I will further discuss the influence of a person's knowledge in finding tasks in Section 3.3.4 and Section 3.4.

According to Capra (2005), “waypoints” are usually used when navigating in a PIS to locate specific items. Waypoints can be any specific nodes on the path towards the goal, without necessarily being on the exact path towards the target. According to their findings, waypoints for web items can include titles, URLs and descriptions of pages or the website. Browsing is usually accompanied by some manipulation of the collection such as sorting or filtering.

In traditional IR interfaces, the results are usually ordered by a relevance score given by the IR system. However, due to the often unreliable nature of the ranking score, it is be difficult for the users to predict where their target is located on the result list. Sorting is usually used to help people roughly locate their target information. For example, if the users remember at least the beginning part of a file name (e.g. “file…”), they can order the result by name (alphabetically), so that at least they know that they should scroll a bit further after seeing files beginning with “E” or scroll back when seeing files beginning with “M”.

3. Faceted browsing

Faceted browsing, also called faceted navigation or faceted search, is a technique for accessing a collection of information represented using a faceted classification, allowing users to explore by filtering the available information[3]. A facet usually corresponds to a single property of the information elements. A faceted classification system allows the assignment of multiple classifications to an object, enabling the classifications to be ordered in multiple ways, rather than in a single, pre-determined, and taxonomic order. It is slightly different from a location-based storage metaphor in the physical world, as things can exist in more than one place at the same time. It can be considered as a more flexible way of navigation than navigation in a static hierarchically structured information collection. To apply a facet filter, users need to make a judgement of the correct property for the target. For example, if the facets in a faceted browsing system include month, date, location of events, the user should be able to recognize the correct attribute among them for the target event. Similar to the navigation approaches, faceted browsing methods also benefit users by relieving their cognitive burden (compared to query based search) as the facets are provided for recognition, so that users do not need to recall the details.

[3] http://en.wikipedia.org/wiki/Faceted_search

3.2.4 **Phases of information finding and refinding processes**

According to the above review, the traditional information search models (described in section 3.2.1) do not consider issues such as uncertainty of information needs and the flexibility of information finding strategies. In this section, I propose a framework for information finding, shown in Figure 3.3, which takes into account interaction with context and alternative approaches to search. The process is not composed of a single workflow, but can have many loops and divisions.

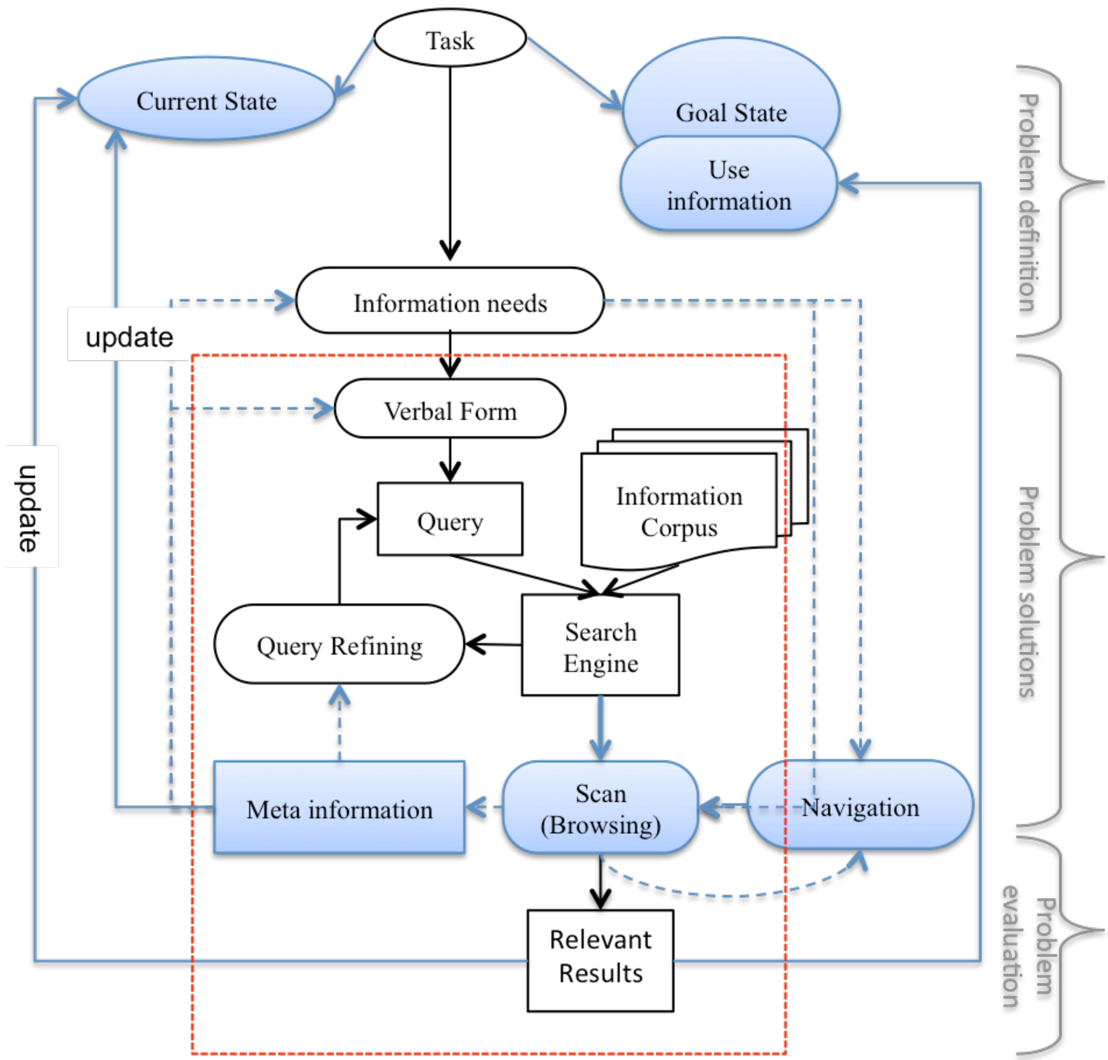

Figure 3.3 Augmented IR model for information finding as problem solving

Note: The elements in blue are the extended elements in this framework. Only the part inside the red box is the information search behaviour. Elements inside black boxes are those from the traditional information search model. Dashed lines indicate that the process is optional.

1) Problem definition and presentation: in an information-seeking task, the goal states are usually defined by the task itself regardless of how clearly the information needs are defined. The context of the task and the searcher's internal status (knowledge) at that time defines the current state. The gap between the perceived current state (the resources that the problem solver is processing at the moment) and the defined goal state (as understood by the problem solver) give rise to the information needs. In short, the person's understanding of the information needs defines the problem. According to the principle of uncertainty, the information need is consistently changing, from uncertain to focused, by selecting the most relevant topic or sub topic to explore. The changes are usually due to newly learnt information from feedback (meta-information) from the information search results. One can go through this step multiple times for a single problem.

2) Information finding (problem solution): once the "current" information need is defined, the ISKer starts a finding task. He or she may adopt various strategies and methods during the finding task, for example, navigation, browsing, and searching. Indeed, if the user adopts the searching method, a traditional IR process starts.

Finding tasks can have several sub tasks. For example, one may want to find a booking web site to book a hotel, and may go through at least two stages: locating a web site, and then getting information on the website. Every time after some relevant information has been found, the ISKer compares the current resources (including the newly found information) and the resources needed in the goal state, to evaluate the results of the task. Query based search is not the only tactic in locating a source or information, navigational tactics (chaining) and browsing tactics are also frequently used.

When a search method is used and after the search engine has retrieved a list of results based on the match between the users query and the data in the information corpus, users usually need to scan the result list, unless the needed information sits perfectly at the very top of the list. It is not unusual that the user cannot find any relevant information at first glance. Yet, the information in the result list that the user does see may help him or her to understand the topic better or form a better query for a follow on search to attempt to find the desired information.

This framework can also be applied to information seeking in a PIS or lifelogs. For instance, Mary may want to find some nice photos of her experiences to share on Facebook. She may not have a clear idea of the information needs, that is, exactly which photos she wishes to find. She may start by navigating and browsing in the directories where she stores her photos. As she browses the folder or photos (the results), she may find or remember that there is a certain folder which contains quite a few interesting photos that she may want to see. Thus she starts to search to navigate to locate the folder. If the folder has not been found yet, a sub task is created, that is, to find the folder. At the same time, her information needs may have become more specific, that is, some photos in that specific folder. When she finds the folder and browses it, she will recognize the photos that she wants.

In general, according to this augmented framework of information finding (IF) processes, IF tasks in lifelogs are: i) triggered by the gap between an information need from a higher task and the current state, therefore, any information that fills such a gap could be "relevant", therefore, the evaluation of the results can be flexible as the target items may not be unique; ii) the tasks may be an integrative process, and may have several sub IF tasks; iii) multiple methods may be used. Of course, whether to search or navigate for targets, and where or how to start the information finding task depends on many factors, e.g. least-effort and risk-gain principles. The next subsection reviews the factors that can potentially influence the choices of methods and information sources.

3.3 Factors influencing the information searching process

According to the framework described above, there can be a variety of choices of strategies or approaches that an ISKer can take to solve a problem. This section discusses the factors that influence the choice of strategies and the finding behaviour, and proposes a knowledge-based information finding model. This model describes the role of the information searcher's knowledge in the process of information finding. It can provide a theoretical base for further explorations of human memory that are related to the process of IF in PLL s.

Ingwersen and colleagues proposed a model for information search (retrieval) and seeking behaviours, called the *cognitive model* (Ingwersen, 1996; Ingwersen & Järvelin, 2005). In this model, they consider the information-seeking process as interaction between cognitive actors (both the authors of the information and the ISKer), the context, the information system, the interface of the information system and the information objects. Of course, in a heterogeneous information corpus like a PLL, not every piece of information has a human author. For example, visual information captured in a photo may not be created by a person, and may not be captured by a person's intention. But the interaction does exist between the cognitive space of the ISKer and other elements in the framework. For example, people's choice of using orienteering or teleporting methods depends on their knowledge of the information system, information objects, and functions provided by the search interface. On the other hand, knowledge of the problem is influenced by the social context that the ISKer is in. These issues are explored in the rest of this section.

3.3.1 **Tasks**

Tasks have been found to influence people's information behaviour. Some researchers have categorized tasks by complexity or predictability, e.g. (Bystrom & Jarvelin, 1995). Taking the example I mentioned in ISP models (described in 3.2.2.2), people looking for specific items or information on a specific topic might go through different sets of stages. Vakkari and colleagues (2003) found that queries become longer (more keywords) and conceptually richer when the information need is more clearly defined. I suggest that a search system should try to identify the seeking stages based on what the users are doing (e.g. their queries) and provide different types of results, e.g. a list of information sources rather than pieces of information themselves. In fact, the influence of task types discussed above can also be considered as an influence of memory, as categorization of tasks is based on knowledge of the information need and the problem.

3.3.2 **Information Corpus and Information system**

Alvarado and colleagues (2003) found that people generally favour the orienteering approach to find their emails and files, while using teleporting when looking for information on the web. The authors explained that this might be due to sophisticated keyword based searching tools and the inconsistency of the structure of information on the web. It was also found that improved desktop search tools brought more users to find personal information through searching, although this advantage was not big dramatic (Bergman, 2008). Again, this finding supports the view that the strategies people use depend on their knowledge of the information corpus and the tools to enable them to access the information in the corpus.

3.3.3 **Personal differences**

It is suggested that not only the context of the information seeking and finding tasks, but also the personality of a person also influences their information behaviour (Heinström, 2003). In this proposal, a person's traits such as neuroticism, conscientiousness, extraversion, openness, and competiveness all interact with contextual factors to impact on the person's information behaviour. It has been found that those people who used keyword search more as a tactic tend to put more effort into organization (Alvarado, 2003). One potential explanation for this may be that these people are better at language or verbal skills and rely more on verbal forms. On the other hand, since organization and teleporting strategies require more effort, but tend to bring larger rewards, the preference differences may be related to personal achievement requirements. For example, people with higher achievement requirements may tend to be willing to make more effort.

3.3.4 Knowledge in information seeking

Knowledge is an important factor that influences the information finding process. The more exact knowledge one has for the problem, the less uncertainty exists. According to problem solving theories, the knowledge people have and the information at hand can significantly influence people's definition of the problem and the selection of problem solving strategies. Apart from the influence of personality, the other two factors (task and information system) functions through the ISKers knowledge, that is, the knowledge of the task, and the knowledge of the information system and information corpus.

There are three types of information needed to solve a problem, these include: *problem information* (the characteristics of the problem such as the structure, properties and requirements of the problem at hand), *domain information* (scientific facts), and *problem-solving information* (methods of problem treatment, e.g. how problems should be seen and formulated, what problem and domain information should be used (and how) in order to solve the problems)). In a well-defined problem, the above information is usually given, and the process can almost be done almost automatically. However, as I noted earlier in section 3.2.2.2, most information seeking and finding tasks are ill-defined problems. People either have little clear idea of the problem itself, or the solutions towards solving the problem. In order to solve these problems, the ISKer or problem solver holds the information given, and what they already know (knowledge/ memory) in their mind (their *working memory*, as will be explained in Chapter 4) to formulate strategies. The information is perceived and held in working memory as temporal knowledge. In this sense, all the information that the ISKers has about the problem is presented mentally as their knowledge, although some knowledge is temporary.

Corresponding to the types of information above, Ingwerson (2005) classified two types of knowledge during information seeking and retrieval: *domain knowledge*, and *information seeking and retrieval (IS&R) knowledge*. He believes that "the domain knowledge constitutes the original cause for seeking". Quality of knowledge is a continuous range of levels between these two opposites: well-defined and ill defined. Both types of knowledge are in procedural and declarative forms. He defined the following types of knowledge:

1) *Problem and task solving knowledge*: refers to the perception of the process of performing the task, e.g. how to use the keyboard, the mouse, how to open a folder.
2) *Information source and system knowledge, encompassing retrieval and seeking task knowledge*: refers to understanding the declarative structure of the information objects, such as personal desktop knowledge sources, webpage organization and of IR systems, i.e. the context of sources, visual interface patterns, icons, database content.
3) *Search task solving knowledge*: deals with how to perform seeking and retrieval tasks. This is the procedural experience of search strategies, tactics and techniques. For example, it was found that experienced email users tend to make use of their knowledge of the construction of email subject line to generate queries on the subject field (Elsweiler, 2008).
4) *Person and group knowledge*: is the knowledge needed when people are considered as sources, e.g. if this person knows the answer, or knows about the topic area.

In short, there are several factors that influence ISKers' choice of strategies, including: their personality, knowledge of the information needs, information corpus and information systems, and of course, knowledge updates during the course of an information-seeking task. The next section further explores the role of ISKers' knowledge in their finding tasks.

3.4 Knowledge based information finding and refinding in PLL s

According to the above models and theories, knowledge of the information need, information corpus and information systems play important roles in the information finding process. This section proposes a *knowledge-based information-seeking model* based on the above review, and discusses how this model applies to information finding and refinding in PLLs.

3.4.1 Knowledge-based information-seeking model (KBISM)

This knowledge-based information-seeking model (KBISM) aims to depict the information finding process from the knowledge perspective, describing the interaction between the ISKer's knowledge or "internal information space" and the outer information space during an information-seeking task. The model is depicted diagrammatically in Figure 3.4. The "internal information space" consists of what the person already knows (that is, existing knowledge retrieved from the ISKer's memory), and the information acquired from the information-seeking task and context of the task.

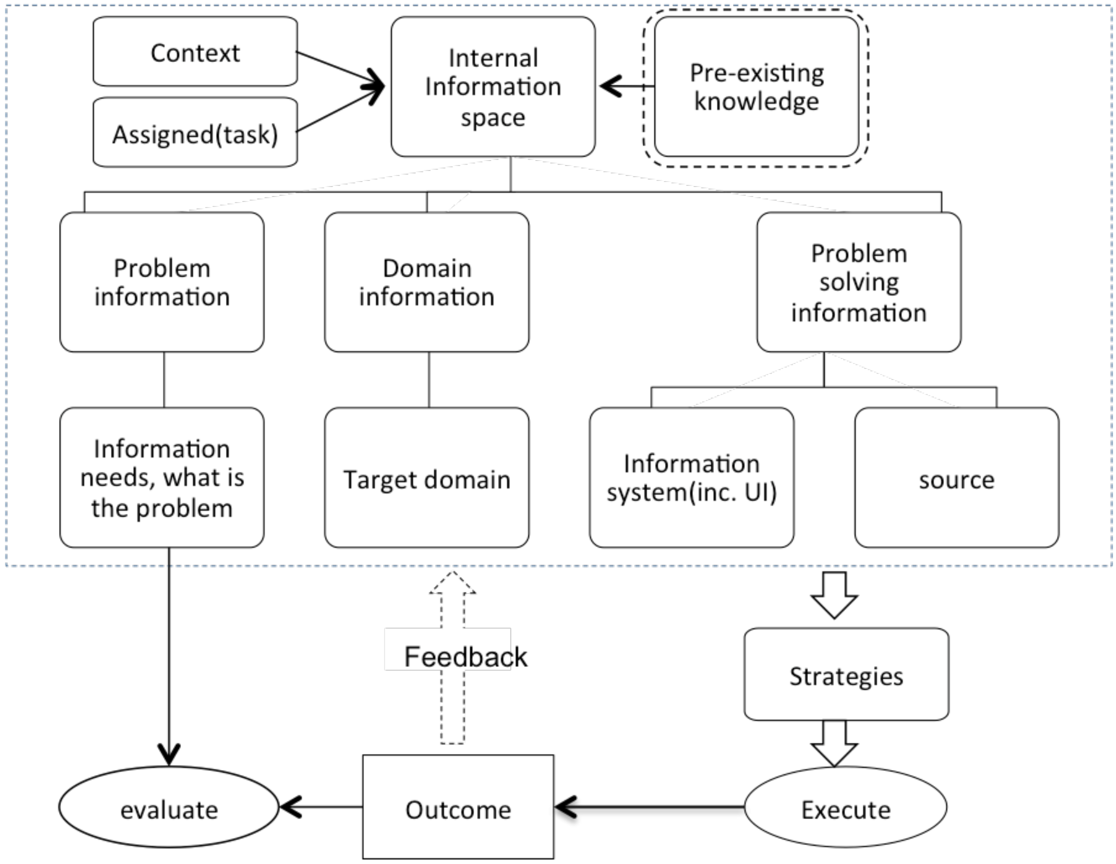

Figure 3.4 Knowledge-based information-seeking model (KBISM)

Note: Elements inside the dashed-line box describe the components of knowledge that a person possesses at the time of the information seeking/finding task.

During an information-seeking task the ISKer's problem solving knowledge (of the information systems and the information corpus), domain knowledge (of the information related to potential target) and problem knowledge (regarding the requirement of the task, e.g. information needs) work together to "reach a decision" which determines the strategies to be used in the finding task. For example, the ISKer may turn to information channels and systems that are more likely to easily provide them with the information needed, where this choice is based on their previous *problem solving knowledge* of these systems and their *domain knowledge* of the potential targets which meet the information needs according to their *problem knowledge*. This *problem solving knowledge* may also tell the user whether search or navigation may be a more efficient approach with the selected information system. The outcome of executing the strategies gives feedback to the user's internal information space (knowledge). People learn from the process of carrying out a finding task, including their experiences with current information system, the information corpus. Of course, as I mentioned in the information finding process framework in section 3.2.4, the ISKer can also learn from the outcomes and update their domain knowledge, which may further influence the problem knowledge (information needs), resulting in another finding task with an alternative or more precise target, or a refined query for the current target.

When evaluating the outcome of a finding task, one compares results (perceived outer space information) with the knowledge of the information needs (problem information). During this step, the perception of the result items is sometimes rendered by domain knowledge which enables the ISKer to recognize relevant features of a "potential target", e.g. "this item should belong to X type, it should have the information to solve the problem", "this items does not have the typical features of that sort of thing"… (So it is not likely to be relevant). The rendering function from the domain knowledge accelerates the evaluation process, since it allows the ISKer to make judgments without finding out all the required criteria or learning the full details of the result item. Therefore, the more domain knowledge one has about the result items, the faster and more reliably one can make a judgement. Explanations of this "rendering" function can be found in literature about domain-experts in decision-making, e.g., (Hutton, 2009).

3.4.2 Knowledge-based information refinding: What happens before one looks for information in lifelogs?

As described in section 3.1.4, refinding is one strategy of finding information, by locating a target that the ISKer has encountered before. This means that people may look for the information that they need from other resources and with other approaches to solve the same problem. According to the KBISM, the choice of strategies largely depends on the ISKer's knowledge at the time of finding the information. In my opinion, the likelihood of choosing a refinding strategy or choosing to look for the information in a lifelog system depends on the levels of two categories of knowledge: "where is it?" and "what is it?" In the following two sub sections, I discuss how the knowledge of "what" and "where" influences behaviour (strategies, tactics) during an information-finding task, and how these two types of knowledge direct people to find information in their lifelogs. This discussion leads to a list of potential scenarios of information finding or refinding tasks in PLLs, to provide further answers to pre-development question 4, described in section 1.4 of the Introduction chapter.

3.4.2.1 ***Knowledge of "What"***

Knowledge of "what" is about "what exact piece(s) of information or item(s) is/are needed to solve the problem". The "knowledge" can either be given (required by the task) as information or inferred by the ISKer. These levels of specificity can be different problems, or different stages of the same problem. For example, Jim is required to find some pictures about Paris, the initial knowledge of the target was provided with the following features (criteria): the type (photo), the visual content of the picture (Paris). If he has never heard of Paris, he may start to learn about this topic, and acquire information about it, e.g. it is the capital of France and has the following famous iconic spots. Of course, many people have heard about this city many times, and may immediately (remember) associate it with some iconic features such as the Eiffel tower. With such knowledge in mind, Jim may try to look for pictures which contain these objects. He may recall some (specific) impressive pictures of Paris that he has seen before, and start to look for these pictures or pictures like these. Of course, he may end up finding an image which does not have any of these features, but rather, contains or reflects some aspect of Paris that he has never seen before. Yet, this definitely is about Paris (for example, according the description of the picture).

The evaluation of the outcome would be based on the match between the expected or known features of the potential targets and the corresponding attributes of the result items. If the person wants to find a specific item that was encountered before, the details for this item may be gradually recovered from the person's memory, and the assessment of relevance will depend on the person's recognition memory by comparing various features of the result item and those in the user's memory.

3.4.2.2 ***Knowledge of "Where"***

The knowledge of "where" is about the potential location of the targets. It is the knowledge that directs the ISKer to find information in different information channels, e.g. the Internet, one's hard drive, or other people. The choice of the channel(s) depends on the ISKer's knowledge of the channels, in particular, how likely it is that they believe the target can be found and how easily it can be retrieved from the channel.

Take the task of doing an assignment during a class for example, the channels which contain the answer (information needed) may include text books, the internet, related materials that the teacher has pointed the students to read, and of course, the teacher him or herself. Although the teacher may be the most reliable source for the answers, he/she may be the last choice for pursuing the knowledge, since the teachers are unlikely to tell a student the answer before the time for announcing it. If the question is very specific and can easily be transformed to a web-recognizable query form, the student may try to search it using a web search engine, given that internet is available at that time. Or if the students do not trust answers from online resources such as Yahoo! Answers, they may prefer to scan books or other materials instead, whichever is easier for them. If they have read about this topic somewhere, it is also possible that they may try to look for that "place" first. In this case, if they have their own PLLs, which contain all the information that they have read before, they may potentially try to search in this PLL archive, if they think that it would be easier (although not necessarily quicker) to find the information.

In another example, Jim is asked to send his colleague a document that he has been working on. In this case, he is likely to look for this target on this computer (known information channel). If Jim is a well-organized person, he may even know where exactly the target is (known location). Of course, this depends on his memory about the location. For example, he may remember that it is in the folder named by the project, and even remember some features of the folder such as other files in it, but may not necessarily remember the exact path of it. Yet, it is likely that he will be able to recognize the path and specific "place" (i.e. folder) when he navigates there.

To summarize, a person's knowledge can significantly influence the definition of information needs, potential targets, and evaluation of search results as well as their choice of seeking, or finding or refinding strategies. Accessing information in one's own PLL is one type and approach of information seeking or finding tasks. It is not necessary that the ISKer immediately defines the information needs clearly as something that they have encountered previously in order for them to find it in their PLLs. They may not even know what kind of information can serve the purpose, or what is present in their PLL. Even if there is something in their PIS that can potentially meet the requirements, the seeking process can differ depending on how much the ISKer recalls about these exact items. Therefore, there are some specific situations in which people would decide to find things in a collection like their PLLs, if they have any. The following sub-section discusses these situations or scenarios.

3.4.3 Types of Tasks: When do people find Information in PLLs?

According to the knowledge of "what" and "where", there can be the following three types of situations in which a ISKer looks for information in his or her own lifelog collection, although other situations can arise as well:

1) The ISKer has seen the exact information when using PLL system previously, and expects to find the same information again. She/he may trace the previous route in the PLL system to locate it.

2) The ISKer remembers encountering the target item, and knows that the PLL system should capture and store these types of encountered information or items, e.g. all their visited web pages. Therefore, they can expect to find the specific items in their PLLs. For example, Mary remembers reading a recipe for making a specific dish, and wants to find the recipe again. Since almost all the electronic types of information that she encountered before has been captured and stored in her PLL, she can expect to find it there. Of course, she may also find it elsewhere, e.g., on the web.

3) The ISKer knows that the target exists in their PLL system, e.g. photos, digital capture of events which they have experienced, regardless of whether they have seen the target itself before, and whether they know exactly what item (e.g. which photo) they are looking for. Of course, whether the ISKer will look for it in her/ his PLL depends on her/his knowledge of her/his PLL collection and the information system, regarding what types of things the collection contains and what the system can provide. In this type of task, the ISKer may not necessarily have any knowledge of the target item apart from its type, e.g. a document that was visited, an event that he should have experienced. For example, Jim wants to find where he parked his car before he left for his holiday. He may not immediately have any recollection of any things that happened on the specific date. Yet, since he knows that he was doing lifelogging almost every day, and things should have been captured for all his actions, he may locate records on the date to browse and learn or recall some more details regarding the action of parking his car. Of course, unless the information that he needs is exclusive to his PLL, Jim may try to find it in other information channels. For example, if he only needs to find a photo from last holiday, he may also be able to find it on the memory card of his camera or in corresponding folders on his hard drive.

In short, people may look for information in their PLLs when they know that their PLLs can provide them with such information. Although I only listed three types of finding tasks for accessing PLLs, these are already more diverse and complex than the often discussed types of finding tasks in the typical information corpus, e.g. learning about a topic, or looking up specific information. In many cases, the ISKer may have more than one channel to find their information. Whether or not they choose the PLL as the channel to pursue the information that they need depends on many factors which contribute to the likelihood and the difficulty of finding the information.

3.4.4 Supports for different types of tasks in PLLs

Recalling the discussion in section 2.3.4, in chapter 2, the PLL should support following types of tasks to the lifeloggers: fact-finding, item finding, and reminiscing. These correspond to different types of information finding tasks. With a better understanding of the information finding and seeking behaviours, I now further discuss how these types of activities and information seeking or finding tasks should be supported.

Retrieval: known-item finding

This function allows users to retrieve a specific item to re-use. The corresponding information finding task is also called “refinding” or “known-item search”. These information-finding tasks can either be required by others (“can you send me the photo taken at the party?”) or by the lifeloggers him or herself (“I read a paper about this question, where is the paper?”). For this type of task, users (lifeloggers) usually have some idea of certain features, attributes or content of the target. The user’s evaluations of retrieved results is likely to be based on the matching of features or the recognition memory of the specific item, e.g. “this is the one I read, I remember that this one talked about …”. Therefore, to help users to locate the “relevant” items more efficiently, it is desirable that the known features of the target are easily visible, or the features by which the user tends to recognize the target item are presented.

Recollection (Fact finding): information finding

A recollection function provides details or memory cues for lifeloggers to find or recall specific information or facts of an event, e.g. time of an activity, the location where the event took place. The target of a corresponding information finding task may or may not be captured directly or explicitly by the PLL devices. For example, the fact of “where I left my key” may be captured by some lifelogging devices such as a camera, but such small actions may also happen to be missed by the camera. If it was not captured and stored, one may check for other related information, trying to bring into memory that specific moment. For this type of task, the lifelogger may not necessarily expect the existence of an exact copy of fact that they want to look up. Indeed, any information can be “relevant” if it can act as evidence of the fact or bring back a vivid memory of the target information (if it was known), e.g. to confirm that the key was in the second drawer, or help the lifelogger recall that he placed it in the second drawer.

Reminiscing: information seeking

When reminiscing, people do not always have a clear goal for what they wish to see, since they may not have a clear idea initially regarding the exact information that can help them to reminisce about the past. The "relevance" of information is very flexible, subjective, and emotion dependant. This is not like the traditional information-seeking tasks where the "relevant" information should belong to a "topic". For example, when missing a person, anything related to that person may be "relevant" to cater for an emotional need, including both the information that contains content directly relating to the person in some way and information which does not. If a user has a specific event or item in mind as the initial target for reminiscing, she/he might look for this specific item or event (collection). Yet, the things that trigger most of his tearful or cheerful memories may not necessarily be what first comes to mind or that he sets out to look for. For reminiscing functions, while it is important to support users in finding specific items, events or collections (e.g. a folder of data which belongs to the same event), it is also helpful to recommend some other emotionally related information.

3.4.5 The finding process in PLLs

As discussed above, people decide to find things in a PLL system because they "know" or at least they expect that the system can provide the information they need. This knowledge is usually acquired from previous experience (memory). This section explores the potential process of finding tasks in lifelogs, and further discusses the issues people may encounter, which leads to my suggestion of the possible functions that a system should provide to support the lifeloggers when finding information in their lifelogs.

3.4.5.1 *Uncertainty and problem definition*

Although, different levels of uncertainty also exist for the information finding tasks in PLLs, it is unlike the usual uncertainty associated with seeking information in an almost unknown information corpus, e.g. the internet or the library. Since most of the content in one's PLL is directly or indirectly known to the user (the lifelogger), the uncertainty of the exact information need is usually a result of failure to recall the existence of potentially relevant items that can meet the requirement of current situation. For this reason, the strategies people may use to solve the uncertain problem during accessing their PLLs can be different from those used in current information-seeking tasks over information sources for which the content is unknown. The lifeloggers may still set out by exploring the information space to get a clearer idea of what exactly to retrieve, but instead of aiming at learning about new information related to target topics, they are more likely to try to recall the existence of potential targets or the sources of targets that could satisfy their current needs. For example, if the user (lifelogger) wants to see interesting photos taken with someone, she/he may first try to explore or recall the potential sources (events or other types of collection) where there can be photos of that person. They may not immediately recall all the occasions where that person was present if they used to be together a lot. For this reason, the system should try to help the user to recall the potential sources (e.g., photo collections) or target (e.g. events) as quickly as possible, by providing them with some useful "memory cues". Memory cues are pieces of information or stimuli that triggers one's memory; more details of memory and memory cues are explored in Chapter 4.

3.4.5.2 ***Strategies for finding in PLLs***

Once the target is defined (i.e., what events or directories should be found for current requirements), the lifelogger can look for those directories or events, and interesting items in them. The choice of approaches depends on the knowledge and information the lifelogger or ISKer has about the target and the information system. They may take the search approach if their knowledge (including the criteria) of the target can be more easily transferred to a verbal form which is accepted by the information system, and if they have built up a certain level of confidence that the system is likely to return what they need based on this input. If they know that the target item exists in certain sources (folders, collections, or groups of items, e.g. an event), and also know approximately where the sources are, they may adopt the typical two step pattern: approaching the sources through navigation or browsing first, then try to locate the target in the source (Capra & Perez-Quinones, 2003), see the review in section 3.2.3.1. Similar to finding in any other types of information space, finding tasks in PLLs can also be an iterative process. People may gradually learn or recall more potential qualifying sources or targets, or more precise features of specific targets, and update their strategy or tactics, queries accordingly. Sometimes, they need to find some information in order to proceed. For example, one may need to find the exact spelling of a city's name to search for an event by location.

3.4.5.3 ***Evaluation***

Finally, users need to judge whether and which of the presented results might be the one they need. As discussed earlier, relevance judgements of information finding tasks in PLLs may usually involve the user's memory, e.g., to recognize if the result item is "that specific item" which has been encountered previously in a specific context. In many cases, the understanding of the items may also require the user to recall some exact details, as only the data owners have the necessary "private keys" in their memory of the specific experience, triggered by the presented data. While others can only interpret the presented information based on their own knowledge and experiences, which may make the interpretation of result items different from that of the data owner. This means that in tasks which require the "result items" to act as memory cues for triggering certain memories, whether a result item is "relevant" depends on whether the result item cues the memory. Of course, everybody has different memories. Therefore, the "relevance" judgement is personal. For example, it was found that people interpret the lifelog data of other people's events differently (Byrne, 2011). It is also "dynamic", since a piece of information may not always be able to trigger the required memory. This is explained in the context of our discussion of memory in Chapter 4. Moreover, people do not always need the exact piece of information to solve the "problem". Take a reminiscing "task" for example, anything related to a person, suitable to the current emotion, or anything interesting can be "relevant". Of course, if there are some solid or exact requirements for the targets, the user may only need to compare the corresponding features of a result item with the requirements, without any need to recall anything in order to determine its relevance.

3.4.6 Summary

To summarize, the finding process in PLLs shares many similarities with typical information seeking or finding tasks, including the uncertainty of information needs, the iterative process, and the types of strategies such as searching and browsing. Yet, because the content in PLLs is different from that in current typical information corpora such as the web, people may expect to get other types of target from PLLs rather than what they usually expect to find on the web, and to conduct some types of tasks that they seldom do in such typical current information corpora, such as reminiscing. The target items themselves are seldom unknown or uncertain to the ISKer, as they are usually something the ISKer has encountered before. Therefore, the strategies or tactics that they may take and the cognitive involvement in these tasks, may be different from that for finding in a typical information corpus. The predominant difference is in the involvement of the ISKer's memory. For example, when finding information in one's own PLL, the uncertainty of the potentially suitable target can be solved not only by learning about the information space, but also by recovering information from their memory. During evaluation of results, the "relevance" judgement is personal, usually dynamic and may be emotional. Because of the unique features of PLLs collection, diverse types of tasks, and the flexibility of strategies, it may be more feasible to provide support for each small step or tactic in the finding process, rather than developing a perfect IR algorithm that attempts to always provide the most "relevant" set of results.

3.5 Guidelines for developing an information system and interface for accessing PLLs

This section discusses the question of how to support each step of information finding, based on the guidelines suggested by Shneiderman in a five-phrase framework (Shneiderman, 2005). This framework is from the user interface interaction perspective, suggesting how to design and evaluate an interface for finding in a typical information corpus, such as an electronic library.

The five phases in this framework are: formulation (expressing the search), initiation of action (launching the search), review of results (reading the results and outcomes), refinement (formulating the next step), and use of the information (compiling or disseminating insight). I believe these steps can also apply to finding in PLLs. Of course, since the framework is focused on the search tasks in library user interfaces, there are some limitations to these guidelines when attempting to apply them to finding tasks in PLLs. For example, this framework considers that people only start with searching rather than browsing or navigation. Similar to the traditional IR model, it assumes that users tend to know what they want to look for. Therefore, they did not suggest how to help people start by defining the target or information needs. This section reviews this framework, and discusses and proposes guidelines for the following steps during information finding in PLLs: initializing, query formulation, browsing, navigation, and result recognition.

3.5.1 Initializing

To help people to quickly and easily start the finding process, it can be very helpful if suggestions are provided for where to go, e.g. what to search for, or where to navigate into. According to the knowledge-based framework I proposed in section 3.4, it is the knowledge of information needs and the knowledge of how to solve the problem (e.g. the functions available in the information system) that work together to shape the plan of the finding activity. The lack of either knowledge source can hinder the finding process. A quick reminder of potential targets and the functions available in the information system is desirable in such a case. When finding information for reminiscing, for fun, or for killing time, people are usually uncertain of "where to start”. This uncertainty also exists for finding known-items when only some blurry impression of the target item is recollected. Therefore, in the first step, the system should provide the users with more recommendations (cues), for them to recollect information in their lifelogs that can potentially meet their needs, e.g., what events are there (they can potentially review), or which documents may provide the information that they need.

Since the uncertainty of finding in PLLs is usually due to the difficulty of recalling past events and information, rather than a lack of knowledge of the target topic, proper memory cues which tend to trigger people’s memory of relevant events or items should be presented. The question of how to select the proper cues is explored theoretically in Chapter 4 and empirically in Chapter 7. Apart from this, the important functions of the information system should be easily visible, so that the users can be reminded of the possible solutions to the problem while planning their finding strategies.

Once the user has started the finding process, they learn about the problem and the potential target domain, and they may immediately choose a tactic and take action based on easiness, effort and gain of each tactic for this task with the given system.

3.5.2 Search by Querying

The search approach should be supported for generating search queries and for refining queries. A user-friendly information system should provide the following functions:

1) Flexible query options

It is desirable that the search system should provide a variety of search options to cater for whatever the user recalls about the target.

Several studies have highlighted the importance of enabling people to search their PIS with what they remember (Blanc_Brude, 2007; Dumais et al., 203; Elsweiler, 2008). Search is like telling an assistant what one needs through search queries. From a technical perspective, the user should construct search queries in a form that the algorithm perfectly “understands”, so as to maximally utilize the potential of the IR system. For example, if a person wants to search for events that happened on the date “2008-12-15”, he should try to make sure the system understands that the query “2008-12-15” is the date of occurrence of an event, rather than text within the content of a document. The more precise the details (required by the search fields) a user tells an IR system about the target, the more likely it is that the search can be effective and efficient. From the user's perspective, it would be desirable that the IR system "understands" whatever they describe about their target items. According to Sheneideman (1997; 2005), the IR system and interface should be adjusted to what the human tells it, e.g. be able to process the query as phrases instead of individual words, allow variants of the query, e.g. case sensitivity, stemmed versions (e.g. "teach"'s variants can be "teacher", "teaching", "teaches", etc.), and partial matches (e.g. keyword biology to socio-biology, astrobiology). Of course, most of these typical word-level variants that he mentioned have been taken good care of by advanced IR algorithms.

In fact, the communication problem people usually encounter during refinding and potentially during finding in PLLs is not just about the spelling or exact value in the query, but that people tend to remember a gist of meaning instead of the exact details (Lansdale, 1988). Therefore, it is desirable if the IR algorithm can match content even if it is expressed in totally different words. Before the IR algorithms are as advanced as this, the system should support search by providing more query options for which users may remember the exact details. In short, to support the search function, improved system and IR algorithms that can allow more flexibility in the queries to cater for different levels of user's knowledge of the target. For example, not only accepting exact words from the content or the filename, but other types of information that the users may remember, for example, date of an event. Chapter 4 and 6 will explore what people tend to remember according to theories in psychology literature and describe findings in our empirical studies.

2) Support query refining with instant and efficient feedback

Shneiderman (1997; 2005) suggested that instant, clear and meaningful feedback (message or suggestion) is useful to guide people when refining their queries and changing the search parameters in progressive search situation. He suggested using incremental search to give users immediate feedback, and allow rapid, incremental and reversible actions to encourage exploration. However, dynamic queries require fast response speed (on the order of 100 milliseconds), which can be problematic for a personal computer if there are large volumes for of data. Shneiderman suggested an alternative approach called query preview (Greene, et. al., 2000), which returns the distribution of hits (result items) instead of result items themselves. He also suggested that there should be some obvious ways for users to stop the search if it is taking too long, and that search interfaces should keep a track of the user's search histories to enable them to make use of earlier search queries and corresponding returned documents. I believe that the same or similar functions should be provided to support finding tasks in PLLs.

3.5.3 **Browsing**

Browsing usually accompanies navigation and searching, it enables the user to learn and probably re-learn or recollect the structure and content of the current collection. It would be very helpful if the user can be told or helped to recall the structure of the collection, and approximately where the target lies. For example, if the collection is sorted by time, some cues should be given to remind the user what things are in each of the part of collection, and help him to figure out the relative position of the target. Methods like scrolling, sorting, zooming, filtering, grouping are usually used to manipulate the collection for learning about the collection as well as approaching the targets. When browsing search results, Shneiderman (2005) suggested that the search interface should provide overviews of the result set and previews of result items, present explanatory messages of the results, and allow users to adjust the size of results set, as well as to change their sequencing (sorting) and explore clusters (by shared attributes). To summarize, to support browsing functions, the interface and system should provide the user with the freedom to manipulate the way in which results are presented, to adjust the result set to their habit and knowledge, so as to make it easier for the users to learn or recall the structure of current information space and locate their results faster.

3.5.4 **Navigating**

Hierarchical folder based navigation is said to be a much preferred approach than query based search when looking for one's own files on one's computer (Bergman, et. al, 2008). According to Bergman et al. (2008), the virtues of the folder navigation approach include: i) it suits people's habit of location based storage and finding, ii) the location of target items and procedure of finding an item is more consistent, and iii) rich contextual cues, such as the directories and items in current directory, make it easier for the user to recall and recognize the correct route.

Unfortunately, the huge amount of data in a PLL will typically make it almost impossible for the user to manually sort their lifelog data into folders. Indeed, an automatic mechanism in an information system is needed to sort them into places, which can be "recognized" and act as context cues to tell the user where they are within their PLL and whether this is right path to the target. To do this, some commonly shared attributes of properties of all types of PLL targets should be used to categorize the data. In order to inform the user that the target item is in a folder, it is necessary that the information about the folder can have some connections to the target (Kensinger, 2004). For example, a folder named "events in May, 2009" suggests to the user that it may contain events in May 2009. If the user remembers the month and year of the target event (or the occasion of accessing an electronic item), he may think that this is the right folder. However, since the traditional folder structure only allows a single location for each item, there can only be one dimension of categories in a single parent folder, e.g. category by month, or category by location. Otherwise, the user can be confused. For example, if at the same level of the folder "events in May, 2009", there are other folders like "event in Dublin", and "events with family", the user may not be sure where to go to find the event of her sister's birthday party which happened on 5^{th}-May-2009.

3.5.5 **Faceted browsing**

Faceted browsing enables users to navigate in multiple dimensions, providing flexibility in browsing based on what the user remembers about the target. For example, one can narrow down the collection by location (one of the remembered attributes of a target), and further narrow it down by other attributes such as date. I suggest that faceted browsing can be a better choice than building hierarchical folder system for navigation in a PLL. Since the faceted browsing process usually involves knowledge of certain facets of the target, to make it easier for users, it is desirable that the most easily recognizable and more reliably remembered features are extracted as facets.

3.5.6 **Utilizing results**

The last step in the five phase framework is the use of the results (Sheneiderman, 2005). Sheneiderman (2005) suggested that systems should allow queries, parameter settings and results be saved and annotated, or even transferred for use in other programmes. That is, making use of the search outcome (not only results) to complete the higher-level tasks which triggered this finding task. As discussed in Chapter 2, people may want to find events and to reminisce on them, share them with friends, retrieve and re-use or transfer electronic items and so on. Therefore, the system should provide functions such as event browsing, file or information sharing, and file transfer. For example, it should allow users to open the items in the file system and manipulate them as they wish, e.g. open and run, or attach them to an email and to send to others. In short, the result should not only be presented like the search results in a web search engine, but also be should be "usable".

3.6 **Chapter Summary**

This chapter reviewed existing literature in information seeking and information refinding, and discussed issues relating to using the traditional information search model to represent general information finding behaviour, including the principle of uncertainty and flexibility of approaches, which are not limited to the search method. A framework was proposed for information finding process in section 3.2.4 which augmented the traditional information search model. This framework describes the IF process as a problem solving task, taking into account interaction with context and flexibility of solutions, e.g., alternative approaches to search, update of information needs and iterative finding process. This framework was applied to the case of IF tasks in PLLs in section 3.4.5, to discuss the factors which influence the choice of methods in finding, including but not limited to: tasks, personal differences, and most importantly, knowledge. In section 3.4.1, I proposed a knowledge-based information-seeking model (KBISM), which describes the process from a cognitive dimension, that is, interaction of internal information space (knowledge) and outer information space (task context and search results) during the IF process.

There are basically three types of knowledge that are involved in a finding tasks:

- *Knowledge of the problem:* the knowledge of the information needs
- *Knowledge of information domain*: features of potential targets
- *Problem solving knowledge*: what information systems are available and how to use these systems to find this information.

The above knowledge comprises of that learnt from task context and that from the ISKer's long-term memory. This knowledge significantly influences the choice of information channel and IF strategies, and evaluation of results (judgement of "relevance"). Of course, the knowledge is also updated by the search outcome, which may lead to updating of the knowledge of the information domain as well as problem solving, and result in another round of finding action with refined queries or alternative problem solving methods.

Based on the KBISM, I discussed how the level of knowledge of "what" and "where" contributes to the selection of tactics and strategies in the finding processes, and how it leads to finding in PLLs, section 3.4.2. Three potential scenarios of information finding tasks in PLLs were predicted based on the knowledge of "what" and "where", in section 3.4.3. This provided further answers to the pre-development question 4.

Based on Shneiderman's (1997; 2005) five-step framework for designing search interfaces, the proposed frameworks for information finding process, and KBISM, I discussed the question of how to support different tactics and phases during finding in a user's own lifelogs, and proposed the following guidelines:

1) To initialize, users need to be reminded of what is in the current information collection and sub-collections (directories), since they don't always have a clear idea of their information needs.
2) While searching, it would be helpful if remembered attributes or features are included in the information system for people to search or filter by.
3) While browsing, the target items, including sources such as the directory or collection of items, should be made easy recognizable.
4) Lifelog data should be automatically structured in a way that can be easily understood and recognized regarding the potential content in each directory. In this way, users can adopt the folder based navigation approach in their PLLs with ease.
5) When the target items are found, the system should allow the user to open the electronic items in their preferred ways, apart from allowing them to view the content of files from the current information system.

It is noticeable that the user's memory of the target and their previous experience with the information system plays a very important role in the process of information behaviour in PLLs. When users know the IF target (e.g. having encountered or used it previously), or when the user knows the information system or information collection, the knowledge involved in the tasks is largely retrieved from the ISKer's memory. Therefore, I hypothesize that:

Better support of the user's memory during the information finding and refinding task will improve the user experience in a PLL information system.

The next chapter reviews relevant literature in psychology to develop a strategy for supporting user's memory by understanding of the features and processes of human memory.

Chapter 4
Human Memory

In Chapter 3, I highlighted the importance of the user's memory in finding information in their own personal lifelogs (PLLs), and hypothesized that supporting the user's memory can result in better usability when accessing their PLLs. This chapter reviews psychology literature about human memory (section 4.1 - 4.6), from which, I develop a set of guidelines for how an information finding system can cater for and support a user's memory in information finding tasks in the user's own PLLs (section 4.7).

4.1 Topology of the human memory system

Human Memory is a cognitive system to retain and utilize information. It takes in information through a biological process called *encoding*, stores information through the mechanism of *consolidation* and make use of the information after a successful *retrieval* process. Before discussing the cognitive models of human memory, and how memory could be utilized or supported when finding information in PLLs, it is essential to understand some basic concepts of human memory, including the types of memory and their structure.

There are two basic systems of memory, *declarative memory* and *procedural memory. Procedural memory* is generally about "how" and *declarative memory* is about "what". Procedural memory is also called *implicit memory*, meaning that it is usually encoded or retrieved with little explicit awareness or mental effort. This type of memory is retrieved and used via performing rather than conscious recollecting. There are several types of the procedural memory, such as *classical conditioning*, skill learning (e.g. learning to ride a bicycle), and *priming* (a phenomenon where an exposure to a stimulus facilitates the retrieval of this information or a related memory unintentionally). *Declarative memory* is what we usually mean by saying "memory". It refers to the memory of information and facts which can be stated or described. It is also called *explicit memory* as it can be explicitly (consciously) recollected. This thesis mainly focuses on declarative memory, including how they are acquired and retrieved. Declarative memory has two major categories: *episodic memory* and *semantic memory*. *Episodic memory* is memory about facts experienced in a specific context. It contains a large portion of temporal and spatial components. *Semantic memory* is memory of concepts, which does not involve any temporal-spatial contexts of encoding. These different memory systems are biologically different. For example, neuropsychological studies have found ample evidence that different types of memory have different mechanisms and reside in different regions of the brain. For example, people who have severe problems with forming new and retrieving old episodic memory can still have preserved semantic memory (Tulving, 2002; Vargha-Khadem et al., 1997). The rest of this section will discuss some of the memory systems, including semantic memory, episodic memory, and memory for time, which is an important element of episodic memory, and autobiographical memory, which is that memory concerns “I”, including both semantic and episodic components.

4.1.1 **Semantic memory**

Semantic memory is the memory of concepts, facts about the world, and generalized knowledge from episodic memory. It is stored in abstract forms such as concepts, rather than as visual, oral or any other perceptual forms, nor is it stored in the form of texts or images. Although it is said to be contextual free, it not only stores individual pieces of information, but also have schemas which organize and associate these pieces of information together. The schemas usually include *scripts* and *frames*. *Scripts* deal with events and consequences of events (Schank & Abelson, 1977), while *frame* concerns the structure and relationships of the things in the world, e.g. a cat is an animal, and a cat has four legs and fur. Schemas allow us to form expectations, fill gaps in what we read or hear so as to help with our understanding, and help us perceive visual scenes (e.g. having a glimpse of the front of a car, one could expect to see four wheels at the bottom). It has been found that people tend to “remember” things better when they are schema-consistent. This is because when retrieving the memory about the scene or event, one re-constructs it based on schema of that category. Therefore, there tends to be a smaller chance of going wrong (loss details or retrieval of the wrong features) when large parts of an object have default values. For this reason, it is easier to “remember” details of things constructed largely with the default values of the category to which it belongs, and easier to learn (and remember) things that are meaningful, that is, things that are largely consistent to the framework of one’s knowledge. On the other hand, people’s retrieved memory of scenes and events can be distorted to become schema-consistent (what things “should” be), unless those features were paid specific attention to when encoded in memory.

4.1.2 Episodic memory

According to Tulving (1973), episodic memory is the memory of "temporally dated, spatially located, and personally experienced events or episodes, and temporal-spatial relations between these events". It contains highly detailed sensory perceptual knowledge of experiences of short time periods (minutes to hours) (Conway, 2001). It has been found that females tend to have better episodic memory than males.

4.1.3 Temporal memory & memory for time

Temporal memory is an important component of episodic memory. Generally speaking, it is the memory of "when". However, this is not simply the same as memory of the date and time of an event. Date and time are just symbolic tags attached to a time point, given that the date or time information was explicitly learnt. Friedman (1993) concluded three types of theories that tried to explain the memory of time: distance-based theory, location-based theory, and relative time (or serial) based theories. The distance-based theory argued that our memory of time is the perceived distance between the time of encoding and the time of retrieval. The location-based theory suggests that time is attached to events when encoding, so people remember the relevant temporal location of event in a period of time, e.g. at the beginning of a time period, a day in a week, time in a day. The relative-time theory claims that people remember the serial order of events, e.g. after Christmas. People sometimes use multiple dating methods, such as combining distance-based and location based, e.g. at lunch time a couple of weeks ago.

4.1.3.1 *Temporal schema*

One example of location-based theory for time is the reconstructive theory, which states that memory for time is structured based on relations with some temporal patterns, which is called *temporal schema* (Larsen & Thompson, 1995). *Temporal schemas* are usually used to reflect the recurrent pattern of time, e.g. time of day, day of week, and seasons of years. Schemas at different levels of temporal scale work independently. For example, people may remember it was in the middle of the week in an evening, but not necessarily remember which season it was. The schemas are usually determined by cultural, personal habits and domain of life (e.g. leisure or work) (Boardman & Sasse, 2004). For example, day of week is location-based temporal information, describing the position of an event in the period of a week. It is mainly reconstructed based on a person's temporal week schema. People can usually distinguish week days from weekends as the context and life are so different (if they work regularly from Monday to Friday). Some people who do not go to work regularly or do their own business at home, may not always know if it is a weekday or the weekend. Their perception of the week can be influenced by people around them, or, for example, when they go out and find all the shops are closed, they can get a signal indicating it is a Sunday.

4.1.3.2 *Memory of date and time*

Date and time are only tags associated with "time" when they are presented at encoding. It has been found that dates are seldom remembered even dates and time that were known at the time of encoding (Brewer, 1988). For example, although the date is usually used and explicitly learned when an event is recorded in a diary, it has been found to be a very bad recall cue and weakly remembered, e.g. (Burt, 1992; Wagenaar, 1986). People usually estimate the date and time based on the temporal relations (temporal distance, sequence) of the target time point and a reference event, the exact date or time of which is known. Of course, this is not always accurate. According to Brown (1985), events that happened at a more recent date tend to be estimated as more familiar. People tend to have better accuracy in referring to time when that period is better remembered, or when there are more landmark events available in their personal memory of that period (Burt, 1992).

4.1.3.3 *Landmark events*

Landmark events are events that are important to a person, and are usually well remembered with comparatively accurate temporal information, e.g. when did it happen. To serve the role as a temporal landmark, the event itself should be well remembered or easily recognized. According to Shum (1998), several factors can make a landmark event: personal importance (e.g. a change point of one's life), emotionality, pleasantness, rehearsal, and predictableness (e.g. scheduled events). For the predictability (i.e. scheduled events tend to be better remembered), they explained that this is because when the event occurs people are better primed or prepared to encode it, and therefore may have better memory of it. People generally have better memory of first time experiences, or the beginning of a period. People do not sample the same number of events in each period of time. For example, students may remember more events in the first month of their university life than the rest of their time at university.

4.1.4 **Autobiographical Memory**

Autobiographical memory (AM) is memory about experiences and facts of one's self. It is usually used interchangeably with "episodic memory". However, it is argued in recent theories that autobiographical memory has both episodic and semantic components, e.g.(Conway & Pleydell-Pearce, 2000; Levine, et. al., 2002). According to Conway (2000), there are basically three levels of specificity of knowledge that structures autobiographical memory, including: i) life time periods, ii) general events, and iii) event-specific knowledge.

4.1.4.1 ***Lifetime periods***

Lifetime periods are long term periods which are distinguished thematically. They usually have an identifiable beginning and ending, although these can be fuzzy rather than discrete. The content of a lifetime period usually includes temporal knowledge about the duration of periods, and thematic knowledge of common features in those periods. For example, in the lifetime period of “when I was working at company M”, the features could be the company, typical experiences in the company (always do …), and some typical scenes in the company (e.g. the building); in another example, “living with X”, the person X may be the thematic feature. Although the period of “living with X” and “working in M company” may overlap, the thematic features of two lifetime periods tend to be indexed as distinct parts of a person’s autobiographical knowledge base. According to Conway (2000), the temporal knowledge of a lifetime period is largely dependent on one’s temporal schema (Larsen & Thompson, 1995; Thompson, 1996), together with landmark events to infer the boundaries and orders.

In short, the core features (thematic knowledge) of a period, the landmark events (such as begin and end events) and other temporal schemas define a lifetime period in a person’s autobiographical knowledge base. Lifetime periods can further relate to higher level themes such as work and relationships.

4.1.4.2 ***General events***

General events are the most heterogeneous of the three. They include both repeated events (e.g. Friday evening meetings) and single events (e.g. a holiday in Spain). General events tend to be goal-oriented, therefore they usually contain information about the results, e.g. success and failure.

4.1.4.3 ***Event-Specific Knowledge***

Event-specific knowledge contains a large portion of sensor-perceptual information of a single short period lasting from minutes to hours. According to Conway et. al. (2000), event-specific knowledge can be accessed in two ways: i) some distinctive or thematic details, ii) the beginning of the event. In both cases, the rest of the details of the event or episode tend to be accessed in a temporal order.

Of course, autobiographical knowledge is not a rigid hierarchical network. A unit event can have multiple themes, and belong to multiple general events. A general event can belong to multiple lifetime events. Figure 4 shows examples of the structure of autobiographical memory and samples of this level of autobiographical memory.

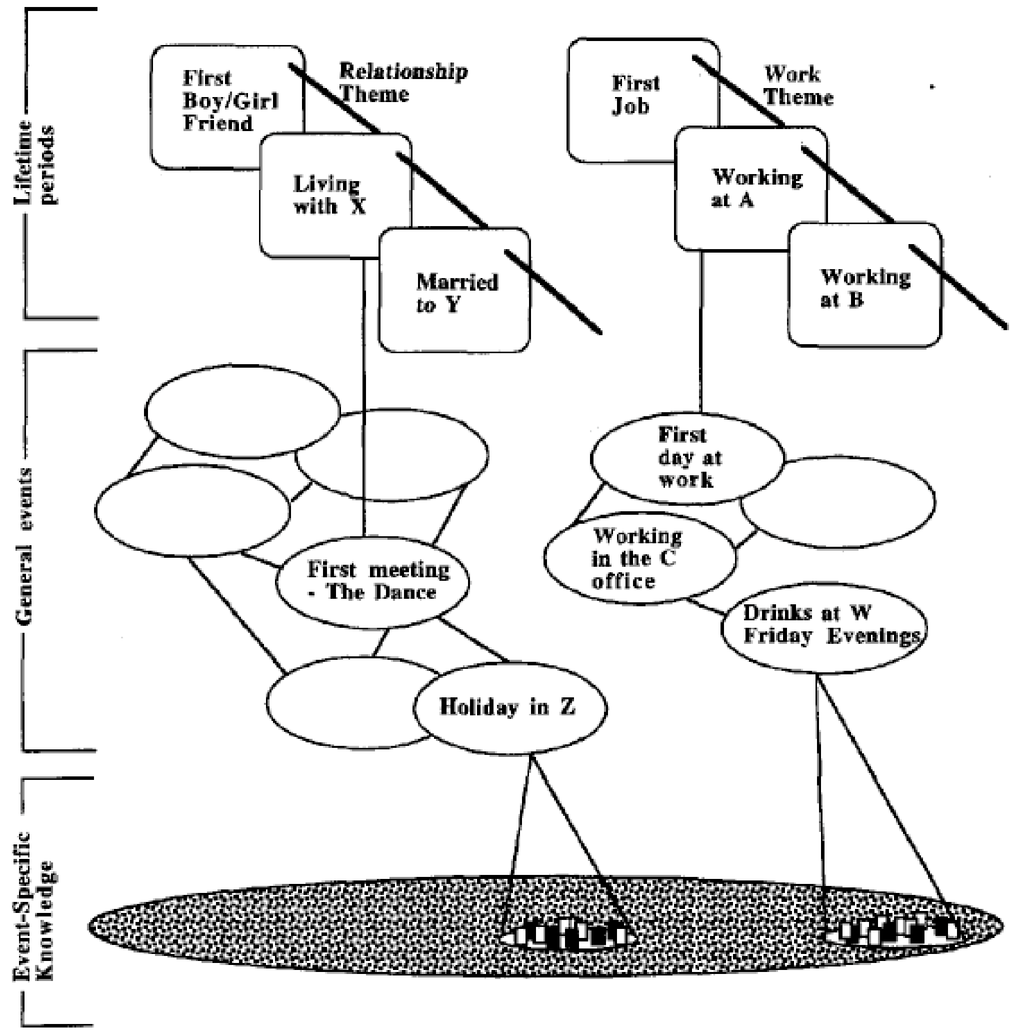

Figure 4 Relation and cueing in Autobiographical knowledge base[4]

4.2 **Models of the Memory Processes**

There are many cognitive models which attempt to explain the mechanism of human memory progress. Although there is not yet a complete model that can explain all the phenomena of the human memory, some of well-established models can approximately predict the strength or

[4] This figure is taken from (Conway & Pleydell-Pearce, 2000).

accuracy of memory. Most of these models are built on empirical observations, and have successfully been used to explain many phenomena. In this section, I adopt the *associative memory model* (section 4.2.1) as the base theory, and review related models which explain the how memory is acquired, stored (section 4.2.2), consolidated (section 4.2.3) and prepared for retrieval (section 4.2.4). Based on these models, I discuss the factors that influence the likelihood of remembering a piece of information (in Section 4.2.5 and 4.2.6).

4.2.1 The associative memory model and memory cues

The associated memory model assumes that a human's memory is a complex network with interlinked nodes of atomic units of memory, called memory traces or engrams (Anderson & Bower, 1980). This means that the objects or events which we usually consider as a single entity are not stored as a single whole in our memories, but rather as a network of interlinked engrams. The information or stimuli that activates a memory trace is called a cue. Cues are extremely important for retrieval of memory. A memory trace can also act as a cue to retrieval of its associated nodes (memories). The activation of one node (memory trace) may spread the activation to all its linked nodes. The stronger the link, the less energy will be consumed to spread the activation, and the more likely it is that the linked memory trace can be activated. There are two types of associative memory: *auto-associative memory* and *hetero-associative memories*. *Auto-associative* memory refers to the phenomenon where we remember a big piece of information as a network of small linked pieces of memory, presentation of part of the information can trigger the memory of other parts. For example, we do not remember an event as a whole, but remember various attributes of it such as the person involved in it, the visual features we saw around that time. *Hetero-associative* memory refers to the networks of inter-linked independent items. For example, the association between a fish and a cat, or an email and a person are hetero-associative associations.

4.2.2 Encoding

All the information in our memory is acquired through encoding. Traditionally, memory storage is believed to form through three stages: the sensory buffer (also called sensory registry), short term, and long term. These stages are distinguished in their capacity, duration of holding the information and most fundamentally, their biological basis.

The *sensory buffer* is the briefest form. It is the residual sensory neural activities which hold sensory impressions of stimulus for up a few seconds. Sensory memory can usually hold a large amount of information from each sensory channel, e.g. *iconic memory* for visual stimuli, *echoic memory* for auditory stimuli (sound) and *haptic memory* for touch.

The *short-term memory* (STM) usually lasts up to around 30 seconds without rehearsal. The classic theories about STM suggest that there is a limited capacity for a person's STM that it could only hold about 7±2 items. For example, only a very limited number of words (or syllables) can be retained for spoken material, and even a four-by-four checkerboard grid is enough to overload visual short-term memory. The information can remain for a longer period through rehearsal.

According to the theories of working memory, there are multiple channels of STM which hold independent resources. *Working memory* (WM) is the cognitive system which is responsible for providing temporary storage and manipulating necessary information for such complex cognitive tasks as encoding new knowledge, retrieving from memory, language comprehension, reasoning, and mental problem solving. It is important for both encoding and retrieving stages. According to Baddely (1992; 2000), WM is comprised of multiple components including two short term storage channels (sub systems) for visual-spatial and acoustic (sound, speech based) information respectively, an *episodic buffer* which aims at linking newly incoming information with what is already in long term storage, and a *central executive* which assigns its limited cognitive resources, in particular, attention, to the above sub-STM systems. The existence of the episodic buffer in WM means that once a group of information has been encoded: i) it is usually stored in the form of linked pieces of elements in an associative network with other pre-existing small pieces of memory; ii) it will not always remain in the same group as it was before since new pieces of encoded information can join them.

Long term memory (LTM) is a vast and almost permanent storage that can last for a lifetime, e.g. memory about your childhood. It is believed that memory traces do not fade away, but can be interfered with and made difficult to retrieve. There is another stage between short term memory and permanent long term memory, called *intermediate-term memory*. This type of memory lasts longer than STM, but is still far behind long term memory storage in duration, e.g. remembering what you had for lunch a couple of hours ago is intermediate memory, and remembering what you had for lunch the same day two years ago is long term memory. This type of memory can be transformed to permanent storage through a process called *system consolidation*, which I will talk about in the next subsection.

During encoding, external stimuli are perceived via sensors, briefly stored in a sensor buffer, and selectively processed in short term memory in the sensory areas of the cortex. The activation of certain areas of the cortex can trigger older memory traces that are stored in that area. These memory traces are usually sensory perceptual details of episodic memory which have been consolidated and moved backed to be stored here permanently. In this way, new information can be associated with older memory traces and be integrated into the associative memory network.

4.2.3 Consolidation

Consolidation is the process of stabilizing a memory trace after encoding (McGaugh, 2004). There are two types or stages of consolidation: i) *synaptic consolidation*, which occurs within the first few hours after encoding, forming recent long term memory in the hippocampus (an important organ in the brain that is responsible for memory); and ii) *system consolidation*, which takes place over a period of weeks to years after the synaptic consolidation, moving the memory from the hippocampus to the neo-cortex (another part in the brain, at the outer layer of cerebral cortex, responsible for sensory and executive functions) for a more permanent form of storage. This means that remote long-term memory may be stored differently from that of recently formed memories. In some amnesia patients with hippocampus impairments (usually temporal lobe degeneration, that is the volume of this area of the brain is shrinking, it has been found that their remote memory (e.g. interesting events 20 years ago) are still intact, while the patient may have little recollection of what they did two hours ago or what happened last week. The consolidation mechanisms suggest that when designing information systems which involve user's long term memory, the difference between recent LTM and remote LTM should be considered. For example, different supporting functions may be designed for tasks which require recent memory (intermediate term memory of things that happened recently, e.g. a few hours ago or in the last couple of days) from tasks which require long term memory (e.g. what happened a couple of years ago).

Re-consolidation is the process in which previously consolidated memories are recalled and actively consolidated again. In order to retain information that was acquired many years ago, reconsolidation is essential. Re-consolidation is usually carried out by mentally reviewing the memory trace (through memory retrieval) or re-exposure to the stimulus. The retrieval of memory makes memory traces active as well as unstable, and prepares the memory trace to be updated and linked to other ones. This mechanism means that our memory changes from time to time, with the result that it can become “distorted” or elaborated.

4.2.4 The Retrieval Process

Retrieval of memory is involved in most of daily tasks, since almost all our activities require our “knowledge” based on our previous experiences. There are basically two types of retrieval tasks: *recall* and *recognition*.

The recall process actually *reconstructs* rather than retrieves an entity or event. The brain fetches many associated pieces of memory traces and reconstructs the entity or event with these fetched pieces of memory according to certain schema. Since the links between memory traces keep being updated when new information arrives and is integrated into the network, the recalled object is different from what was encoded, and from what was recalled previously.

Recognition memory is the ability to decide whether one has encountered a stimulus previously in a particular context. It adopts a dual-process model, combining familiarity and recollection. *Familiarity-based recognition* simply judges whether the stimulus is familiar to you or not, yielding a perception of the memory trace’s strength, without the need to recall the particular experience. *Recollection* involves the retrieval of memory of the context under which memories were acquired (information was learnt), which is called *source memory* (Johnson, et. al,. 1993). These contextual details include spatial, temporal and social context, and the modalities through which the events were initially perceived, e.g. visual, verbal, haptic or tactile. For example, sometimes you could hum a few bars of a familiar tune, but could not recall what song that they are from and where you heard them previously (or learnt) this tune. Remember/know is one of the most often used methods for testing of source memory and distinguishing these two processes, namely, recollection and familiarity based recognition respectively (Tulving, 1985; Yonelinas, 2002). For tasks that require accurate recognition, the easier and more completely the specific circumstances can be recalled, the more likely it is that it can be recognized correctly. There are two types of errors for recognition memory: misses and false alarms. The former means a failure to recognize a stimulus that was actually encountered or learnt, while the latter refers to a false judgment of encountering an item under a certain circumstance, which did not actually happen.

For both recalling and recollection (in recognition memory), people seek specific pieces of memory traces, called *target memories*, or *target traces*. We usually have some idea of the target traces when we want to retrieve (Anderson & Neely, 1996). Such ideas, which are either generated from external stimuli (cues) or from other memory traces (e.g. during free association, imagination), act as cues which trigger the associated memory, and these memories may trigger their associated nodes. However, not every associated memory trace can be retrieved. *Spreading activation theory* (Collins & Loftus, 1975) assumes that there is limited activation or energy available to spread and activate associated memory traces. The activation keeps on spreading until the energy or resource is fully consumed. It argues that the energy cost on each link depends on how closely the two nodes are linked. Therefore, the stronger the link, that is, the more closely two memory traces are associated, the more likely the activation can be spread on to its neighbour memory traces.

The *Search of Associative Memory* (SAM) model (Raaijmakers & Shiffrin, 1981), holds a different view, arguing that memory traces automatically and randomly pop out into a conscious awareness after the retrieval process from long term memory is initiated by a cue. The probability of being sampled depends on the strength of association between the cue and the item being retrieved. The stronger the association, the higher the probability is for an item to be retrieved. This model argues that the longer and more often the items occurred together, the more strongly they will be associated. Thus, the strength of the association between a memory trace of an item and a specific context is determined by how long the item is present in the context.

The *Adaptive Control of Thought* (ACT) theory argues that the probability and speed of accessing a memory trace depends on its activation level, which is determined by both the *base-level activation* (the possibility and speed of a memory trace being retrieved without any triggers from an associated node), and the activation received through the associated node (reviewed in (Anderson et. al, 2004)). They proposed a formula to predict the activation level of a chunk of memory trace (Ai) as shown in the first equation below. Bi is the base-level activation of the chunk i, the Wj's reflect the attentional weighting of the elements that are part of the current goal, and the Sji's are the strengths of association from the elements j to chunk i.

$$A_i = B_i + \sum_j W_j S_{ji},$$

Every time a node is activated, its activation level increases. If the actions spread to its associated nodes, the links between these memory traces and the nodes that the activation spread to are also boosted. For this reason, the pre-activation of a node (e.g. one saw item A) can accelerate the spreading speed if an item directly or indirectly linked to A is presented later. So for example, when one saw the word “doctor” in one list, the word “nurse” is likely to pop into one’s mind when asked to think of a word starting with “n”, if the word “nurse” is associated with “doctor” in one’s memory.

However, according to Conway (1994), the recall task is an effortful process, which requires attention resources to retrieve specific memory traces. If one node received enough activation to get into conscious awareness (WM), the activation of other associated routes can be inhibited (Anderson & Neely, 1996). Therefore, attention and effort is needed to monitor, inhibit and guide the direction of activation spreading. In order to let the person retrieve the required memory traces with less effort, proper cues are needed to activate the nodes that are strongly associated with the target traces, but weakly associated with others. This means that the cue should be distinctive to the target trace.

In short, retrieval is a process that brings pieces of memory traces to re-construct a scene or event in one’s mind. Recollection, which is the more accurate way of recognition memory compared to familiarity-based recognition, also requires the retrieval of rich memory traces such as the context of experience. The likelihood of memory traces being retrieved (if they exist in one’s memory) depends on the activation level. The activation level is not a static value, but changes dynamically, depending on the base activation level of the memory trace itself and the additional activation spread to it from its associated nodes, which is further influenced by the strength of the links and cues. The stimuli that activate the memory traces are called *cues*. The next section dives deeper into the memory literature to explore the factors that influence the base activation level (in section 4.2.5) and strength of activation received from the associated links and cue memory traces which it receives the activation (in section 4.2.6). Based on these, I further explain the memory problems and, based on these, discuss possible supports to people’s memory.

4.2.5 **Strength of memory trace and associations**

There are several theories which seek to explain and predict the factors that determine or reflect the base level activation. This subsection reviews and discusses some of the most well established theories or hypothesis.

4.2.5.1 ***Chance of encoding and attention***

Since short-term storage has dramatically smaller capacity than the sensory buffer, only selected information can be processed and stored in our memory. According to the *time-based resource sharing model* (Barrouillet, Bernardin, & Camos, 2004), the time allowed for processing each item (or the rate of incoming information) and the resources required for processing each item determines the amount of information that can be remembered. For example, it is more difficult to hold 7 phrases than 7 digits, and it may be more likely to remember 7 digits if they are presented every minute than if they are presented every second. In short, the less cognitive resources that are required to process the information, and the more abundant the time and resources that are available to process the information, the more likely it is to be retained in WM, and finally to get access to long-term storage.

One important and frequently used mechanism or strategy to “expand” WM capacity is called *chunking*. Chunking does not make a person’s short-term storage capacity bigger, but instead, it compresses the incoming information by grouping them into larger units. For example, instead of holding O-N-E-T-W-O-T-H-R-E-E-F-O-U-R as 15 digits, one chunks them as a 4 item series, one-two-three-four. In this way, the WM only needs to hold 4 digits. This explains why it is easier to hold a series of known words or familiar names than new words or foreign names. For new words, one remembers them letter by letter, or syllable by syllable, but for known words, one holds each word as a whole, and the cognitive load is consequentially much lighter.

The WM system is an essential path for us to gain new knowledge. Things that we paid more attention to or spent more time and effort processing, have a better chance to pass into our long-term memory. Owing to the chunking mechanism, the things that we are familiar with tend to be more likely to be encoded than the same amount of information in which no elements are familiar to the person.

It is generally believed that attention is important for selective encoding of information into memory. There are generally two types of attention regarding the involvement of intention: overt and covert attention. *Overt attention* is to explicitly direct one’s sensors to something. *Covert attention* is drawn passively by the target item, rather than by the person’s intention. Since the former type may repeatedly require cognitive resources (in WM) to control or supervise direction of attention, the cognitive load is higher than covert attention. Our memories of daily life and our environment usually come from information which was covertly attended to, while the semantic knowledge we learn (e.g. what we learn in classes, or from books) usually requires overt attention. Therefore, it seems that we tend to remember more personal experiences than the knowledge we learnt in middle school.

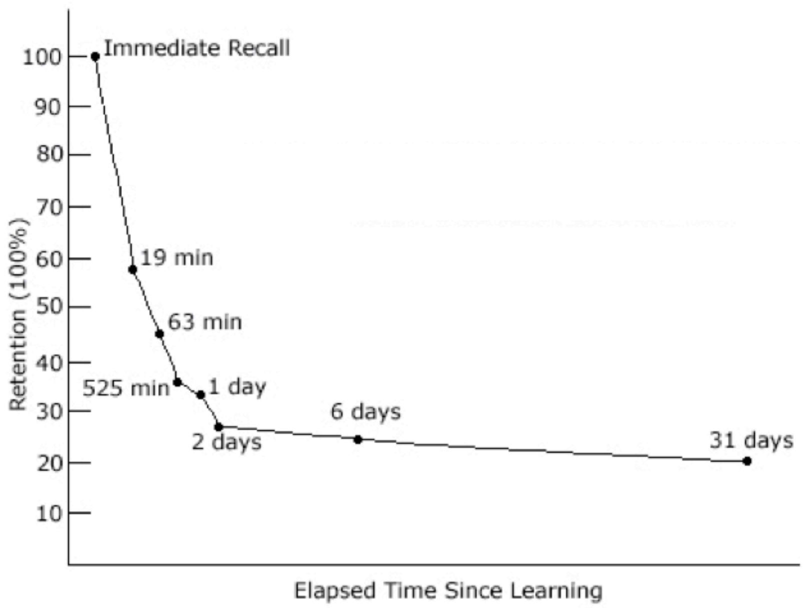

Figure 4.1The Ebbinghaus Forgetting Curve

4.2.5.2 ***Recency: the forgetting curve***

Although it is believed that forgetting is not due to the fading away of memory as time goes by, it is generally true that the longer from the time of encoding, the less likely a memory trace is to be recalled. For this reason, I believe that recency can also act as an indicator for the strength of a memory trace as well as the association of two memory traces.

According to Ebbinghaus (see the review in (Baddeley, Eysenck, & Anderson, 2009) for more details), the likelihood of recalling newly learnt knowledge decreases as a function of time (the power law: $R = e^{-\frac{t}{s}}$, with R being the ration of retention and S being a relative strength of memory). Figure 4.1 shows an example of the Ebbinghaus Forgetting Curve. There tends to be a rapid decrease of activity level of memory traces before the consolidation, in the first few minutes, hours and days, with the rate of deterioration becoming less noticeable afterwards (after the first few days). Of course, the forgetting curve originally described the statistical pattern of percentage of memory traces that remain (can be recalled). Statistically, it can also be considered that the longer ago an item was last encountered, the less likely it can be retrieved. However, if an old piece of information (encountered 10 years ago) is remembered, it is less likely to change or be forgotten than information encountered 10 minutes ago. There may not be a big difference of memory traces consolidated a year ago and those consolidated two years ago, regarding the recency effect.

4.2.5.3 ***Repetition (rehearsal)***

Repetition is believed to be one way of increasing the strength of a memory trace as well as associations between memory traces. As described earlier in section 4.2.4, every time an item is retrieved and reactivated, the activation of the item and the links which spread the activations are boosted. This means that the more often one attends to a piece of information, the more likely the information is remembered. Similarly, mentally rehearsing a piece of information can also improve the strength of corresponding memory traces and associations that link them. Repetition can also reinforce memory of associations. For example, the association of the word "chair" and "red" can be boosted if they are encoded together several times. According to the SAM theory (described in section 4.2.4), things that are held in WM for a longer total time (the sum of all the length of time for each encounter) tend to have stronger association. Therefore, it can be assumed that things that occurred together more often tend to act as better memory cues for each other.

The effect of rehearsal is subject to the *spacing effect*. That is, the bigger the interval between each rehearsal, the better the memory trace is remembered (review (Hintzman, 1974) for more details). For example, an item one learnt twice with an interval of a month tends to be better remembered than one learnt twice within an interval of 10 minutes. The mechanism behind the space effect may be: i) longer intervals allow more time for processing, ii) there is more chance of re-consolidation, and iii) can be more elaborately processed as longer intervals can expose the items in more diverse contexts, which in return, provides the memory trace a greater possibility of being triggered with contextual cues.

4.2.5.4 ***Depth of processing***

The *depth of processing theory* argues that the more deeply and elaborately a stimulus is processed, the better it tends to be retained (Craik & Lockhart, 1972). *Elaboration* is the process of creating links between newly encoded information with previously stored memory traces. One explanation is that the elaboration process links the memory trace with many other memory traces, which gives it a greater chance of being triggered and getting a greater total spreading activation level. It has been suggested that a stimulus will have a greater strength if it is highly compatible with existing semantic structures (Craik & Lockhart, 1972). This is because existing semantic structures can facilitate it to be elaboratively processed by connecting it to other nodes in the structure. For example, it is easier to learn a regular word than learning a non-word or a foreign word. Similarly, information related to oneself was found to be better remembered. This is called the *self reference effect*. One explanation for this effect is that "self" is a well-developed and often-used *schema* that promotes elaboration and organization of encoded information (Baeza-Yates & Ribeiro-Neto, 1999).

4.2.5.5 ***Emotion***

It has been found that people tend to have better memory for emotional information. Emotion has two dimensions: valence (pleasantness) and arousal (exaltedness). Numerous evidence has suggested that emotionally arousing experiences or objects tend to be well remembered. Emotion influences memory via the following mechanisms:

1) Emotion in encoding

It was found that emotional-arousal stimuli are more likely to attract attention than neutral stimulus. Since things that one attends to may be more likely to get encoded, the emotional stimulus has a better chance to be encoded and stored in one's memory (see (Kensinger, 2004) for a review of this work). According to Kensinger (2009), negative emotion tends to be associated with increased engagement of sensory processes, and positive emotion tends to enhance recruitment of conceptual processes. Therefore, it can be assumed that negative stimuli tend to be remembered with more sensory perceptual details (in episodic memory), while positive information tends to be encoded better conceptually (in semantic memory).

2) Emotional and consolidation

Neurology studies (e.g. (Cahill & McGaugh, 1998)) have found that there are certain types of neuron-transmitters which can affect the consolidation of memory traces. Emotional-arousal information is more likely to become permanent traces, while non-arousing memories are more prone to disruption. Yet, non-arousing information with either negative or positive valance tends to be elaborately processed, and therefore better remembered.

3) Mood-congruency and state-dependency effect

Studies also found that it is easier to retrieve information that is encoded at the same or similar mood status as the person has at the time of retrieval. This is called the mood-congruence principle (Bower, 1981). For this reason, depressed people tend to recall negative experiences or objects, while people in a happy mood tend to recall pleasant experiences or information. Thus depression could become more severe with accumulated memory of negative mood. Also, people tend to recall information that is encoded at the same mood status, in particular the same valence (happy or sad), regardless of the emotion features of the information itself. This is called *state-dependent effect* (see the review in (Blaney, 1986) for more details).

4) Valence and retrieval

It has also been found that retrieval of episodic memory is usually biased in favour of pleasant information (Walker et. al., 2003), when free recalling events that happened in the past, one tends to recall more of the positive events than negative ones. One explanation for this effect is that people tend to review pleasant experiences more often, and that the rehearsal of these experiences contributes to better maintenance of these memory traces, through re-consolidation.

5) Temporal adjacency and strength of association

You may have the impression that things learnt one after the other another tend to be associated, e.g. each being cued by the presentation of one another. According to the SAM theory (Raaijmakers & Shiffrin, 1981), things encoded together tend to be associated. Yet, this does not necessarily mean that things which occur together are encoded together. In fact, it has been found that people have poor judgement regarding the temporal relation of two events (e.g. for whether they are in the same week), if the events are not related in any sense apart from the temporal adjacency, but much better judgment when the events are related (Friedman & Janssen, 2010). Of course, since temporally adjacent events are more likely to take place in the same or very similar context, these contextual cues may equally trigger all these events. Similarly, when one of the events acts as a cue, memory of the shared contextual information can be triggered, and eventually, memory of other events that happened in similar contexts may be triggered. In short, temporal adjacency itself does not create any association between events, unless the events are related, sharing some common features or if some aspects of the events are processed in WM together.

4.2.6 The activation from Retrieval Cues

According to the theory of retrieval, the likelihood and easiness of a memory trace being triggered also depends on the activations spread from its associated nodes, which are activated directly or indirectly by external cues. This subsection discusses the factors that influence the strength of cues.

1. *Number of Cues*

According to the formula of ACT (as reviewed in section 4.2.4), the more relevant cues that are presented, the higher overall activation level a node can get at retrieval. Of course, each cue may have varied strength.

2. *Distinctiveness of Cues*

The *fan effect* is the phenomenon that the more traces that are associated with a memory trace (node), the slower and less likely is the retrieval of any of these traces when this node is activated and acts as cue. That is to say, the more distinctive the cue is, the more likely it is that it can trigger its associated memory traces. According to the *feature overwriting theory* (see the review in (Oberauer & Lange, 2008)), items which share the same features, will be linked to a shared node (about the common feature). The more information shares the same feature, the less distinctive the feature is, and the less strength it can spread to its associated memory traces.

3. *Modality and Form of Retrieval Cues*

For stimuli to directly activate certain pieces of memory traces, it should be presented in the same modality and format as the memory trace is presented. As discussed in section 4.2.3, memory of sensory-perceptual information is consolidated and stored in the brain regions where it was first encoded. This means that in order to activate perceptual memory traces directly with external stimuli, the stimuli should activate the same region of the brain, which means that they should be in the same form, e.g., visual, verbal. According to semantic encoding theories, we tend to grasp the ideas and store these in our memory rather than the perceptual details, e.g. the exact shape or colour of the text, or the exact words used in a talk. These are found in story re-telling studies that participants usually cover the main points of the story without recovering the exact words (Tabbers,et. al., 2004).

4. *Contextual cues*

When searching for a target in memory, we usually have some idea of what we are looking for. These initial ideas act as cues to further spread and get more details about an object, scene or event. These ideas are usually triggered by the context at the time of retrieval.

Contextual cues are retrieval cues that specify certain aspects of the conditions under which a desired target was encoded, e.g. the location and time of an event. As for encoding, context refers to the circumstances where a stimulus is encoded, and as for memory of digital items, the specific circumstances under which an item is encountered. Since many aspects of the context or information in the context may be encoded together with the target memory traces, contextual information can also be associated with target memory traces. Therefore, if more of the context at the time of retrieval matches that during encoding, more memory cues would be available to trigger the target memory.

Researchers have claimed that a cue needs to be presented at encoding for it to be useful (Dourish et al., 2000). This means that it is more likely that some information which occurred at the time of encountering a piece of information tends to be a better cue than information which was not present. The phenomena that people tend to have better recollection in a similar context as that during encoding is called the *encoding –specificity principle*.

5. *Attention at Retrieval*

A retrieval cue is less effective if it is presented but not attended to, as it could hardly enter the mind to spread any activation. Attention can be directed by the goal in WM (Desimone & Duncan, 1995) (a top-down process, also called *selective attention*) or by salient stimuli (a bottom-up process, that the attention is attracted by various stimuli). When browsing a search result list to locate a refinding target, some features of the target, which the user retrieved and holds in his or her working memory, direct the attention. When browsing a photo gallery freely for anything that may be interesting, one is more likely to be attracted by objectives with salient features.

6. *Retrieval Schema*

It is suggested that people might often adopt a viewpoint when recalling the past. The perspective provides a schematic structure that guides retrieval, constraining our recall to things relevant to the schema (Anderson & Pichert, 1978). This means, information which fits the schema tends to be recalled. Thus, if material is not organized in schema “A” when encoding, it is less likely to retrieved when using schema “A”.

4.3 Memory problems and explanations

While memory is structured in a way to make much information easy to retrieve, it has quite a few problems too. To better support the user's memory, it is important to understand the general problems with people's memory too. Most of our daily memory problems are declarative in nature. Although most memory problems can only be observed during retrieval, due to the fact that current techniques are not advanced enough to know what is happening in the human mind, failures at any stage can cause problems in memory. For example, failure to encode encountered information makes the information unavailable in one's memory.

4.3.1 Seven sins

Schacter (1999) characterizes seven daily memory problems including: *transience*, *absent-mindedness*, *blocking*, *misattribution*, *suggestibility*, *bias*, and *persistence*. Table 4-1 shows the definitions of these seven sins of memory. The sins generally fall into three categories of memory problems, namely: forgetting (transience, absent-mindedness, blocking), false or distorted memory (misattribution, suggestibility, bias), and the inability of forgetting (persistence).

Table 4-1 Seven sins of memory

Sins	Meaning
Transience	Gradual loss of memory over time.
Absent-mindedness	Incapability to retrieve memory due to lack of attention while encoding the information.
Blocking	Failure to retrieve encoded information from memory due to the interference of similar information retrieved or encoded before (proactive) or after this (retroactive).
Misattribution	Remembering information without correctly recollecting where this information is from.
Suggestibility	Reconstructing a set of information with false elements, which are from the suggested cues at the time of retrieval.
Bias	People's current retrieved or reconstructed memory is influenced by their current emotions or knowledge.
Persistence	Inability to forget things which one wants to forget.

The remainder of this section explains the mechanisms for these memory sins (problems), and discusses possible solutions that PLLs can offer.

4.3.2 Memory problems induced by encoding failure

Encoding newly encountered information or thoughts needs to process them in WM. The absence of attention can reduce the encoding efficiency or even cause encoding failure of some information input at that time (this is the so-called "absent-mindedness" in the seven sins of memory). Information that was paid more attention to is more likely to be better encoded and therefore more likely to be better remembered. It has been suggested that emotion can often influence attention at encoding, and therefore influence the memory of items.

4.3.3 Forgetting at retrieval

Forgetting generally describes the inability to retrieve required pieces of memory. It can be caused either by poor encoding or failure at retrieval. It was previously believed that forgetting is due to the decay of information in long term memory, experimental examples including the famous Ebbinghaus forgetting curve (see section 4.2.5.2), which describes the memory loss as a function of time, and can be retained longer only through repetition or rehearsal. The *interference theory* has challenged the decay theory, and is widely accepted as the most important reason for forgetting. This theory argues that forgetting is a matter of retrieval failure that items in long term memory are kept intact once they were stored (see the reviews in (Anderson & Neely, 1996; Anderson, 2003)).

There are three types of interference: proactive, retroactive and output interference. *Proactive interference* describes the effect that existing memory prohibits the in-take of new memory. This interference is said to be caused by the capacity limit of WM. *Retroactive interference* is when the retrieval of previously learned information is impeded by newly (recently) acquired memory. It is particularly obvious in procedural memory, such as motor skills and language. For example, recently well-practised movements may block the retrieval of similar types of movements which have not been practiced lately. *Output interference*, also known as "retrieval-induced forgetting" (Anderson, Bjock, 1994), is when the retrieval of pieces of memory are "blocked" by a previous retrieval action. This is what Schacter (1999) calls "blocking". This type of interference is due to a mechanism that information competes to get retrieved in WM. One popular example of *output interference* is "tip of the tongue", which describes the phenomena that one cannot recall a familiar thing, usually a name which the person knows well, but feels that the memory is being temporarily blocked. Since one node of memory may be linked to several other nodes, it is important that only the required information be triggered. Thus, inhibition is an important function of human memory.

4.3.4 Misattribution and false memory

False memory, meaning memory errors or inaccurate recollection, is another problem due to the mechanism of retrieval from the associative memory network. Since the retrieval of entities or events involves a reconstructive process which associates memory traces that fits to a certain retrieval schema, the bias and error in assembling the information can cause misattribution and false memory. False memories can bring various problems in daily life. For example, "misattribution" of witnesses can cause serious legal problems if a witness does not know whether the source is from reality or a dream, on TV or even imagined. Since PLLs store some fractions of facts, it may help in justifying error reports from reconstructing memory with wrong elements.

4.3.5 How can we forget?

While there are many pieces of information that we are sometimes desperate to remember, such as the answers while taking an exam, forgetting is itself important function (Bannon, 2006). Among many of its functions, one important thing is to relieve people from sorrow or traumatic past experiences. However, these unwanted memories do not simply fade away. Schacter refers to this as "the sin of persistence" (Schacter, 1999). The main reason for "persistence" is that some unwanted and sometimes even traumatic memories, are so well encoded (due to the emotion at the time of encoding), rehearsed and consolidated, that they cannot be buried or erased, just as other memory traces that the individual would wish to remember. However, undesirable memories can be temporally "blocked" if external cues can trigger memories of other experiences, ideally happy experiences, while these unwanted memories are about to be prompt into conscious awareness. Similarly, it can be helpful to reduce the activation level of these memory traces and make them less competitive at the point of retrieval by reinforcing memory of happier experiences. For example, with PLLs, people can be presented with happier experiences in different contexts or with a rich variety of information, which could enhance the likelihood of retrieving these memories as they have been rehearsed and associated with more cues.

4.4 Summary of the human memory mechanism

So far in this chapter, I have introduced the basic concepts related to human memory, reviewed the topology of the memory system, the processes used in acquiring and retrieving memory, factors that influence memory, and typical problems of human memory. Memory is a mental system that encodes, stores and utilizes the information that a person encounters and experiences. The information in memory is not encoded and retrieved as a whole, but stored as and reconstructed (when retrieving) from small pieces of memories (called engram or memory traces) in an associative network, with the person's general knowledge (schemas) and expectations (goals for retrieval) to fill in blanks when recalling. In the associative memory network, memory traces are linked from one to another for various relations, e.g. belonging to the category, part of, accompanied, and following, etc. When one node (a memory trace) in the memory network is activated, it spreads the activation to its linked memory traces and so on.

According to associative memory theories (see section 4.2.1), the likelihood that a memory trace can be retrieved depends on its activity level at the time of retrieval. The activity level can be considered as the sum of the base activity level of the memory trace itself and activations it received from its associated nodes. The stronger the association, the faster the activation spreads and the greater activation it receives. Several factors contribute to the strength of the links and the activation level of memory traces, including: *attention* at encoding, *emotionality*, *rehearsal* (repetition, with the *spacing effect*), *recency* (how long ago was the last time it was encountered or rehearsed), and *depth of processing* (how elabaratively the memory trace is processed). For two memory traces to be linked, they should have been encoded (presented in the WM) together. This means that things that are presented at the same time or one after another in adjacent time are likely to be associated. For this reason, information about the context (location, weather, background), in which some information is encountered, is usually associated with the memory of the information. The information about the associated context is called *contextual cues* if it is presented at the time of retrieval.

At the time of retrieval, the more nodes a memory trace links to, the less power or energy that it can spread to each of them. Therefore, the more distinctive the information (e.g. the less items share this feature), the greater activation it can spread to each of the linked memory traces, and the stronger cue it tends to be. On the other hand, the more activated nodes that link to a memory trace, the greater activation the memory can get, and the greater chance that it can be triggered and pop into conscious awareness (be retrieved). For this reason, a person is more likely to have better recall when he or she is in the same or very similar context, as many things in the context can act as cues to activate corresponding memory traces (of the environment) which links to it. This phenomenon is called the *context-dependent memory*. Emotion and physical status seem to be encoded as memory traces together with other information encountered under the status. Therefore, people tend to have improved retrieval performance when under the same or similar emotional or physical status as that at encoding. These are called *mood-congruent* and *state-congruent* effects. Therefore, the cues that trigger a person's memory not only include the items or stimuli provided by the task, but also the environment of the task and the internal status of the subject.

After the memory traces have been retrieved, they are put together to mentally reconstruct the information or events that happened in the past. The reconstruction is based on a person's general knowledge of the world, e.g. what things are generally like, how they work. Since people's general knowledge develops or changes over time, the memory retrieved today may not be exactly the same as it was when retrieved a year ago, and from that retrieved a year afterwards. The difference is not simply a matter of more or less detail due to the fading of memory traces, or by coincidence that some different cues help them to retrieve some other aspects of the target, but also how they fill in the gaps with their current knowledge base to reconstruct the information and events. Because of this mechanism, people can reflect on their past with the cues from different perspectives, getting different feelings.

4.5 Implications for designing information accessing systems in PLLs

Based on the human memory mechanisms reviewed above, we can foresee several potential problems when a person tries to access his or her PLLs. Some examples are: memory failures in recalling specific features of encountered information and generating proper queries for search, or difficulty in recognizing the correct target. This section discusses the possible problems and corresponding potential solutions for people's memory in accessing their PLLs, including: how is memory involved in each step, what do people tend to remember about their encountered information, and the presentation of autobiographical memory.

4.5.1 Memory at each stage of information finding in PLLs

In Chapter 3, I proposed a framework and highlighted the following steps and subtasks in which a user's knowledge (memory) is needed to complete the task: initialization, query formulation, location-based navigation and recognition of potential targets. In this subsection, I further explain how the user's memory is involved in accessing their own PLLs and discuss the possible solutions.

4.5.1.1 *Initialization*

At the initialization stage, when a person wants to get something out of his or her PLL, there are basically two situations: i) there are some specific targets in mind, either being events, electronic items or pieces of information; ii) there is no any specific things in mind to look for, but the user is looking for something to kill time or for emotional comfort. In both cases, the information needs are usually triggered by the context (e.g. being asked to find something, current problem requires something to solve it, or some items in the context triggering a desire for something), or status of the person (emotional status, e.g. feeling bored or nostalgic). The initial cues activate corresponding memory traces which spread the activation to their associated nodes until enough details have been retrieved to construct the "target", or until the person is tired of recalling even before any useful memory traces are found (activated).

For example, I may be asked to show some photos of my most enjoyable holidays. The word "holiday" may trigger all memory traces associated with the "holiday" node, including the theme of holiday (my general impression of holidays), general events under the holiday theme (e.g. a holiday in Spain), event specific items or scenes which are encoded with the concept of "holiday" (e.g. a souvenir), any object with a noticeable text "holiday" on it, or scenes in which the word "holiday" is mentioned. If no satisfactory memory traces pop into mind (e.g. a photo or a group of photos taken in some holidays), one may follow one path of traces to further search for any existence of memory traces about photos for "holiday". For example, if the person chooses the "theme" path, he may mentally search for visual images of photos which have such features of a holiday in it, e.g. blue sky, a bunch of smiley faces. Of course, it may also trigger memories of some specific events of holidays such as "the holiday in Spain last year". According to the mechanism of memory retrieval, the event is not retrieved as a whole, but with some of the most memorable or thematic features (memory traces) being activated first, e.g. the most impressive scenario, or moments which were captured. One may also recall that a folder was created to hold all the photos taken for the holiday. So all one needs to do is to look for the folder. Or if one has some specific photos in mind, one would probably go directly to look for the photos. In this case, all the lifelog system needs is to provide is functions to support searching, filtering, navigation and so on to enable the user to find the specific photos that have come to mind.

The case given above may be very straightforward. In some cases, the person is not required to be performing any explicit tasks relating to what they decide to look for, but just feel like seeing some of their past experiences, or interesting, funny or sweet moments with significant ones. He or she may not have a specific event or items in mind. In fact, it may be the case that he simply cannot recall any specific events, as no cues are strong enough to trigger a corresponding memory trace. What the system should do is to provide more cues for the person's autobiographic memory, including what kind of themes, what lifetime periods or general events are there in his life, and this information could act as top-down cues to trigger more of his or her memory about things or events in the past, that he or she may want to see now.

Even If the searcher has some specific target in mind, it is possible that they do not know how to start the search, since they have not recalled any searchable features (related information of the target that could be transformed into a query) or may not know where to start navigating (e.g. if the system allows people to navigate and browse events by dates and the searcher does not remember the date or even the month). In this case further memory cues are needed to help the person to recall more information about the searchable features of the target, e.g. if the system enables searching and browsing by date and time, probably features that could act as good cues for date and time of an event should be presented.

4.5.1.2 ***Querying***

One of the main approaches people employ to find things in an electronic environment is by querying an information system, which is expected to return what best matches the user's description of what they want, though mathematical computing. This approach is the standard searching approach. The supporting of the search function differs for different types of finding tasks. When querying, the knowledge of the target items may or may not come from the searcher's long-term memory. For example, it may also come from the description of the task or newly learnt from the feedbacks from previous search.

According to my discussions in Chapter 3, there are basically four situations that can make a person decide to search in a PLL:

1) The person has encountered the exact target contained in the lifelog system before.

2) The searcher recalls a previous interaction with a potential target, or an event which satisfies current task's requirements, and believes that it should be in the lifelog system according to his or her knowledge of the content in PLLs.

3) The target is known or expected to exist in the PLL system (e.g. photos, digital capture of events the user experienced), according to his or her knowledge of the content contained in their PLLs.
4) The person is told by others that the required information is in their lifelog and some of the potential targets' features that could be transformed into queries.

In different situations, "information seekers" (ISKers) have different levels of information and memory of potential targets. For example, in the first case, most of the knowledge of the targets may be reconstructed from their memories, together with memory of previous experiences of seeing it, how it was found and so on. In the last situation, the knowledge may largely come from the instructions, and may not need anything to be recalled initially. Apart from this situation, the user need to recollect more or less pieces of information about potential targets in order to search, e.g. where and how he found it last time, what the target item is like, what are their searchable attributes. To support people generating queries from their memory, there are some issues need to be addressed. According to the encoding and retrieval mechanisms, what a person sees (e.g. a paragraph of text or file) may not be encoded and retrieved (re-constructed) as it was, and what a searcher "remembers" (the memory traces that exist in long term memory storage) may not be recalled at the time when needed, therefore the required query may not be properly filled. Besides, what the user remembers may not be the same types of information that the information system stores, requires and accepts for search. For example, when thinking of a book, one may recall the summary of the story or a summary of part of the story, plus the book's cover (visual). However, what the information system stores for the book may be the exact title and author.

There are basically three solutions to these problems: i) allow people to search with what they actually remember, ii) provide memory cues for them to recall the required details, if these pieces of information are available in the user's memory; and iii) design the system in a such way that that tasks can be accomplished via recognition instead of recall, as recognition tasks are generally easier than recall tasks. The first two solutions will be discussed section 4.5.3. The reason that recognition tasks are easier than recall tasks is that: i) recognition does not always require the recollection of exact details, but rather just to make judgements; ii) recall and report requires memory reconstruction and reproducing. For example, copying a picture not only requires a person to mentally "recreate" it, but also to draw the line and dots precisely where they should be. For this reason, a system which involves the user's memory should try to provide things for them to recognize and choose, rather than requiring the them to recall and reproduce. For example, letting people recognize a name of a foreign location would be easier than requiring them to spell it and enter in a search box. The faceted-browsing method is another way to magnify the superiority of recognition memory over recall. The faceted browsing should include the facets that would be easy to recognize an event if the ISKer might feel it difficult to recall the exact details. The items or facets to be recognized should be distinctive for the target (event or item), but the exact details not well remembered. For example, a photo may be easy to recognize but may be difficult to reproduce; a long word, especially the words or text that people do not usually see or use, e.g., a long foreign name of an author or place, may similarly be easy to recognize, but not to recall.

4.5.1.3 *Recognizing and Recognition Memory*

In information finding tasks, "recognizing" is important in the course of navigation (recognizing and finding the correct route), browsing and making the relevance judgements of the targets. For example, one usually needs to make such judgements as "this is the right folder I sorted the target items into", or "this is the article which I read the store about …". The recognition tasks involved in search tasks in PLLS are different from those studied in most psychology experiments, in which the exact same items (texts or images) are presented for participants to judge the previous encounters. When presenting items (e.g. folders, events, or electronic files) in search tasks, they could hardly be presented in the same way as the users experienced them previously. For example, it is impossible to present an episode as what the user saw and felt in the real world. Even the presentation of documents or web pages in a result list is unlikely to be what one saw previously. For example, people may view the pages within an application window (web browser), but the representation of these web pages in a search result list may just be a couple of lines.

In fact, there are two forms of recognition involved: i) *knowing*: identifying an item from the presentation features based on sematic knowledge and past experiences, e.g. the barking furry animal is a dog, the building in the picture is the parliament house; ii) *recognition memory*: judgement of encountering an item in a specific context. While presenting a fraction of an object or event, e.g., representing an event with an image, the first type of recognition is initially required. For example, people need to understand what the objects in the picture are in order to be able to judge which event it represents. This type of "recognition" depends more on semantic knowledge or the semantic component of autobiographical memory. The second type of "recognition" involves a recollection process of the source in which the presented information was encountered. The latter type is particularly important when people want to find a specific route to something (e.g. to locate a folder) and specific information (e.g. a specific event or specific file) that was visited before. In order to let make people "recognize" objects (including events) represented with limited features, these features should be easy to identify and strongly associated with the core of the object. For example, a visual presentation of a visited webpage (e.g. a thumbnail of it) may be easier to recognize than textual descriptions of the page. This is because while browsing the page, the person was continually exposed to the overall visual features such as the background colour or image, its layout, but only spent a short time reading each word on the page. Therefore, the visual features can often be more strongly associated with the page. Apart from this, more contextual cues may also be helpful for better recollection. In refinding tasks when some specific items are to be found, or in navigation tasks that a specific (previously visited) path is to be located, this type of support is particularly useful.

4.5.1.4 *Structuring and Navigation*

It is suggested by some personal information management (PIM) researchers that the people's navigation tasks in their personal information space (PIS) is usually assisted by "contextual cues", e.g.,(Bergman, et. al., 2008). As the system does not know what the target is until the user has found it, it can hardly provide cues based on the strength of the cue towards the "target" in the user's mind. However, the system could provide the user with suggestions for what potential things are in the folder, and give the user some ideas of the possible content in the directories. Since people usually have some source memory associated with encountered information, not to mention the events themselves, I suggest that the lifelog collections and search results could be organized autobiographically. As reviewed in section 4.1.4, autobiographical memory is a hierarchical network of both general and specific events. Events that one has experienced can be retrieved through multiple pathways, e.g. top down in the hierarchy (from general themes to specific events which belong to the themes), sequentially within a series of events or a single episode (moments after moments in a temporal order), and in parallel across life themes that involve contemporaneous and sequential events. In this thesis, a specific episode is considered as a basic unit for presenting events. This suggests that the system can structure the collection hierarchically, from general events to unit episodes, and order the events (within a directory) in a temporal order. In addition, it would be helpful if events of a similar theme can be linked together.

4.5.1.5 *Assisting browsing with landmark events*

When browsing in a sequenced list of items, it could be helpful if landmarks could be given for the user to determine where they are and where the target item (episode or event) is (how far away: is it a big step further down or slightly back from the current position?). Since people have a general sense of order of events, it would be better to organize them by time. In fact, it has been found that when browsing search results of visited items, people tend to prefer sorting them by time rather than by system recommended relevance score (Dumais et al., 2003). To make users recognize landmark events quickly, the events themselves should be well remembered, and the features representing the events should be strongly associated with the core of the events or temporal aspect of the events. In this way, users are likely to recall the temporal relation of the target events and the landmarks, so as to adjust the browsing location to approach the target in a temporally ordered list.

4.5.2 **Working memory in information search tasks**

As I discussed in Chapter 3, information search can involve multiple steps such as mental planning of strategies, browsing for results, refining results, and generating queries. Many of the tactics in information search involve the user's WM. This section explores these involvements of WM in finding tactics, in particular, browsing and iterative search.

4.5.2.1 ***Visual search and chunking—browsing***

Browsing (scanning) is a visual search task which requires searching for a target in a complex array incorporating context and noise. As reviewed in Chapter 3, browsing is not an entirely random activity. Indeed, it can be directed either by salient features which attracted the user's attention (bottom-up process), or be guided by high level functions such as goals and knowledge (top-down). The latter involves some strategies, overall idea of what is in the current view space (e.g. a screen, a page) and how it is organize. The user needs to hold such information in WM while browsing, in order to predict the locations which have a high likelihood of containing the target.

Rodden and colleagues (2001) conducted a study which examined the effect of clustering visually similar pictures together for browsing tasks. Their participants generally reported that it was easy to locate the areas of interest, but some participants also reported that it was more difficult to browse within a visually similar cluster. The reason for this may be that since the images with similar visual features are clustered, when browsing the entire page, one just needs to briefly hold the features of the clusters in WM, rather than the entire collection, and direct attention to the corresponding clusters. In this way, the burden of WM is reduced. However, when browsing in a visually similar cluster, since the items are visually similar, many of their visual features are overwritten, thus, the short term memory of each cluster is prone to loss due to interference from other clusters. Therefore, it creates a burden to WM which must rehearse and retain such information, in order to guide the browsing.

In short, it is helpful to cluster content which shares similar visual features to reduce the amount of information that WM may need to hold. When browsing into such a cluster or group, things should be somehow re-arranged to maximize the difference between adjacent items in order to reduce the burden on WM when browsing within the cluster.

4.5.2.2 ***Iterative search and navigation***

People often need to modify their search query several times to approach a more relevant results set which contains the potential target. There are typically two ways that people can modify their query: alternative values for certain fields which were known before the search, or to used new learnt or recalled values for certain fields. If no external support is provided, people usually need to hold the queries they used and the results of searching using these queries in their WM , as well as the potential queries that they might use, and think about how to combine the criteria and how to form a new query. Similarly, when navigating from directory to directory, one may need to go back to an upper-level directory, or other sub-directories under other upper-level directories. To relieve the users from retaining so many pieces of information in WM, it would be helpful to keep the following information always visible to the user: the current path for navigation functions and the queries in use and used for iterative search.

4.5.3 **What do people remember about electronic items?**

Archiving and enabling users to refind previously encountered electronic items or information is an important function in PLLs. Several studies have been done in the area of PIM which explore memory related issues in refinding. While psychology studies have found that *where*, *who*, and *what* are facets which are likely to be remembered for events, very limited studies have been conducted to explore what tends to be remembered for encountered information. Most of the studies which have been carried out focus only on the types of attributes of a document (or email, webpage) that people may recall, and are usually limited to the features available in a current electronic system, e.g. filename, subjects of email, last modified time. In fact, there are many more aspects that should be considered during the course of retrieving an electronic item. For example, since it is the information or electronic items are encountered through a person's activity, it may also be associated with the person's episodic memory of the time when interacting with the item. When a person has a potential target in mind, such an "idea" could usually spread the activation to the associated memory traces, which have a chance to be "recalled". As reviewed in section 4.2.1, there are several different types of links between memory traces, e.g. *auto-associative* (e.g. elements of an object), hetero-associative (e.g. two words which are present together), sequential (in which the order information is embedded, this is usually in memory of audio, movements, etc.). Any information that was encoded together with the target information could be associated with the target. The associated information could include the context in which an electronic item has been encountered, and what the user was thinking about at the time of encountering the electronic item. For example, if the user was working on multiple tasks (with different electronic files) around the same time, these items may have the chance to stay in the person's WM together and get associated with the target item. So in short, any memory traces that are associated with the target in mind have a chance to be recalled. The likelihood of which one is recalled depends on several factors: what happened at encoding time, the context when retrieving, and how the information has been consolidated. In this subsection, I discuss these factors in detail.

4.5.3.1 *What information is encoded for encountered electronic items*

What a person remembers about an item depends on what has been encoded. For example, if the date and time are not explicitly known at the time when the item was encountered, these can hardly be encoded. Therefore, they cannot be recalled when asking for the date and time of last accessing the item. Presenting an object in front of a person is not a sufficient condition for it to be encoded. It usually needs the user to pay attention to it. For example, if a person was concentrating on understanding a paper rather than learning about the expressions and wording of the paper, what he remembers is the idea of paper that he grasped, rather than the exact text. Sometimes attention is directed by the goal of an action while for the rest of the time, it is directed by attractive objects, e.g. salient items. For example, an image among many texts may be salient and therefore it tends to catch the attention easily. Of course, it depends on what the user attended to on the picture. If just a brief glance was given to the image, only features such as the colour, general pattern, shape and position of the image may be roughly remembered. If the image is comprehended more fully, the person may remember what the picture is about. If the person concentrates on reading or listening to some of the content, the context may not be very well remembered, as they are less likely to be attended. Similarly, if an item is very emotional and easily attracts attention, the surrounding items may be ignored. In such situations, information about the context may not be strongly associated with the target.

In short, if information is presented and attended to at the time of interacting with the target item, it is likely to be recalled, with the target items as a memory cue. These may include some elements in the target item such as the content, the images or other salient visual feature, the format, the application window in which the item is viewed. They may also include information from the context such as the desktop background (if it was visible at the time, and of course if it was distinctive), other tasks that the person was doing round that time, or even the physical environment, e.g. it was extremely cold (due to the overactive air conditioning), the layout of the office, or even the food the person was eating. The likelihood of related information been recalled depends on the activation level of the item itself and the link between the item and the active memory of the target or presented cues.

4.5.3.2 *What information is likely to be recalled?*

Once a memory trace is encoded, it does not stay at the same activation level forever, but fades very quickly unless rehearsed. As described in section 4.2.5, the more a memory trace is rehearsed (either presented or recalled), and the more recently the memory trace was activated or encoded, the higher activity level it has. In addition, the longer it stays in WM, the stronger base level activation scores it gets. Emotional items or items encoded when a person is emotional tend to be better consolidated, and thus have a greater chance to be recalled. These effects also apply to the association between two memory traces. The stronger the association, the more likely a piece of information tends to be recalled when thinking about the "target item". According to the spreading activation theory, the more distinctive the link between a piece of information and the target item, the more likely it is that it can be recalled.

As I discussed earlier, information that is likely remembered includes not only the facts relating to the target item itself, but may also includes the specific context in which it was encoded. That is, the episodic specific memory of it. If the person worked on it repeatedly over a time, there may be a general event with this item as a theme. If a person worked on the item repeatedly over a long period of time in a variety of the contexts (in all sorts of places with similar frequency), then the item could be associated with too many episodes so that none of them may have a strong association with the target, due to the fan effect. This means that the episodic context of any of these occasions is not likely to be easily recalled. In another words, if there are some shared features of context relating to the occasions of accessing the item, and these features are distinctive, they could be associated with the target item. For example, if a person always writes a report in a certain place which he or she seldom goes to otherwise, this place is likely to be recalled when thinking about the target item.

Since there is all sorts of information which could potentially be associated with the target item, it would be difficult to theoretically arrive at a list of things that people may recall when a target (electronic item) comes into mind, some empirical study is needed to statistically explore the types of things that are most likely to be remembered. Chapter 6 will report our empirical studies which attempt to explore the types of information people remember related to refinding targets, and discuss the types of information that a lifelog system should and could capture to enable the users search by. This is important for building a memory friendly interface for a system for refinding and accessing from PLLs.

4.5.4 Presentation of time

Time (including date) is a shared feature (attribute) of all items in PLLs, e.g. time for starting and finishing viewing the electronic items, time at which photos were taken, and the time of start and end of an episode. Therefore, date and time seems to be an ideal feature for organizing and searching items in lifelogs. However, people do not tend to remember the time in terms of the exact numbers. Rather, time is estimated in several ways: the temporal distance from now, the relative position (depending on one's temporal schemata, e.g. beginning of the week, end of the semester), or position relative to a landmark event (e.g. shortly before last Christmas).

Most current personal information search (e.g. Window Desktop Search) allow people to filter their collection or results by the absolute temporal distance from now, e.g., yesterday, a week ago. This type of temporal feature may be useful for locating information encountered, but can be every inaccurate for events more than a few weeks or months ago, e.g. it would be difficult to recall whether it happened 6 months ago or 7 months ago, but it is generally easy to judge whether it happened yesterday or a month ago.

People also remember the relative position of events according to certain temporal schemata. Some of the most commonly used temporal schemata for some people include: week, day, year, and month. For this reason, the date and time values could be split into several independent parts, and people enabled to search or filter by these elements independently. For example, the user could search by time (e.g. 5pm), day of week (e.g. Wednesday), or distance (e.g., about two or three years ago).

Location relative to landmark events could be another useful feature for filtering functions. Yet, to do this, the landmark events should be located first. To reduce the effort of this step, some landmark events could be automatically detected and presented. According to fan effect (described in section 4.2.6), landmark events are usually distinctive and well remembered; including those marked at the beginning or ending of a life period, or lifetime experiences. With proper landmark events presented, one can simply estimate the relative temporal distant and order between the target episode and certain landmark events.

4.6 Hypotheses

Based on the above review, I conclude with the following hypothesized methods which are expected to support the user's memory in information finding tasks in their own lifelogs. Since people usually remember the source of information (including both that encountered in electronic environments and in real world), it should be helpful in most of cases if a system enables people to find specific information with related information in autobiographical memory. Therefore, I hypothesize that:

1) *People are more likely to retrieve a target from an IR system if they are allowed to generate a query with information from autobiographical context.*

2) *Browsing and locating a target would be more efficient if the user generally knows where it is. I* hypothesize that:
    a. A lifelog collection should be organized by where (city, country) and when (month, week, date), as people usually remember where, what, when and who of events.
    b. Since thematic features of general events could act as good memory cues for general events, faceted browsing with extracting representative facets can improve effectiveness and efficiency of finding tasks in PLLs.

3) Important events can act as reference points for users to more easily locate target events when the collection is ordered by time.

4.7 Chapter Summary

This chapter reviewed cognitive psychology literature related to human memory, explained the basic mechanisms of information processing in the memory system, including how information is encoded, stored and consolidated, and how it is retrieved (in particular, recalled). It also reviewed and discussed the factors which tend to make certain memory traces to be more likely to pop into mind. These factors influence memory at different stages. For example, attention is important at the time of encoding. information is more likely to be encoded and remembered if attention has been paid to it. The presence of strongly associated memory cues are important for reducing the time of retrieving memories. Based on the psychology literature of human memory, I further discussed the involvement of a user's memory in finding, refinding and information seeking tasks in personal lifelogs, including how to support the user's memory during their finding tasks. Finally, I hypothesized approaches that an information system can employ to support the user's memory when accessing their PLLs.

Summary of Part 1

In Chapter 2, I reviewed the current research in lifelogging. Since there is little existing work exploring information systems to enable lifeloggers to access their personal lifelog (PLL) data, I explored the potential applications of PLLs both theoretically and based on relevant documented studies, and derived a list of functions that people are likely to want related to accessing the content of their own PLLs.

To further explore users' needs from PLLs, it is important to construct and evaluate a prototype system. This system should provide the following functions, in particular, the first three.

- Retrieval
- Reminiscing
- Recollecting
- Reflection

To build up a user-friendly information system that supports these functions, it is important to understand how users tend to carry out corresponding information finding or seeking tasks, the problems they usually have with related existing systems, and the functions which they desire them to support based on their experience when using existing systems. Of course at this time, there are neither existing information access systems nor users for PLLs for such systems. Nor has there been any documented theoretical work or models developed of information finding or seeking behaviour specifically developed for PLLs.

In Chapter 3, I explored the possible processes in information finding and seeking tasks in PLLs based on the literature on general information seeking, finding and refinding behaviours. I explored the factors that may potentially influence people's information finding and seeking tasks in their PLLs, including the types of tasks, user personality, and a user's knowledge. I discussed how a person's knowledge can direct their information seeking and finding behaviour in PLLs, including how they may go about finding the information that they need and how they are going to make judgements of the results.

As their knowledge is mostly retrieved from their own memory, I hypothesized that:

Better support to user's memory can improve usability and task efficiency as well as effectiveness of an information system for accessing one's own PLL.

To test this hypothesis, a better understanding is needed regarding how a human's memory functions. Thus, in Chapter 4, I further explored people's memory from related theories in cognitive psychology. With a better understanding of how people's memory systems function, I further investigated how a user and their memory of their lifelog are involved in an information seeking/finding task for information from their PLLs. At the end of Chapter 4, I proposed the following suggestions to support the user's memory during different types of tasks for accessing their own personal lifelogs:

a) For look up tasks, the system should enable users to search for information using what they tend to remember about events. Therefore, I hypothesize that: *people are more likely to be able to successfully retrieve a target from an information retrieval system if they are allowed to query using information from autobiographical context*.

b) To support navigation, the system should dynamically *group the data into lifetime periods, general events, and episodes*.

c) Thematic features of general events or life time periods and distinctive events can act as good cues for people to recall potential targets contained within a given collection. Therefore, I hypothesize that: *things that are presented with episodic context tend to be more easily recognized.*

While the psychology literature explores reasons which explain why some information tends to be better remembered, and the mechanisms that enable a memory trace to be retrieved, the answers to some important questions that I need to know in order to develop a memory-friendly PLL system are still not available. These questions include:

- What exact types of information tend to be well remembered for PLL search targets?
- What data in PLLs can act as good cues to trigger people's memory of events?

To answer these questions, I seek answers through empirical investigations in the next section.

Part 2

Empirical Explorations

Overview of Part 2

Part 2 of this thesis reports my pre-development empirical studies for the design of a prototype personal lifelog search system, which further investigates potential answers to the two questions that cannot be addressed from the existing literature, these are:

1) Exactly what types of information tend to be well remembered for personal lifelog (PLL) search targets?
2) What data in PLLs can act as good cues to trigger people's memory of events?

Only with concrete answers to these questions, can I proceed to develop a memory-friendly personal lifelog search system to test the main hypothesis of this thesis: *better support for user memory will bring improved usability and efficiency for accessing one's own PLL archives.*

Chapter 6 explores the first question, or more precisely: the types of attributes, metadata, and episodic context that are likely to be remembered. It reports a series of studies, including diary studies and online surveys which aim to explore the potential types of search targets, and an experiment to investigate the reliability of recalled information for each type of metadata. To examine the reliability of recall, the types of recalled information (in particular, episodic context) need to have been recorded. For this reason, subjects who have such a dataset are needed in these studies.

Chapter 7 explores the second question: the types and features of personal lifelog data which can act as good memory cues for representing specific episodes, general events (a directory of specific episodes) and which can act as landmark events. I aim to develop an algorithm to automatically extract these memory cues for presentation in a PLL information system. Again, people and their PLL data collections which contain rich data of episodic context are needed in these studies.

Three long-term lifeloggers participated in both of these studies using their prototype PLL collections. The prototype lifelog collections and their owners, the test subjects for the main experiments are described in Chapter 5.

Chapter 5
Prototype Lifelog

As part of the larger iCLIPs project[5], three researchers carried out lifelogging for about 20 months. Taking this opportunity, I further explore the questions introduced in Part 1 and test my hypothesis by using these datasets with the participation of the lifeloggers who collected them. The datasets are described in summary here, further details of their collection can be found in (Byrne, Kelly, & Jones, 2010).

5.1 The three Lifeloggers

The three lifeloggers in the iCLIPs project were research students who did their PhD research in topics related to lifelogging. Due to the value and uniqueness of their personal lifelog (PLL) collections, they were used by each of the students to carry out the main studies of their PhD research. Of course, due to privacy issues, the data was not made directly available to the other lifeloggers. The data was processed by algorithms and tools from the other two researchers, and was only exposed to the data owner him or herself to conduct experiments on their own computers. Notably, one of the lifeloggers was the thesis author (lifelogger C). In most of the experiments presented in this thesis, the author was not an outlier in experimentation, due to the small number of subjects.

During the data collection period, Lifelogger A was using a Windows XP system as her only computer environment, Lifelogger B was using Mac OS as his only computer environment, and Lifelogger C used both systems. All three subjects used a Nokia N95 as their main mobile phone during the period of collection of their PLL data.

5.2 Lifelog Data collection

The prototype lifelog was collected continuously over a period of about 20 months by each of the three lifeloggers. This collection contains the following data:

1) Computer activities: every time a graphical window comes to the foreground, it was defined a single instance of computer activity.

[5] http://www.cdvp.dcu.ie/iCLIPS/

2) Mobile phone activities: including the receiver and sender number or contact name of phone calls, short text messages (SMS), and full text of SMS messages.
3) Photos: the prototype photo collection includes both automatically captured SenseCam images and actively taken Digital photos
4) Geo-location: the lifelogger's location was captured by the embedded A-GPS on Nokia N95 mobile phones.
5) Bluetooth: the name of surrounding Bluetooth devices (e.g. mobile phones which have Bluetooth turned on) was captured using an application on the Nokia N95 Mobile phone. This is used to detect surrounding people if they have their mobile phone's Bluetooth on. Bluetooth signal records may also be used to detect the location of certain Bluetooth enabled objects, which are always in the same place, e.g. detecting my location as in my lab with the Bluetooth signal from my desktop PC.
6) Biometrics: the core biometric data in this prototype PLL collection includes heart rate and Galvanic Skin Response (GSR). These were captured for only a one month period, due to the physical burden of wearing these devices.

The above types of data were captured based the technologies that were available to us when beginning the data collection in 2008. In the rest of this section, I describe the data collection in more detail.

5.2.1 Computer activities

Desktop Activity: Computer activities were collected mainly using two software applications: *Slife*[6] and *MSR Digital Memories*[7]. Slife was the main component used for computer activity monitoring, It monitors each computer activity and records the event of a graphical window being brought to the foreground (which I also refer to here as an item access) in separate XML files. Each computer activity has the following information recorded (where applicable): begin and end time of the activity, name of the activity, name of the application (e.g. firefox.exe), title of the activity window, type of the activity (e.g. web, excel), URL of web pages or path of file, and textual content of a webpage, if it is opened by the internet explorer application (IE 6.0). If it is an email, it also records the subject, to and from (name of contact). Figure 5.1 shows sample XML of computer activities recorded by Slife running under Window XP. Since Slife could not capture the path and content for all types of applications, MSR Digital Memories was

[6] http://www.slifeweb.com/ (September 2011). We used the early 2008 version of the Slife application which was available under license for Windows OS and Mac OS X without source code.

[7] http://research.microsoft.com/en-us/projects/mylifebits/ (September 2011)

also used as a supplement capturing tool on PCs, as it runs only on MS Windows systems. Among many of its functions, it also records the full text of web pages opened using IE and MS office documents, but it only keeps the last version of the file accessed on a calendar day. The data collected by MSR Digital Memories provides a supplement to the information that Slife fails to capture on the Windows system, in particular, the path of accessed files and full textual content of files accessed via MS office. Apart from this, other scripts and tools[8] were written to further complete path information of accessed files and extract the textual information of files, web pages, and emails. Since some webpages update their content from time to time, and may display totally different content from when the user logged in from a web browser, not all the full text content in the prototype PLLs are the same as it was when the lifelogger encountered it on their web browser.

519200912143.xml

```xml
<?xml version="1.0" encoding="utf-8"?>
<EventHeader xmlns:xsd="http://www.w3.org/2001/XMLSchema" ›
www.w3.org/2001/XMLSchema-instance">
  <Activities />
  <Date>2009-05-19T12:14:03.1562500+01:00</Date>
  <EndDate>2009-05-19T12:14:03.1562500+01:00</EndDate>
  <Name>Firefox</Name>
  <Title>gmail - Google Search</Title>
  <Type>web</Type>
  <Url>http:.content hide to protect privacy...</Url>
  <Subtitle />
  <To />
  <From />
  <Path />
  <Application>firefox.exe</Application>
  <Content />
</EventHeader>
```

Figure 5.1 Computer activity recorded as XML by Slife

SMS: Apart from the computer desktop activities described above, text messages (SMS) were also downloaded from the lifelogger's N95 mobile phone using an in-house developed application, and stored in the SQLite database for the prototype system. Each SMS record contains the timestamps of receiving or sending, content of the SMS, and the contact sender or receiver.

Tweets: Tweets were also downloaded from each lifelogger's tweet timeline, and stored in SQLite data, which is used by the prototype system. Each tweet record includes: the timestamp

[8] The scripts and tools were written by Daragh Byrne and Liadh Kelly at Dublin City University

of posting, the content of the tweet, and the names of other users mentioned in the tweeted message.

5.2.2 SenseCam images

SenseCam: Microsoft SenseCams were used as the main passive image-capturing tool in the prototype lifelogs. The lifeloggers were requested to wear a SenseCam for as long as possible everyday. When worn continuously, roughly 3,000 images are captured on average each day. The camera contains a fish eye lens, so that it can capture a wider angle of the sight than does a standard lens, giving a view that is more similar to what a wearer sees. It also has sensors to detect movements, light status change, temperature, etc., to trigger capture of an image. A manual picture-taking button enables the wearer to take pictures with their SenseCam whenever he or she wishes to. The triggers (e.g. time, sensors or manual) are recorded as metadata for each picture. After the SenseCam images were downloaded to personal computers, a sensor file is created, containing the path of each image (where it was stored on the computer), the timestamp of taking the image, sensor information recorded at the time of taking each image, including temperature, accelerometer values (movement), light condition.

5.2.3 Campaignr and context data

Geo-location: To collect information about Geo-location and people nearby, the lifeloggers installed software called *Campaignr*[9] on their Nokia N95 mobile phones. Global Positioning System (GPS) data, Wireless network presence (Wi-Fi) and Global System for Mobile Communications (GSM) location data was captured and polled once every 20 seconds. Due to issues of battery life, GPS data collection was deactivated after 2 months. Geo-location was derived using an in-house script and initially stored in structured XML. These scripts provided latitude, longitude, name and strength of presented Wi-Fi and Bluetooth signals, country code, country, county, region, city and name of street with timestamps.

Bluetooth and People: The Campaignr software also recorded co-present Bluetooth devices present in the nearby vicinity. Since many people have Bluetooth technology activated on their mobile phones and may even name their Bluetooth devices after themselves, it is anticipated that the captured Bluetooth information can provide us some information regarding the presence

[9] http://www.lecs.cs.ucla.edu/~august/campaignr/

of specific named people. The Bluetooth information was included in the XML files generated by the Campaignr software, as described in the above section.

Light status and Weather: The hourly light status information was extracted for each geo-location visited by subjects from timeanddate.com. Hourly weather conditions (e.g., raining, snowing) were downloaded from Wunderground[10] based on the Geo-location of the lifelogger. A record of weather conditions includes the following information: time, temperature (Celsius), dew point, humidity, sea level, pressure (Pa), visibility (km), wind direction, wind speed (km/h), gust speed (km/h), precipitation (cm,) events, conditions, wind direction. Among this data, only conditions (e.g. cloudy) were indexed and saved to the database to represent the weather. This is because the weather condition is more likely to be perceived and remembered by people.

5.2.4 Biometrics

Due to the physical burden of the wearing of the biometric devices, the lifeloggers only captured biometric data for one month. A polar heart rate monitor[11] was worn on the chest to capture heart rate data (HR). A *BodyMedia SenseWear Pro2* armband[12] was used to record galvanic skin response (GSR), skin temperature (ST), transverse acceleration, longitudinal acceleration, and heat flux (HF). Energy expenditure was calculated by the device every minute using inbuilt software and stored on-board with the biometric readings. GSR, transverse acceleration, longitudinal acceleration and HR were captured every second due to their rapidly changing values. The less sensitive ST and HF were captured only once every 10 seconds to save memory and preserve battery life, so that the devices can record data continuously for a whole day without replacement of batteries. All the data was recorded together with timestamps.

5.3 Construction of experimental database

The prototype lifelog data was imported into the database by each lifelogger using an in-house application. The database, which mainly holds raw data of the prototype lifelog collection, has the following tables:

a. SenseCam images, which holds information of: the file path of each image, timestamp of the capture of the image, values of the sensors for each image, and the triggering reason for capture of the image (e.g. trigger by time, manual capture).

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[10] http://www.wunderground.com/

[11] http://www.polarusa.com/

[12] http://www.bodymedia.com

b. All imported digital photos: original file path for each photo, file path of thumbnail images for each photo, timestamp of image capture, camera maker and mode (extracted from EXIF[13]).
c. All records captured by Campaignr, including: Geo-location (latitude and longitude), country, region, city, address (usually the name of street), name of Bluetooth devices and signal strength, name of Wi-Fi and corresponding signal strength, and finally the timestamp of each record.
d. All computer activities, including details such as: title (subject of emails), filename, extension (item type), application name, senders and receivers of emails or SMS where applicable, URL or path, time of starting and closing the activity, full textual content where applicable.
e. All records of Galvanic skin response (GSR), including: GSR, timestamp.
f. Heart rate (HR), including: heart rate and timestamp.
g. Skin temperature (ST) and heart flux (HT), including: ST, HT and timestamp.
h. Downloaded tweets, including: content of tweets, timestamp of posting.
i. Light status and weather: time (e.g. 2008-05-09 10:00:00), light status, weather condition (e.g. rain).

The data in this database was further processed for use in the experiments described in the rest of this thesis, where the prototype lifelog was needed. For example, a table was created for "episodes" when the episodes were segmented, this is discussed fully in Chapter 8. Thumbnails of photos and SenseCam images were created while importing them into the database.

5.4 Gap filling for Imperfect data

5.4.1 Missing Context data

The retrieval algorithm enables retrieval of items by their attributes and context data relating to them being accessed. This algorithm works well for the retrieval of digital items given that every instance of accessing the digital item has been recorded with corresponding context data. The ideal case of the data collections is that the contextual data are captured for every single minute. Therefore, for every document the lifelogger has accessed, there would be corresponding context data. However, according to a mini survey from the three lifeloggers, the context (mainly data captured from Campaigner) was not perfectly captured for the following reasons:

[13] http://en.wikipedia.org/wiki/Exchangeable_image_file_format

- Server corruptions
- Battery out
- Having to stop the software when uploading the data
- Turning off the software for extended periods to save battery life when travelling
- Forgetting to start the software after restarting the phone
- Capture failures and errors

5.4.2 **Geo-Location gap filling**

A data preparation application was developed by the iCLIPS projects researchers to enable the lifeloggers to fill gaps for their location. Since it is unlikely that people can remember the exact address they were at for every single minute, and it would be very time-consuming for the lifeloggers to fill in hundreds of the gaps during the 20 months capture period, they were required only to fill the gaps for missed location data at the granularity of hours.

Locations were filled at the accuracy of level of cities (with country, region and city names). The list was editable, meaning that: i) the lifeloggers could add new locations, which he or she had been to during the lifelogging period, but had not been captured, ii) they could also add meaningful tags to unfamiliar locations, so that they can use these familiar tags to search for things that happened at locations with unfamiliar names. For example, the lifelogger can add a tag "Chicago" instead of "Illinois", if he/she knew that they travelling around the Chicago area, but did not know that they had actually entered some other towns with names that they did not know. The lifelogger cannot recognize the name of these towns, since they did not know them, nor can they search for episodes or related computer activities by the names of these towns. In the data preparation application, the hours with and without location information were displayed in different colours. The lifelogger could select single or multiple hours to add location information by selecting a location from the location list. To help the user to recall the location at given hours, they can view the SenseCam images at the given hour, and the location names before and after the hour (if available).

5.4.3 **Annotation**

As some of the Wi-Fi names are representative of the places (e.g. School of Computing), the lifeloggers were encouraged to annotate as many Wi-Fi names as they could. Strong Wi-Fi signals, which lasted for more than 5 minutes, were listed for users to identify. The name of locations (region, city and street) at the time of the Wi-Fi signal's occurrences can be shown as memory cues for the lifeloggers to recognize the possible place that the Wi-Fi signal was captured (e.g. the Wi-Fi signal at home).

Bluetooth signals can be used as an indicator for people who were present at the time of content capture. This is based on the assumption that people have their Bluetooth devices turned on and name the Bluetooth after themselves. However, it was found that only a small percentage of people turn on the Bluetooth on their phone. Besides, many people whose Bluetooth signals were captured were not known to lifelogger. To use the Bluetooth signals as an indicator of people who were present, the lifeloggers were required to annotate the known Bluetooth devices in their lifelogs.

5.5 Chapter Summary

This chapter introduced the prototype lifelog collections from three lifeloggers used in the experimental studies in this thesis. The remainder of Part 2 will report my empirical explorations from both non-lifeloggers and lifeloggers. The explorations on non-lifeloggers generally aim to collect richer ideas regarding potential possibilities for cue features for use in supporting effective search in personal lifelogs, e.g. the types of information people remember or may act as good memory cues. For studies which examine or explore the question of quantities, e.g. how much the attributes are correctly recalled, how much did each cue item and the features of the cue items contribute to a person's memory, the three lifeloggers were the subjects using their own lifelog data in the studies.

Chapter 6
Exploring Memory of Information in the Digital World

In Chapter 3 and Chapter 4, I discussed questions including how lifeloggers access their personal lifelogs (PLLs), and how to support their memory during this process. One of the solutions that I proposed is that a search system should allow users to search with what they know (can recall) about the potential target(s). As the knowledge is largely from the searcher's memory, it is important to understand what people tend to remember and recall reliably, in order to be able to develop a system that can support this function. In Chapter 4, I systematically reviewed psychology literature on the process of human memory and discussed the factors that may influence the likelihood of a memory trace being recalled. Yet, these theories cannot tell exactly what types of attributes or information (that could be derived from electronic system) that people actually tend to remember. In this chapter, I report our studies which aim at exploring the features and related information that people might remember for any previously encountered information, including those on computers and those from the physical world. The findings from these studies guide the design of search options for the search functions in the prototype system developed and investigated later in this thesis. In this chapter, I use the term *refinding* to refer to the activities of finding previously encountered information.

This chapter is structured as follows: Section 6.1 reviews relevant work which explored the types of information remembered for refinding targets, and discusses methodologies that were used in these studies. This discussion leads to the design of the methodology for our exploratory studies, which combine both diary studies and cross-sectional surveys. The details of both methods are described in Section 6.2, with their findings reported in Section 6.3. The mission of the above exploratory studies is to collect as many types of information which are likely to be remembered as possible, regardless of the correctness of recall. Section 6.4 reports a further study which aims to investigate the reliability of the recalled content.

6.1 Background

In the field of personal information management and interactive information retrieval (IR), several groups have sought to explore a similar question, that is, what people remember about the information or electronic objects they have seen before, e.g. visited web pages or search results, e.g. documents (e.g. (Blanc-Brude & Scapin, 2007)), photos (e.g. (Naaman et. al., 2004)) and video clips (e.g. (Jaimes et. al., 2004)). Yet, what a person remembers at the time of search depends on not only the target itself, but also a complex combination of factors such as physical context and internal state of the person who conduct the refinding task. For this reason, I tried to extensively collect types of facets people may remember, and select facets which are most likely remembered and to be most likely to be remembered most reliably, for inclusion in the prototype system. Of course, the final selection of search options to include in the system also depends on the technical capabilities of the system platform and the features of prototype data collection.

There are two broad types of approaches that have been used to explore this question: i) the implicit log approach in which the system captures user activities (such as key strokes and queries entered) during search tasks and researchers explore the questions from logged data (e.g. (Dumais et al., 2003; Teevan et. al., 2007)), and ii) self-report in which subjects explicitly report to experimenter what they can recall (e.g. (Gonçalves & Jorge, 2005), (Blanc-Brude & Scapin, 2007)). The former is usually less intrusive and effort-consuming compared to the self-reporting method. Therefore, it is much easier to extend it to larger scale of research efforts than the self-report method. Yet, this approach can only capture what users "tell" the information system, which is not necessarily equal to what people remember. Thus, this method can only record the types of information that the search system accepts. If the system only has two search fields, e.g., title and author, data from the implicit-logging method can only show the frequency that people search with each of the attributes. However, this is not equal to the likelihood that people remember these two attributes. For example, if the author field is usually easier to type and tends to return more relevant results than with the title, users may prefer to search with "author", and they sometimes may not bother type any terms for the title field just to save the time and effort of recalling the relevant details. Moreover, even if users remember other types of attributes that they could tell the system, the log cannot capture them.

The self-report approach is less "natural" and more difficult to expand to large scale. Yet, it can give more flexibility in exploring types and accuracy of information that people remember. For example, Blanc-Brude and colleagues (2007) tested recall memory of documents' attributes for 14 participants. They initially used a free-recall approach to allow their participants to recall any features that they remember about the selected documents. The documents were selected through coordinated work between the participants and the researcher, to make sure that different types of documents were involved, e.g. documents created by the participants and those created by others, documents viewed recently and those used more than 6 months ago. In the free recall test, they found that their participants usually remember: (i) textual content (71.4 %), e.g., abstract, structure, distinctive portions of text; (ii) visual elements (25%), e.g., existence of graphics, colours; and (iii) file type or document format (21.4%), e.g., "table Excel", "book format A5". Their main conclusions came from a cued recall test in which they used the names of attributes taken from the major PIM literature as cues (and questions). These attributes included: location (path of the document), type or format, filename, title, file size, time (last modified or visited time), visual elements (whether there is a graph), keywords, links, actions and associated events. They asked their participants to find (retrieve) these documents in their own way in order to check the accuracy of their recalled content, apart from the last two questions (action and associated events). In this way, they not only explored the likelihood of recalling certain attributes, but also the frequency of correctly recalling each attribute. Furthermore, they explored where people make mistakes or the parts of each attribute they remember, e.g. which part of a document's path they tend to recall. Unfortunately, this study only focused on the features of the documents themselves.

In another study, Gonçalves and Jorge (2005) explored recall of documents from a different angle, shifting the focus from attributes of documents to autobiographical memory, which involves context from the physical world. They asked their participants to free recall and "tell a story" of three documents selected by each participant. The freedom of reporting in this approach and the word "story" in the instruction brought some interesting findings which have not emerged in other studies. For example, they found that time, place, purpose, tasks, other documents, related activities (such as exchanges, e.g. emailing the document to others)) are also usually reported elements of the "stories", in addition to attributes such as subject, type, storage and content. The narrative method also allowed the subjects to more freely describe whatever they remembered about "time". For example, they found that their subjects tended to recall approximate temporal distance for recently visited items, e.g. "about one hour and a half ago", and roughly relevant temporal positions for older items, e.g. "I delivered it around April". According to their finding, the memory of places tends to remain less affected by time. They also found that people tended to have better performance in recognition than recall for the name of authors and co-authors, especially for foreign names. One of the most interesting findings was that some participants also reported related "real world" events, e.g. "I went to the library", "I printed the document". They found that these recalled events are usually personal rather than public events. These findings suggest that people usually have source memory of digital documents (where or when it was encountered), and that these source memories are associated with other real life events. This also indicates that related events could be used to search for the targets.

Most of these short-term self-report experiments lack a real task context, as they usually asked the participants to find or recall about pre-selected specific files. According to the findings of Elsweiler (2007), people may also look for pieces of information (targets) which come from one or multiple sources (files, webpages, emails, and so on). Indeed, what a person remembers at the time of search depends not only on the target itself, but also on a complex combination of factors such as physical context and the internal state of the person who conducts the refinding task.

An alternative to short-term experiments are the in-situ methods, such as experience sampling methods and diary studies. Experience sampling methods usually sample participants' status or experiences at certain intervals controlled by the researcher. For example, researchers can send the participants messages every hour or at random intervals to ask them what they experienced during the last hour or what they feel at the moment of receiving the message. The diary study method gives more freedom to the participants, letting them decide when to report. A diary can be taken on a daily basis or at a more flexible interval when some target event occurs (event-triggered). For example, the *diary study* approach can let participants report what they remember of the item in the situation of a refinding task, that is, just before they want to refind or just after they have carried out a refinding task. The experience sampling method is suitable for reporting personal status, e.g. emotional status, but not perfect for event-specific situation reporting, as there is usually an interval between the reporting time and the time the event happened, thus the report mainly relies on memory. As reviewed in Chapter 4, the performance of immediate recall is much better than delayed recall, and the longer the interval of delay, the less reliable the memory tends to be. The event-triggered diary study method is most suitable for reporting experiences during or right after specific events that happen at random intervals, for example, the event of an information-seeking behaviour. Of course, this method requires the subject to remember to react, and to do so at the time when a target event happens.

One problem with the longitudinal method in general is the time and effort involved. For this reason, studies with this approach are usually limited in scope. The cross-sectional (one-off) survey method is another alternative. Instead of sampling one subject's re-occurring behaviour over a long period to get significant behaviour amount of data, it samples the behaviour of a large sample of subjects who carry out a certain behaviour. Compared to in-situ methods such as experience sampling or diary studies, one-off surveys are usually criticized for being unreliable since they largely rely on the participants' memory. For example, if a researcher wants to explore people's refinding behaviour during the last week, it is more likely that the participants would fail report the details, than if they report their refinding tasks for the last hour every two hours over a week with the experience sampling method. However, because the cross-sectional approach requires much less effort and can be done immediately after enrolment, it is more likely that many more participants can be recruited.

To explore the features that are likely to be remembered reliably related to refinding targets, we conducted a series of exploratory studies. These combined diary studies and cross-sectional survey methods, as well as an experiment to validate the types of recalled content with the three lifeloggers and their lifelog data. Table 6-1 summaries the parameters for each of the studies.

Table 6-1 Summary of Methodology

Name	Pilot study (2)	Diary study	Cross-sectional survey	Validation experiment
Ref	P1	D2	C3	E4
Method	Diary study + interview	Diary study	One-off online questionnaire	Experiment
Material	Physical diary book, online questionnaire	Physical diary book, online questionnaire	Web-based questionnaire	Excel spreadsheets, lifelog data, in-house developed code and IR system
Participants	4 (invited in person)	11 (4 from P1, others were recruited via miscellaneous channels)	634 (recruited online)	3 lifeloggers
Data	Answers from physical and online diary questionnaire, interview notes	Answer from online questionnaire	Answer from online questionnaire	Excel spreadsheet, data collected in the in-house developed application, lifelog database
Section No.	6.2.2.1	6.2.2.2+6.2.2.3	6.2.3	6.4

The rest of this chapter is structured as follows:

Section 6.2 reports the methods for the exploratory studies which seek collect the types of remembered types of features.

- Section 6.2.1 describes the methods for the diary study.
  - Section 6.2.1.1 reviews and discusses the methods and problems encountered in the pilot studies. Prior to conducting any full study with many participants, pilot studies were conducted to verify the design of methods and questions to be asked to the participants. Two pilot studies were conducted. Since the design of the first one is found to be problematic and it collected very little useful data, its results are not further analysed or discussed. The second pilot study (pilot study 2, ref: P1 in Table 6-2) was more successful. Since all participants in this study also subsequently enrolled in the main diary study (ref: D2 in Table 6-2) which asked similar questions in each diary entry, the data collected from P1 is analysed together with that collected from the main diary study (D2). Since the questions in the second pilot study are generally the same as the full studies, the results are included in the discussion.
  - Section 6.2.1.2 and section 6.2.1.3 describe the participants and material used in the main diary study (D2), an MS Word version of the questionnaire in the diary is contained in Appendix I.
- Section 6.2.2 describes the method used in the cross-sectional survey (ref: C3 in Table 6-2). As the questionnaire used in this study is almost the same as the one used in the diary study, the material is not explained in detail again. Therefore, this subsection focuses on the recruiting of participants (section 6.2.2.1) and the quality control of the online questionnaire study respectively (section 6.2.2.2).

Since both studies (D2 and C3) explore the same questions and used similar questionnaires to collect data, the results of both these studies (and study P1) are analysed together and discussed in section 6.3.

Section 6.4 reports a study that investigates beyond the frequency of recalling a feature, but also considered the reliability of the recalled content, and leads to the design of the prototype system. This is the only study reported in this chapter which involves real lifelog data and their data owners, the three lifeloggers.

6.2 Methodology for extended exploration

I combined the diary study and the cross-sectional survey methods to further explore the possible types of things that people may remember about the information they previously encountered. The diary study was expected to collect high-quality answers and investigate personal responses and views. The cross-sectional questionnaire aimed to collect as many types of remembered information as possible. This section describes the methodology of these studies. Their results are reported together in the next section (6.3).

6.2.1 Diary Study

The diary study focused on qualitatively exploring the potential types of remembered information, and the influence of personal differences, that is, what types of personal traits or habits may influence an individual's refinding behaviour and their remembered types of information. The design of the diary study was an iterative process. The methods and questions were refined several times during a pilot stage. The main study was carried out after a comparatively successful pilot study. Therefore, the relevant pilot studies are briefly reviewed prior to reporting the methodology of the main study, and a survey conducted as an additional exploration of the design of the detailed procedure and questions.

6.2.1.1 *Experiences gained from pilot studies*

Initially, I adopted the event-triggered diary study approach which requires the subjects to add a diary entry as soon as a there is a refinding need, in order to explore what people may remember before they actually find the items. This is because re-exposure to an item may change a person's memory of it, e.g. re-consolidating the memory of certain aspects or details, or learning some new details or aspects which were ignored in previous encounters. Besides, it is not always reliable for people to distinguish whether a memory trace is newly learnt, recently retrieved and reconsolidated, or was well remembered before being exposed to it recently. Therefore, I asked the participants to add a diary entry when they have a refinding need or when they were about to conduct a refinding task. The participants were asked to add the diary entries through an online form, to describe the type of information they looked for and what they remember about the target.

This method proved to be difficult as the subjects usually found it inconvenient to stop in the middle of a refinding task, and forgot to report it afterwards. Therefore, I decided to re-balance the trade-off of the amount of diary entries and the accuracy of records regarding what people could recall, by allowing them to add diary entries after they completed a refinding task. It was also found in the pilot studies that sometimes the participants simply did not realize that they are about to or have just conducted a refinding task. I believe that reminders could be helpful to keep the subjects alerted to any refinding tasks they've conducted. I built up a reminder desktop application and installed it on the participants' computers. This application pops out an alert window every 30-100 minutes to remind them to pay attention to refinding tasks they are conducting and add diary entries. Participants commented that this reminder was helpful. Yet, another problem became more obvious, that is, there seemed to be too many refinding tasks to be recorded. For example, tasks such as navigating to a frequently visited website, or locating and opening a frequently-used software application, all involved refinding. Therefore, I suggested that the participants report only significant cases events. Of course, this might introduce a bias in the results, since simple and easy refinding tasks are less likely to be recorded. Furthermore, as the online questionnaire was anonymous, it was not possible to explore how different personal traits (including their lifestyles and habits) influenced the types of information they recall, unless they answer questions relating to their personal traits in every entry.

In the second pilot study (study ref No. in Table 6-1: P1), I modified the methods to avoid or reduce the problem that was encountered in the above pilot study. The participants were allowed to add a diary entry after the refinding target was found. The modified pilot study was conducted for another one-week period. In addition to the changes I talked above, I also put more focus on the memory of related episodic context. Both physical (paper) diary book and online version of the questionnaire were provided for all the participants. The physical diary book was designed to serve a reminder function with clearly labelled cover. Due to the limited number of subjects and the way of recruiting participants (in person), this study could hardly be anonymous. Yet, this facilitated us exploring personal difference in the refinding tasks. Therefore, the online questionnaire also required the subjects to indicate their identity by their email or name. More details of this study can be found in (Chen et. al., 2010).

This pilot diary study was followed by an interview with each subject to clarify some of their answers. During the interview, it was found that the subjects actually remembered more (reported in interview) than they reported in the diary entries. For example, one participant reported that he did not know "when" he encountered the item previously. However, when asked why he looked for the information, he reported that he used it previously for another project, which was more than a year ago, "for last year's [name of a conference]". These findings are congruent with the psychology findings in memory for time that people remember temporal relations of events rather than the name of date and time (review Chapter 4 for more details). Such gaps between the answers to the diary questions and that in the interview suggested that a rephrasing of the question could help people recall more relevant information. For example, instead of asking them when they encountered the item previously, some more specific questions can be asked, e.g. how long ago it was, do you remember any other event around that time. The refined questions were used in both the main diary study and the cross-sectional one-off survey (section 6.2.2.2).

6.2.1.2 *Participants for main diary study*

The participants in the man diary study (D2) were mainly recruited via leaflets, university mailing lists, and notice board posters. These advertisements included a brief statement of the study and a link to the introduction page to the diary study[14], where the participants can read the instructions of the diary study, and sign the consent form for enrol in the study. Seven participants were recruited via email and leaflets, in addition to which, four participants from the pilot study agreed to continue participating in this diary study. Thus, a total of eleven subjects registered to participate, including six males and five females, age ranging from 22 to 39. Five of them were researchers, and the rest were undergraduates and taught masters students in School of Computing at Dublin City University.

To encourage the participants to contribute more diary entries, a 50 euro reward was available for the first participant to add his or her 30th diary entry. While a completely anonymous study would be helpful to encourage the subjects to contribute more details regarding their information refinding tasks and their remembered features, this would make it difficult to track the activities of individual persons. Therefore, upon registering for the study, each participant was assigned with an automatically generated ID, which was made up of six randomly generated digits. At the time of registering, the subjects were also required to answer 5 questions regarding their gender, age group, usage of computers, frequency of travel, and information management habits respectively. This enabled us to explore how personal traits influence the types of information recalled, and the type of information refinding tasks that they are likely to conduct. Since the subjects from the pilot study had a number of diary entries recorded in the previous study using their own names, they were not anonymous to the investigators during this study in order to keep track of them while continuing to use their

[14] http://www.computing.dcu.ie/~ychen/diary/ (Last accessed in January 2013)

contributions to the pilot study. As this study is supposed to be anonymous to the rest of the subjects, no face-to-face interviews were conducted at any point. Only the answers from the online diary questionnaire were downloaded one month after the starting date of the study.

6.2.1.3 *Material*

As stated above, the diary study mainly involved two materials: a physical diary book and an online questionnaire. The physical diary book mainly served as a place for taking instant notes and a physical reminder while the online questionnaire provided a place where the participants gave detailed answers.

The physical diary book: Participants were expected to take notes right before or shortly after undertaking any refinding task. They could complete the online diary entry at any time afterwards when it was convenient for them. The physical book version questionnaire included a open question for description of the target, the reason and purpose of finding it, a free text description of whatever related information the subject remembered about it, and a multiple choice question to indicate the remembered features about it from a list. This is to makes sure that when answering the online diary questionnaire, the participants reported all types of information that they remembered at the time of the refinding task. As this study was expected to be anonymous, the physical diary book was not collected from the participants after the study.

Online diary questionnaires: Every time a participant added a diary entry, (s)he needed to answer this questionnaire in full together with their unique ID assigned in this study. The questionnaire was designed based on the pilot studies described in section 6.2.1.1. It also included two other part questions: i) the task, target and the context; ii) the memory of the target. Since it was found that during the pilot study, participants sometimes left over-simplified answers such as a name or a term instead of a description the target, this questionnaire combined both open questions and multiple choice(s) questions to try to avoid any ambiguity introduced by over-simplified answers. For example, the participant may have simply answered "Johnny Depp", but what they actually looked for was some website about Johnny Depp. In this question, apart from the open question, the participants also needed to select which category it belongs to. In this case, the participant may select "a specific web page" for the type of target. In addition, examples and detailed instruction on how to answer such questions and hide privacy were provided. The detailed questions of the questionnaire are available in Appendix I.

The online questionnaire was structured as follows:

1) Descriptions of the target and task

This part started with an open question asking the subjects to describe the target. This is followed by a list of options asking the subject to select or add a new type of the target. The types in the list were based on the findings from the pilot studies. This is followed by questions regarding the task (what the subject was doing) and how they carried out the re-finding task, presented in the form of multiple choice(s) questions.

2) Types of information that they remember

This part also began with a free narrative approach to collect types of remembered information from free recall, without directing or limiting the types of information to be recalled. Yet, people cannot always recall everything which they actually remember. Multiple-choice questions were presented after this question, asking the participants to select their remembered types of information in pre-defined lists. The options were designed based on the finding from other related works (e.g. (Cutrell, Dumais, & Teevan, 2006)) and our pilot studies, including: the author, the source (where did you download it from or who sent it to you), the type, the physical context of the subject (where he or she was, the approximate time, other activities taking place at the same time, personal events or public events) and so on.

6.2.2 Cross-sectional survey Method

In order to collect a wider range of refinding tasks and achieve more generalizable conclusions on the types of information people tend to remember about their previously encountered information and the types of information (including that encountered in the physical world) people tend to look for, I decided to take a cross-sectional one-off survey approach. To reduce the memory problem of typical one-off survey (e.g. recall what happened during last few months may be not very accurate), the questionnaire only asked each participate to recall one refinding task which happened within an hour prior to answering the questionnaire, if there had any. This survey was posted on a questionnaire-hosting website[15], which had more than 2 million subscribers. These subscribers receive onsite messages and emails of new paid surveys.

6.2.2.1 *Participants*

The participants were called for via the survey's hosting website, mailing lists and social networks (e.g. Facebook). In the instruction of the questionnaire (which included a brief description of the survey), it was clearly stated that only those who have just looked for some

[15] www.sojump.com

previously encountered information could participate. It also asked participants if they had looked for or wanted to find any previously encountered information at the beginning of the questionnaire, in order to filter out people who did not qualify to complete the questionnaire. Therefore, the participants who completed the question are those who had a "refinding" task within an hour before doing the questionnaire. Due to the popularity of this website, paid-surveys can often get hundreds of replies (completion of a new posted questionnaire) within an hour. This means that if the survey is posted at 11.00pm at night, most of the answers will be from subjects who are still using their computer at 11.00pm or later. Since people may do different types of things at different times of the day, e.g. they are more likely to interact with information related to their work in the daytime, and do more casual things or things related to their personal interests in the evening. In addition, some people only use computers during a certain period of the day, which means that they can be omitted if we only sample at a time other than that when they usually use their computers. To avoid such bias introduced by time, the survey was posted four times in four different days and at different periods of day: Thursday morning (around 9.00am), Friday afternoon (2.00pm), Saturday evening (7.00pm), and late evening on Thursday (10.00pm). A total of 634 subjects completed the questionnaire, including 258 female and 376 male.

6.2.2.2 ***Questionnaire and Quality Control***

The questionnaire (in Appendix II) was similar to the online questionnaire for the above diary study, but a Chinese version was provided for Chinese-speaking participants recruited from the survey hosting website, as the subscribers of the website should all be Chinese speakers. A disadvantage of online surveys is the un-monitored quality of the answers. It is usually difficult to know if the subjects fully understood the questions and if they answered the question seriously. In particular, in multiple choice questions, subjects can give an answer without knowing what the question was asking. As for open-ended questions, the subjects may not always make their answers clear enough for the examiner to understand them. For this reason, it is necessary to include certain mechanisms to avoid or to filter out answers which were not clear or entered seriously. The combination of both open-ended questions and multiple choice questions for most of the questions provides an solution to these problems. Apart from this, answers to some questions should be matched if the participant's answer is reliable (e.g. question 1 and 7, question 8 and 11). A minimum answering time was set for some pages, so as to increase the likelihood a subject reading the question carefully and thinking about their answer. The answer to open-ended questions was also considered as an important criterion to assess the quality of a participants' answer.

6.3 Results of Extended Exploration

A total of 61 entries were collected from the diary study, and 491 qualified questionnaires (out of 634 total submissions) from the online survey. The invalid questionnaires were either full of meaningless words for open-ended questions, obviously unmatched for both reliability-testing questions, or were not a refinding task. In the above studies, I mainly explored two questions: what type of refinding targets do people have, and what do people remember about these targets?

6.3.1 What do People refind? Types of Refinding Targets and Tasks

6.3.1.1 *Target types*

Among the 552 replies from both longitudinal studies and cross-sectional survey, only 37 of the tasks were about information encountered in the physical world, with the remainder relating to information previous encountered on computers. The targets range from documents, files, video clips, music, and photos to information on topics, which involve information from single or multiple sources such as webpages, emails, and chat records. Among the reported tasks, 47% of them were easy to find, 19% were not found, 10% were difficult to find, and 24% of them were to-be searched, all of these to-be-conducted tasks were from online questionnaire. I combined the selected category and the free description of targets, and found that most of the targets fell into following types: a specific website (30%), a specific document, email or article (29%), a specific piece of information such as a number (8%), software or applications (10%), folder or directory (6%), objects or entities such as an image or online shopping object (5%), and finally, the source (6%), that is, where or when an object or information was encountered, e.g. where I hear this tune, "the name of a TV series in which I saw the actress …".

The types of *targets* for information in digital world collected in this study include:

1) ***Specific piece of information***: these are usually small pieces of information that the user needs to use directly. Examples include a phone number, an email address, or a reference of a paper. Some of this information was used to support planning of real life events, e.g. opening hours, exact name of an event.
2) ***Specific items (known-items)***: such as a specific document, email, application (software) or multimedia object (e.g. YouTube video, image). These types of items are usually used directly, transferred (give to another person) or as a source for browsing and finding other information.
3) ***Specific source***: examples include a specific website, folder or document. These targets are usually a middle stage in an information seeking task, where the user usually

proceeds to find other information based in it. The information may or may not have been encountered previously.

4) ***Details from specific source***: The “details” can involve both what one has seen and that one has not. This type of target is usually for learning purposes. Of course, learning about the information is usually not the ultimate purpose. Such information are learnt for better decision making, planning, or applying the newly learnt knowledge to a current work activity, e.g. learning about a function for a current programming task, learning about an agenda to have a better plan for the next couple of days.
5) ***Topic***: this type of target usually multiple pieces of information from multiple sources, and is what one has seen before but about which one cannot recall all the details. For example, all of the papers that one has previously read on this topic, information of all recent movies that one has seen, prices of the flights that one saw the other day.

As for information or objects needs from physical world, following types of targets were reported:

1) ***Attributes of event***: date, time or location of conducting some activity.
2) ***Information seen in the physical world***: this includes items such as: a number, opening hours, a name of a place, names of encountered people, etc.
3) ***Details***: usually details from conversations or talks, e.g. what was said in the meeting. This suggests that encountered audio information is a usually a needed resource. Other types of detail information include movies or TV programs viewed long ago. If such information were digitalized and stored in a personal lifelog, the task would be similar to type 2-4 described above.
4) ***Physical Objects***: these are usually small objects that one often used, such as a card or a key. Since electronic copies (e.g. a photo of the key) cannot serve the functions that are needed from the physical object, refinding cannot be completed entirely through an electronic information system. Instead, images captured in lifelogs could act as evidence to show a user where they left their key if it happened to be captured by the camera, or images could act as memory cues to help the person recall the last time they saw the key. The refinding tasks in this case are similar to topic finding tasks, and may involve type 5 (topic finding) and 4 (detail finding) tasks from an information system which contains such images or other evidence/cues.

To summarize, there are no absolute distinctions between the information needs in the digital world and those in physical world. In fact, some participants tried to look in the digital world (internet) for previously encountered information in the physical world (e.g. movies one watched, paper books one read).

6.3.1.2 ***Types of tasks***

Most of tasks found here could fit into the categorization of refinding tasks as defined by Elsweiler (2007), but there are also some exceptions. Based on his three categories, I conclude the following types of refinding tasks as reported in the diary study:

1) ***Look up tasks:*** for exact details (e.g. phone number, address, contact names), attributes of an object such as price, date and/or time of an event, source (e.g. name of the song which sounds like this, the name of a book which have an episode like this...), etc.
2) ***Known-item search tasks:*** the targets are usually specific objects that have been encountered previously, such as a file, email, specific article, or software, multimedia object (e.g. images or videos clips), online shopping items. This type of task does not always stand-alone, it is sometimes one stage of a more complex information-seeking task or look up task.
3) ***Exploratory tasks (topic learning):*** in these tasks, people usually do not have a clear idea of exactly what information they are looking for. The information that they need could be something the user has viewed before or something that they have never found before. Yet, they usually have some idea of potential sources where they encountered the relevant information. This type of task usually happens after a known-item finding task, that the subject is looking for some specific potential sources (e.g. a folder, a collection, a website, or a document), and browsing it for interesting content.
4) ***Navigational tasks:*** the target is usually a website, folder, directory, group of pages (such as a person's home page), or a blog. Targets of this type of task are seldom the final step of a finding process. The previous three task types, in particular exploratory tasks, are usually followed after reaching the target, by navigating or browsing in it.

The tasks reported in these studies showed a variety of levels of uncertainty for the target (information needs), which is congruent with what was discussed in Chapter 3. Refinding targets are not always known-items or specific encountered information. For example, the targets in exploratory tasks are usually very uncertain.

6.3.1.3 ***Context of the tasks***

Regarding the context of the finding task, that is, what the subject was doing when he or she wanted to find the target, most of the participants were doing things related to the information

(77.6%), including: reading or doing related work on a computer (41.5%), or talking about related things (23.7%). Other related context (12.5%) includes working on or seeking for information in the physical world, e.g. viewing physical photo albums. Other types of context were reported as irrelevant to the information they were looking for, including: working on other things on the computer, travelling, or in other casual settings. These findings suggest that IR systems may try to predict the user's needs from the above types of context, especially using other computer activities at the time of refinding tasks and conversations. As for the purpose of the finding tasks, most of them (68.7%) were needed to continue with other work, about 12.1% of the targets were required by others, and 19.2 % were just for casual reviewing. Some of subjects said that they just wanted to pick up the feeling they had when reading the book or watching the movie a few years ago.

6.3.2 What do people remember for encountered information?

We also explored the types of information were remembered related to the targets. The free descriptions of remembered information were coded, and the frequency of the reporting the remembering each category of items were counted. Similar to (Gonçalves, 2005), It is not possible to test the accuracy and reliability of the recalled information, as many of the facts are not recorded. For example, it is difficult to test if the participant actually viewed an item previously at the given month he or she recalled. Therefore, I only report the frequency of recalling the recorded types of information at an approximate level. Combining the answers of free description and choice from multiple choice(s) questions regarding what they remember, I made the following findings:

6.3.2.1 *Memory of information in electronic world*

When reporting memory of the target item itself, subjects usually described their perceived summary of content (of the story, article or movie). They also reported remembering part of the content (e.g. part of the lyric, script or word). The questionnaire asked participants who did not find their target, to select the types of information they remembered about their target. Among the list of options, the keywords or sentences in textual target were the most well remembered features (36%), the name of websites, title of articles or subject of emails were also claimed to be remembered in around one third of reported tasks where such attributes are applicable. Visual features such as layout, background colour or salient visual elements were reported to be a remembered feature for a quarter of the reported tasks for finding webpages, online articles, blogs, and about 5% of the tasks for files on computers.

Other types of information that people remembered about the electronic items were:

1) Summary, gist of the meaning or other details (not exact words) of some content within or surrounding the target such as descriptions and other comments on the page of an online shopping item.
2) Function of the website or app.
3) Self-created content in it, e.g., "my comments" on an article.

6.3.2.2 *Memory about previous source*

According to the subjects' reports (across both the diary studies and the cross-sectional survey), most of them (93%) remembered the types of the source where they encountered the target previously, e.g. whether it was from the web, told to them by other people via email or conversation, or created by him or herself. For information received from other people, 54% of subjects claimed to remember the contact name of the sender. As for information previously found on the web, 70% of the subjects who searched the target previously, claimed to remember part of the query they used.

According to the subjects' descriptions in the diary study, many of them remembered how they found the target previously. For example, "…but I know how to find it…last time I used Google, and the keywords were …., I found it easily", "When I read about the museum on wiki, I saw the movie, so I tried to find the wiki page again".

6.3.2.3 *Memory of episodic context for electronic items*

For 91% of the diary entries, the participants claimed to remember at least one occasion of interacting with the targets, though for 60% of these they only remembered a general context. For example, "I was working on it day and night to beat the deadline". People sometimes also remembered why they accessed that item previously, associated events or tasks, or people involved in those events. Another interesting finding is that, in many of the diary entries, the subjects claimed to remember how they found the target previously, sometimes even remembering the exact queries they used to find the items. In three of the diary entries, the participants mentioned that they remembered particularly well the first encounter with the item, e.g. when it was created, first received, or found.

According to the subjects' reports, about 32% of the target were encountered only once, 43% encountered several times in separate period of time, 29% of them were used or visited frequently in a certain period of time, and 2.1% of them were not sure of number of previous encounters. Summarizing from their answers, following types of contextual information were reported as remembered:

- **Digital Context**

  As for the computer context of encountering the information previously, about 53 % of the subjects claimed to remember some of the applications that they were using, and 33% of them remembered the name of the websites or documents that they were visiting around that time.
- **Personal Location**

  As for the contexts in the physical world, most of the participants remembered where they were (65%). Of course, most of these participants reported that they were in their regular locations (83%). About 41% of the participants claimed to remember the name of exact address, name of street or estate, 19% participants remembered the spots around that place, and most of these people also claimed to be able to find the place on a map.
- **Other Physical context**

  Apart from location, approximately 37% of them claimed to remember who was nearby, the weather status (28%), the light status (16%) and their emotional status (15%), most of emotional status reported was either excited or depressed.
- **Other Events**

  Many of the participants remembered what they were doing during that period of time (67%), 37% of them remembered what happened in their organization (e.g. school, company) and public events (21%).

6.3.3 Relevance judgment

As discussed in Chapter 3, refinding is only one of the approaches to address information needs. People can solve their information problem with alternative information which they may or may not have seen before, and relevance judgments can be very dynamic (see section 3.4.5.3). The questionnaires asked the participants whether they tried to look for and found the specific items that were originally in their minds when they started the finding task. The findings generally supported this argument. Many participants searched with an online search engine (e.g. Google) for "any" article or resource that matches certain criteria. In some of the reported tasks, even for "specific item" type of tasks, the participants started with a specific target in mind (seen previously) and ended up finding a similar one or another version of it. This finding also suggests that it would be difficult to detect frequency of refinding ("finding-again") tasks by implicitly action logging, e.g. if the refinding tasks are defined strictly as accessing a same item again.

6.3.4 Personal differences

The data in diary study showed a noticeable personal difference on the types of targets. This may be largely due to the work and task they were conducting during that the period of the diary study. For example, Participant A is a senior researcher, and is usually involved in managing projects and communication with other institutes or project partners, so many of his refinding tasks involved finding contact details. Participant D focused on programming during that period of the diary study, and most of his refinding tasks involved finding instructions and examples of code to learn from, follow and carry out his programming work. Participant C tended to care more about leisure and life, so many of her information refinding involved checking information for planning real life events, e.g. when to see a movie. Participant B seemed to be writing quite a few academic papers during the diary study period, and most of the reported refinding tasks concerned details of references or past papers (to "copy and paste" selected details into her "current work"). Such distinctive patterns were not found in other participants in the diary, as they only added a few diary entries.

6.3.5 Conclusions

The focus of the study described above was to explore the possible types of refinding targets and tasks, as well as the types of things that people might remember about electronic targets. There was a greater variety of targets reported in the cross-sectional survey than any previous diary studies. Based on the results of this study, I developed a list of 9 types of refinding targets as follows:

1) specific information
2) specific item
3) specific source (e.g. a folder, a page full of potentially useful information)
4) details in specific source
5) topic
6) attributes of event
7) specific information encountered in physical world
8) detailed information encountered in physical world (e.g. a full conversation)
9) physical objects.

I concluded that there are four types of tasks based on their task descriptions:

1) look up
2) known item search
3) exploratory
4) navigational

The subjects reported a wide range of information that they claimed to remember about the digital targets. Apart from the textual information from textual targets (e.g. words in a document), people also remembered visual features. This suggests that either search by similar visual items or presenting items with visually similar thumbnails can cater for users' memory, e.g. what they tend to remember. It is congruent with my hypothesis (H1) that people tend to remember the episodic source of the previous encounter with a known target. These include the previous source of the target (e.g. where the subject encountered it before), how he or she found it, other related activities or events, and the approximate time (e.g. how long ago). A small number of subjects also reported remembering the physical context such as where they were and who were nearby.

In short, there are a variety of refinding tasks, rather than the simplified a known-item refinding task that is studied in most of the previous literatures, e.g. (Blanc-Brude & Scapin, 2007; Gonçalves & Jorge, 2005). A refinding task could consist of more than one type of refinding sub-task or activity, and involve more than one strategy. In addition, people could remember a rich context of the previous encounters of the target. A support to refinding behaviour should utilize these types of information that people tend to remember.

6.4 Reliability of Recall

Of course, the above study did not test the correctness of the recalled content, as much of the contextual information is not digitally recorded. In order to evaluate the correctness of the recall, ground truth is needed, that is, the refinding targets and their related context and metadata should be available. This means each participant should have a personal information collection, and the target items and the corresponding attributes or context should be retrieved from the collection. The only subjects who have such long-term lifelogs and are willing to participate in such an experiment are the three lifeloggers (introduced in Section 5.1), who stored information for all their desktop activities together with context of the physical world information from May 2008 until the end of 2009. In the following study I aim to explore: which attributes of the context and metadata of previously encountered items tend to be more reliably recalled by these lifeloggers.

6.4.1 **Data Generation**

The main material for collecting data from the participants was a pre-structured Excel spreadsheet, shown in Figure 6.1. The spreadsheet listed 20 attributes (the top 20 attributes listed in column 1, Table 6-2) with one row pre-filled as an example. The participants were required to generate 50 tasks based on free recall, and add them to the task field.

A	B	C	D	E	F	G	H	I	J	K
TaskNum		TaskDetails	keywords	extension	Date	Month	Season	DayofWeek	partOfWk	partOfD
sample:		E.g: Sigir doctoral consortium - r	E.g: Linking	E.g: pdf tex	E.g: 23/05/08	E.g: May Ju	Spring, Sur	E.g: Monda	mid, begin	morning
1		sigir doctoral cocotium full papte	memory life	pdf, doc		2				late nigh
2		sigir doctoral cocotium camera r	memory life	pdf, doc		11			weekday	

Figure 6.1 Part of the Excel spreadsheet to designed to hold freely recalled targets and attributes

To encourage them to generate a richer variety of tasks, suggestions were provided in the instructions, such as: information related to conferences you went to, interesting videos, websites, articles, some papers you worked on. For each of the generated tasks, the subjects were required to recall corresponding values of each field and enter them as verbal query terms in corresponding cells.

After the participants had generated all the tasks and filled in the attributes that they recalled, the spreadsheet was processed using an in-house Java application, This application extracted the recalled attributes to insert them an in-house developed IR system designed to retrieve potentially relevant items. The retrieved results (represented by their title and path/URL) were presented to the subjects to judge their relevance. For each of the relevant items, attributes and metadata of the context for all occasions of accessing the relevant items were extracted from their lifelog database, including: *keywords, extension (type of target item), date of visiting, month, season, day of week, part of week (week end, weekday), time range (e.g. 8am-9pm), people present, Geo- location (e.g. Dublin, Grafton street), weather, file path, country, file name, from contact, to contact, device, year.*

Of course, there are occasions in which the participants only misspelt the words (query terms), or a potentially relevant item was not retrieved by the IR system. Therefore an additional adjustment step was carried out before the reliability of each type of query was calculated. The query terms which did not bring any relevant results were presented to the participants together with the task description and the field of query. The participants were asked to judge whether any of the terms falls into either categories. Any terms that belong to the former situation were ignored, and those which fell into the latter situation were considered to be useful for retrieving at least one relevant result item.

6.4.2 Episodic Memory of Refinding Targets

The questionnaires also asked the participants to recall the actions they did on the target item (if they remember them), the pattern of accessing the targets (e.g. only once, frequent access), and the number of occasions in which they remember detailed context of accessing the item(s) (multiple times, only once, none). All participants remembered how they interacted with their targets, e.g. writing, reading. This supported the hypothesis that people usually have some episodic memory associated with information they encountered or interacted. The percentage of each pattern of remembered occasion of accessing was calculated against each accessing pattern. For example, if subject A has 20 targets accessed multiple times, and there were 5 out of these targets for which subject A can remember one occasion of accessing, the percentage for remembering one occasion in among multiple access occasions is 5/20x100%=20%. On average, 27 out of the 50 targets were accessed more than once, and 20 of them were accessed very often in a specific period. It indicates that people may remember episodic context for multiple situations of accessing targets. Interestingly, for items which they reported as “cannot recall details for any specific occasions”, they also reported in free notes that they remember some associated events or activities or the general context of that period, when working on the item, although they could not picture the exact moment of accessing the items. In short, these findings further support the view that people tend to remember episodic context of encountered information.

6.4.3 What attributes do people tend to correctly recall?

To explore the more reliably remembered attributes or metadata, I created a programme to compare the extracted value of each field (e.g. date of encountering the information) and the corresponding values reported by the subjects. This code calculated the hit rate and false query rate for each field. The *hit rate* refers to the percentage of relevant items for each task which matches the recalled attribute or metadata. The *false query* rate describes how many terms or values for a field (attribute or metadata) that the subjects recalled that has no matching items in the relevant results. For example, a subject may recall that the target documents were encountered probably in May, June or/and July.

There are two documents, one of them was visited in May, and the other is encountered in August. Therefore, the query for the "month" field only matches one of the two documents, and the hit rate is 50%. This means, the query alone may only retrieve half of the potentially relevant documents. At the same time, only one of the three values ("May") matches at least one of the relevant items, therefore the false query rate = 66.7% (2/3 of the query may bring totally irrelevant results). The higher the hit rate and lower the false query rate, the better the accuracy and reliability. The following formula is used to assess reliability of recalled attributes based on hit rate and false query rate:

Table 6-2 Validation of recalled content

Attributes	False query	Hit Rate	Average Length	Frequency(%)	Reliability	Usefulness
Keywords	0.48	0.77	2.96	96	0.40	38*
Extension	0.28	0.87	1.15	99	0.63*	62*
File path	0.57	0.65	1.02	8	0.28	2.2
File name	0.73	0.50	2.25	15	0.14	2.0
From Contact	0.21	0.67	0.38	9	0.53*	4.8
To Contact	0.35	0.73	1.63	4	0.47	1.9
Device	0.61	0.39	1	71	0.15	11
Country	0.12	0.81	1	81	0.71*	58*
Date Range	0.78	0.64	2.9 (days)	9	0.14	1.2
Date	0.87	0.35	2.87	22	0.05	1.0
Month	0.36	0.59	1.09	83	0.38	31*
Season	0.23	0.47	1.04	95	0.36	34*
Day of week	0.40	0.33	1.17	6	0.19	1.2
Part of week	0.11	0.93	1	54	0.83*	45*
Time Range	0.40	0.67	3.47	7	0.40	2.8
Light status	0.40	0.32	1	6	0.19	1.2
People Present	0.40	0.15	2.3	17	0.09	1.5
Geo-location	0.21	0.32	1.02	94	0.25	24*
Weather	0.52	0.31	1.2	9	0.15	1.3
Surrounding Items	NA	NA	1.59	33	NA	NA
Emotion	NA	NA	1	8	NA	NA
Phone Call	NA	NA	1	6	NA	NA
SMS	NA	NA	1	3	NA	NA
Related People	NA	NA	2.67	3	NA	NA
Related Location	NA	NA	1.5	2.1	NA	NA

NA: not available for validation

$$\textit{Reliability of recall} = \textit{hit rate} \times (1 - \textit{false query rate})$$

Of course, reliably recalled attributes may not necessarily be the most useful search fields for these participants, if these attributes or features were rarely remembered. Therefore, the score of reliability and the frequency of recall are combined to predict potential usefulness of the corresponding search field.

$$\textit{Usefulness} = \textit{hit rate} \times (1 - \textit{false query rate}) \times \textit{frequency of recall}$$

Table 6-2 shows the frequency of recall, hit rate, false query rate, reliability score, average length (number of words for long textual content such as title and content, or number of values for metadata) of queries and usefulness of the fields. The hit rate and false query rate were not calculated for every field, as some of them are either not recorded or have no fixed value, e.g. other computer activities (items accessed around that time).

According to the above table, the extension (item type), country of the person, name of the contact who sent the email or SMS and part of week, are the most reliably remembered features. Attributes or features which seem to be most useful (frequently and reliably recalled) include: extension, keywords, country, Geo-location, month, season, and part of week.

6.5 Chapter Summary

This chapter primarily explored three questions: 1) the types of things people may remember related to information they encountered, 2) the type of refinding tasks people may undertake, 3) the attributes or metadata that are more likely to be correctly/reliably recalled. The first two questions were explored through diary studies and cross-sectional online surveys. Four types of refinding tasks were concluded based on the findings, including: look-up, known-item search, exploratory (topic search/learning), and navigational tasks. It was found that participants recalled a rich variety of related information, many of which are related to the episode during which the information was previously encountered.

I also explored the reliability of recalled information from three lifeloggers, as they are the only people known to have recorded most of the context data that I want to evaluate. I further determined the potentially most useful types of search options that the three lifeloggers tend to reliably remember and that tend to bring more results that are relevant. These types of information include: extension, keywords, country, geo-Location, month, season, and part of week. Of course, this conclusion is only based on the data from three subjects, and 50 tasks each. Other attributes or features that are not so reliably or frequently recalled may also bring valuable results. Therefore, I suggest that all the above attributes or features should be included as search options for an IR system, although the less reliable features should probably be assigned a lower weight. The more reliably recalled features could be included in filter functions to reduce the noise in the search result, e.g. extension (item type), from contact, country, and finally, part of the week.

Of course, a complete information system not only allows users to enter their queries, but also to browse the results, or navigates to locate targets. The next chapter explores how to present the results or data collections with good “memory cues”.

Chapter 7
Towards Automatically Extracting Memory Cues from Personal Lifelogs

As discussed in Chapter 3, it is desirable that while navigating and browsing for information in personal lifelogs (PLLs), users can easily learn about the structure of the collections or directories, recognizing what is in them, and identifying a waypoint or landmark that is close to their target. Based on my review of human memory in Chapter 4, I suggest that to support navigation functions, the data in PLLs should be automatically structured hierarchically as episodes and general events, similar to the structure of people's autobiographical memory, and representative information should be selected to represent each event (folder). Therefore, it is important to automatically detect remindful items to represent different levels of events. This chapter reports a series of studies towards automatically selecting "cue" items from the PLL data to represent events. Section 7.2 reviews and reports studies which explored potential types of cues and factors that may contribute the types of cues. Section 7.3 reports a study with three lifelogs, aiming to collect quantitative data for developing an algorithm to automatically calculate the strength of item for cueing memory. Finally, the study reported in section 7.4 evaluates this algorithm.

7.1 Background

In Chapter 3, I described a classification of 9 types of targets which correspond to 2 types of data in personal lifelogs:

- Born-digital information that a person creates or encounters in the digital world, such as emails and documents
- Digital records of moments in the physical world, e.g. photos, Geo-locations.

According to my discussion in Chapter 4 and findings reported in Chapter 6, people usually have a source memory of encountered information and accessed electronic items, e.g., in what activities, projects or period in which time, they created, interacted or encountered the information or item. For this reason, I believe that an entire personal lifelog collection can be organized in a way that mimics the structure of autobiographical memory, which is a hierarchical network of both general and specific events. I suggest that:

- The data in personal lifelogs could be grouped as episodes, which can be further organized as general events, and ordered chronologically within each general event directory.
- After the events are structured hierarchically, users can navigate to the specific episodes by recognizing the correct parent level events (e.g. general events). Therefore, the information, which represents the parent-level directories (general events), should include thematic features that can act as good memory cues for content in the directories, that is, episodes in this general event group.
- Displaying information which forms strong memory cues for temporal information can facilitate browsing a directory of events that are ordered by time.

The question is: *What good memory cues should our PLLs data provide?*

As a good memory cue, the displayed item or information itself should be at least easily recognizable, so that the user can understand what it represents. To make it a good cue for a digital item or event, it should have a strong association with the target. In addition, it should not be associated with too many other items, or the *fan effect* will reduce its power as a memory cue, see section 4.2.6 for more details of the fan effect.

Lee (2007) studied the categories of content in SenseCam images which tend to be good memory cues for different types of events, and concluded the following type of cues:

- *Person* cues: images of significant persons with which one interacted, and tend to be good cues for *people-based* experiences such as family reunions and weddings.
- *Object* cues: include significant objects (*e.g.,* a birthday cake, a stained glass window) that were encountered during an event, and tend to work well for *object-based* experiences such as a museum visit or a shopping trip.
- *Place* cues: describe the physical setting of the experience such as the façade of a visited store or the dining room, and tend to trigger memory of *place-based* experiences such as a vacation to a new town.
- *Action* cues, show some motion or physical action of an individual, and are usually the best cues for *action-based* experiences such as attending a church.

Although these findings provide us with considerable knowledge of the types of content in images that are likely to act as good memory cues for certain types of events, they were not enough to form an algorithm to automatically extract good cue images. Since the above studies only explored the memory of specific episodes, it is not clear how likely it is that these types of images or information can work for general events (e.g. events that span a few days) or computer activities.

I conducted a series of studies which explored the features and factors that make an item a good memory cue, formulated algorithms to automatically detecting the strength of items and evaluated these algorithms. Table 7-1 lists the methods used in each of these studies.

Table 7-1 Methodology of studies towards automatically extracting memory cues

Study Ref	Participants	Lifelog data	Material	Method	Section No.
E1	3 non lifeloggers	1 day mini-lifelog	Pen and paper (printed cards)	Active selecting + cued recall test	7.2.1
E2	2 lifeloggers	None	Excel spread sheet	Free recall + questionnaire	7.2.2
E3	1 lifelogger (myself)	20 month	Experimental application (1)	Self experiment (Cue-recall + others)	7.2.3
Q1	3 lifelogers	20 month	Experimental application (2)	Experiment	7.3
Q2	3 lifelogers	20 month	Experimental application (3)	Experiment	7.4

The rest of this chapter is structured as follows:

Section 7.2 reports three preliminary exploratory studies using different approaches to collect ideas of the types and features of good memory cues for PLLs:

- Section 7.2.1 describes the first study (E1) which was an initial attempt to find remindful representative cue items for daily events from three non-lifeloggers using one-day mini lifelog collections. This study combines each subject's active selection of cues items and a cue-recall test to evaluate the cues.
- Section 7.2.2 describes the second study (E2) which mainly employed a survey method to collect ideas from two long–term lifeloggers, who know more about the prototype lifelogs than non-lifeloggers, to collect ideas from them for potential remindful cue items for both episodes (short-term events) and general events (long-term) events, based on their free recall.

- Section 7.2.3 details the third study (E3) which used an self-experimentation approach to explore types and features of cue items for episodes.

The results of these studies, especially the last one led to the design of the main investigation in this chapter which is described in section 7.3.

The experiment (Q1) reported in section 7.3 collected quantitative data about the factors which make each type of item a good memory cue. Based on the rating scores of cue strength of each presented cue it, and the attributes (predictors) of these items, which are extracted from each lifelogger's prototype lifeog database, I developed an algorithm which seeks to predict the likelihood of an item being a good cue for each type of target (e.g. an episode, a long period of time).

Finally, the algorithm is evaluated in an experiment (Q2) described in section 7.4. This experiment also worked with prototype lifelog data and their owner, one of the three lifeloggers.

7.2 Exploring types of good memory cues

To automatically extract good memory cues from a collection of digital items, a detailed understanding is needed with regard to the types of information that tend to act as good memory cues, in addition to those already highlighted in the literature, e.g. SenseCam images (Sellen et al., 2007). Apart from this, it is also important to find a list of features that may contribute to the strength of these cues.

7.2.1 Cues for computer events

The first study is a preliminary exploration which aimed to collect ideas regarding the types of remindful cue items from a one-day mini lifelog collection (Chen, 2009). Three undergraduate intern students (non-lifeloggers) were invited to participant in this study. They were not lifeloggers and have no experience of lifelogging.

This study mainly required the participants to pick the most remindful and representative information from their lifelog records, and tested how strong these items were in triggering the memory of events during the time of period they lifelogged. Since they have not collected any lifelog data before, a lifelog collection is essential for each of them. Therefore, the first step of this study was to let each of them collect a mini lifelog collection for one day. They then manually selected up to 10 cue items from this collection at the end of the day. The strength of these selected cue items were tested through a cued-recall test a week after the date of collection.

7.2.1.1 *Data collection*

The mini lifelog was collected using a computer application called Timesnapper[16]. Similar to Slife which I used to capture the long term prototype PLLs, see the review in section 5.2.1. Timesnapper also continuously recorded metadata of computer activities, including the title of the activity window (which is usually the name of a file or subject of an email), URL and path of visited web pages or files from visited web pages or some documents. In addition, it also captures screenshots of the desktop at fixed time intervals. In this experiment, it was set at every 10 seconds to match with the capture rate of the SenseCams which were used for collecting the long term lifelog collection.

7.2.1.2 *Generating cue items*

To "create" the cues and list of activities in the day, the subjects did the following at the end of the day. Firstly, they free recalled their activities during the day, followed immediately by a cued recall test with my selected types of cues: activity clouds (which displays keywords, phrases, titles from computer activities, with the more important ones shown in bigger fonts), web statistics (which lists all the websites visited and the duration of the visit), and application statistics (a list of software applications that were used). All the above three types of information were provided by Timesnapper. During this cued-recall task, the participants were also required to pick up items or information that reminded them of their activities during the day, and create "reminder notes" either by printing a screenshot of the item or writing them down on a 10x10cm piece of paper. After this, each participant was presented with the screenshots of the entire day to generate a fuller list of activities for the day. This list served as a ground truth to test the subject's recall a week after the data capture. During this step, the participants could also select remindful screenshots in Timesnapper and print them as a "reminder note". Finally, the participants were asked to select up to 10 reminder notes for the entire day to help them recall what they did on that day.

7.2.1.3 *Testing cue strength*

These reminder notes were presented to the participants a week later in another cued recall task, to examine the combined effect of their selected "reminder notes". Right before this second cued recall task, the participants were required to free recall their activities and events during

[16]http://www.timesnapper.com/

the data-collecting day. I compared the amount of recalled details from this free recall, cued recall and the ground truth from the previous week to explore the strength of each type of cue.

7.2.1.4 ***Results and discussion***

We found a rich variety of items that had the potential to act as good memory cues for computer-centred activities (episodes which focus on interacting with computers). These items included: the names of the desktop applications used, the names of websites visited, desktop screenshots, information which represented the main content of computer activities, and the subject or the contact of email, etc. In addition, the names of the location and related people were also suggested to be good memory cues for real world events. Detailed results of this study can be found in (Chen, 2009).

Due to the small numbers of subjects and short period of this study, the content and level of events were very limited. For example, participants had to perceive the event as a short period of time which is completed in a day. Besides, there was a dramatic effect caused by the experiment (recalling and reviewing events) on the memory of the experiment day, which made the participants remember much more details of the day (even with free recall) than the rest of the days in the week. This ceiling effect of recalled count on the day also resulted in that the cues could not make the result remarkably better. This suggested that in the studies which employed cued recall as the main approach for evaluating the strength of cue items, the subjects should not be excessively exposed to data in the to-be-recalled period of time prior to the memory test.

7.2.2 **Cues items "required" by lifeloggers**

To explore the possible types of cue objects for the more distant past and a richer variety of events, I conducted another study with two lifeloggers (A and B), who have insight into our prototype, experimental lifelog data collections. Since this study is very subjective and lifelogger C is the investigator of the experiment, she did not participate as a subject. I believe that a better understanding of the available types of lifelog data is helpful in selecting potentially useful cues.

7.2.2.1 ***Event generation***

The main material was a semi-structured electronic questionnaire (Excel spreadsheet). Each subject was required to free recall about 50 to 100 events, which happened between the date they began their lifelog collection and the day before this experiment. In order to explore the memory cues for computer activities, they were required to include at least 20 events which focused on computer activities in the list, e.g. “wrote a report”. To avoid the ceiling effect introduced by excessive exposure to the lifelog data, and due to the much larger amount and complex composition of their prototype life data, I did not adopt the cued recall approach as described in the previous study. Thus their listed events were based on free recall. Due to privacy concerns, I asked the subjects to replace the descriptions of the events by the event type: RE (real life event) and CA (computer activity).

According to associated memory theories (reviewed in Chapter 4), there is very likely to be a relation between events that are recalled consecutively. For example, a recalled event may act as a memory cue for the next recalled event. In order to explore the cue effect of recently recalled events, the participants were asked to leave a blank row between two events if they had a break in the middle of the free recall.

After they finished generating the list of events/activities, the two participants were required to answer some questions for each of the events, including questions about the event and types of lifelog data or items that could potentially act as a good cue for this event.

7.2.2.2 *What makes the subjects recall these events*

A total of 168 items and events were listed by the participants, I explored the reasons that these particular events were recalled. As reviewed in Chapter 4, two types of factors influence the likelihood of recalling a piece of information (retrieving a memory trace): the base level activation of a memory itself, and the strength of retrieval cues. I believe that the reason that these particular events were recalled is due to a joint contribution of the base activation level of these events, and cues, such as a previously recalled event. Therefore, understanding the reasons why these events were free-recalled is helpful for exploring:

- What makes an event memorable?
- What acted as memory cues to trigger the memory of the events?

We explored the reasons for recalling these events from two aspects: the events themselves, and the cue event (previous event(s)). The participants were required to report:

- The reasons that these events were “important”
- The effort they spent on the items when creating them previously
- The distinctiveness of these events (from 1=routine event to 5=extremely distinctive)
- The distinctive aspect of the events

There are five main reasons for considering some of the events as important: important for current work (e.g. "has great influence to my current work") (51.3%), "was important for my work for a certain period of time" (29.7%), novelty (27%) (e.g. activity in an unusual place, "first time experience"), "personal landmark events" (8.1%), and interesting (13.5%). Of course, the reported reasons differ between participants and between types of events (computer activities and real world events). For example, most of the important computer activities were either "important for current work" or "were important for a certain period of time in the past". These reported reasons suggested that recency (or important for current work), effort ("was important for my work certain period"), distinctiveness (novelty), and personal significance are important factors that contribute to the activation level of memories for an event. This is further supported by answers from other questions. For example, among 30 reported computer activities, 21 (70%) of them were reported to have required a huge effort at the time they were carried out. In addition, most of the recalled events were rated as very distinctive (Mean=4.22, SD=0.68). The distinctive aspects were: type of activity (25.9%), location (68.7%), people involved (44.6%), and visual features during the event (22.9%).

To explore whether and how a previous recalled event triggers the memories of another event, participants were asked to describe the relations between adjacently recalled events (the currently recalled event and the previous one). A total of 89 events were reported to be associated with the event which was recalled right before it. The features that link these events were: (same) people who participated in the event (40%), type of event (35%), location of the event (27%), related topic (16%), and that the two events happened consecutively or were temporally adjacent.

7.2.2.3 *Types of memory cues suggested by lifeloggers*

To collect ideas of potential types of memory cues for events, the two lifeloggers were asked to select up to three types of "reminders" for each of their listed events. I provided them with some suggested types, including: a SenseCam image or a manually taken digital photo in the event, the location of the event, and people present at the event. As for computer activities, the following types of cues were suggested: titles, filenames, and name of applications. These suggestions were based on the findings from the study described above in section 7.2.1. Most of the suggested types of items were selected by each participant for at least one of their listed events. Apart from these types of items, the participants also suggested some other types. For example, Participant A believed that some summary information from interaction with digital items (rather than keywords) might be useful reminders. Participant B added three types of reminders: full content of items in the computer events, time and date information, and Twitter messages (micro blog messages). Of course, the suggested cues may not necessarily be good ones for triggering memory of these events and representing these events; other types of information which they did not suggest might also be good memory cues. Therefore, the data collected in this study is not exclusive.

To explore whether the types of cues may vary for different types of events, and how they might vary from person to person, I compared the percentage of each type of lifelog item being considered as remindful cues for each participant, and each type of event. The events were categorized by the participants on the following two dimensions:

1) Distinctive aspect of the event, e.g. location, people, content of the event, visual content
2) Activity type: computer activities (CA), and non-computer activities (RE for real life events).

We found a remarkable difference between the two subjects in terms of their preference for using personal lifelog items to assist them to recall events. For example, Participant B preferred to use a variety of lifelog items as reminders, but Participant A selected one type of data consistently for life events and another for computer activities.

Table 7-2 Types of reminders for each types of event from each participant

Cue type	Subjects		Distinctive aspect of Event				Event Type		Total
	A	B	Visual	Location	People	Activity	CA	RE	
Title	0	12	1	1	0	11	8	4	12
File name	0	12	1	1	0	11	8	4	12
Email subject	0	2	0	1	0	1	1	1	2
keywords in the textual content	0	2	1	0	0	2	1	1	2
Detail or full content	27	3	0	13	5	27	24	0	0
Name of people presented	0	27	13	19	11	0	0	27	27
Name of the location	0	37	18	27	10	4	4	32	37
Date and Time	24	84	47	88	45	3	1	107	108
Twitter	0	11	6	6	5	0	2	9	11
Total Events	78	88	43	114	74	38	52	114	

* CA=computer activity, RE=real life event

7.2.2.4 *Conclusions*

So far, I have reviewed and reported two studies that explored the potential type of information that can be used as good memory cues to help people recognize and recall more related details of personal events. These cue-items include: images, information of the events such as date time, location, people, and attributes or information from computer items such as title, detail of the contents. Apart from these, I also investigated the potential of related events to act as cues. In the second study, it was found that about half of the subjects' free recalled events were associated with the event recalled prior to them. This indicates that about half of the events were triggered by other events which share certain features with them, such as the same "participants", the same type of event, location, topic, or they are consecutive, causal or temporally adjacent. However, the strength of each type of cue-item cannot be calculated on the above study. To develop an algorithm to predict the likelihood that an item or piece of information will tend to act as a good memory cue, a better understanding is needed for the reason that some specific items can act as good memory cues for these specific events. In another words, it is important to understand what factors make these items good memory cues.

7.2.3 **Insight from a Self-experiment: what makes a good cue?**

To study this question, the subject's insight and reflection is very important. Therefore, I decided to adopt a self-experimentation approach (Roberts & Neuringer, 1998) for an initial exploration, in which the investigator acted as the experimental subject, and I'm the only subject. Like most of the case studies, findings from this self-experimental approach may only be applicable to a single person. But this approach can usually provide a more in-depth understanding of the question with minimum cost. The findings can then be further tested with another experiment which involves more subjects. In this study, lifelogger C was the investigator and experimental subject. In the rest of this subsection, the first person "I" is used to describe the subject and investigator.

7.2.3.1 ***Method***

Self-experiment is usually prone to expectation effect, that the results may be biased by the examiner's expectation. Therefore, an in-house developed experimental platform was used to conduct and control the entire experiment, as shown in Figure 7.1.

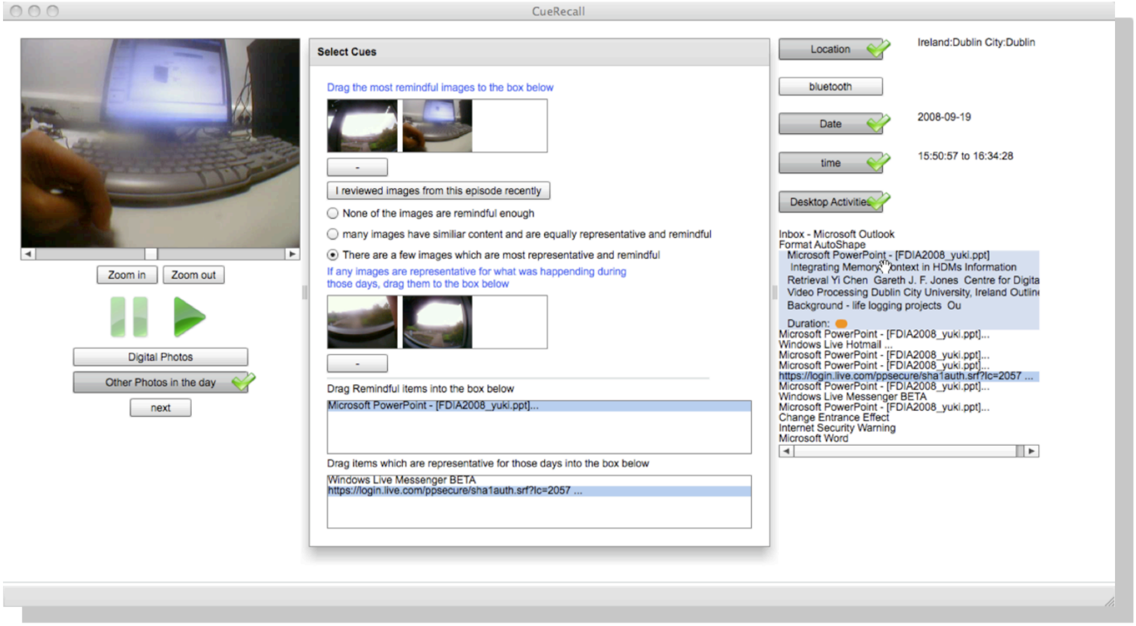

Figure 7.1 Screenshot of Experiment Interface at step 3

For each task, I needed to recall details of each presented event with a minimum number of cues. The episodes were randomly selected by the application from the entire lifelog in two steps. In the first step, it randomly selected one week from each month plus the four weeks when the biometric data was collected. This gave a total period of 26 weeks of data. Then it randomly selected up to two events per week, and presented them in a random order, to avoid the situation of guessing the content of the event based on events presented prior to it, e.g. “it should be some event that happened a week after the one in the previous task”. The events were segmented using an application described in (Doherty & Smeaton, 2008).

Each task was conducted using the following procedures:

1) Cued-recall with baseline key-frame SenseCam image: Each event was initially presented using a keyframe SenseCam image which was selected using the same application as that used to segment the events (Doherty & Smeaton, 2008). These keyframe images were considered as a baseline since they have been suggested as good memory cues. e.g. (Berry et al., 2007; Sellen et al., 2007), where a keyframe image was expected to be the most representative one in a complete episode.

2) Cued recall with textual cues: If I could not immediately recall the details of the event based on the key frame image displayed, I could selectively “uncover” other information about the episode by clicking a button labelled by the name of the feature type, e.g. “location”. The feature types available included:

- Location: presented with precision at city level, e.g. “Dublin”.
- People (Bluetooth): Names of nearby Bluetooth devices that were captured during the episode. It was expected that some of the Bluetooth devices would be named after the wearer, so that they could indicate the presence of the person.
- Date: e.g. 2008-09-27
- Time: shows the beginning time and end time of the event, e.g. 15:50:17 -16:34:28.
- Computer activities: A list of computer activities presented by the titles of the activities, that is, the filename of a file, title of a webpage, or subject of an email. These were expected to act as memory cues for computer activity dominated episodes. An orange colour bar showed the relevant duration of a computer activity.
- Digital photos: A list of digital photos taken in the given episode, if there were any.
- Other events in the day: the keyframe image of other episodes before and after the given episode. This was expected to provide a context for the episode.

At this step, the type of “uncovered” and useful information (I could deselect them if I think the information provides nothing useful) was recorded. I could drag and drop the remindful computer activity item into the corresponding box for explore the features of remindful computer activities. When “digital photos” or “other events in the day” were selected, the images were displayed in the same place where the initial keyframe was presented, and the scroll bar could be used to view other images in selected image list.

3) Validation: Cued recall with all SenseCam images in the episode: I expected that viewing a complete set of SenseCam images captured during the episode could bring all the memories of that episode back to me. When I felt that I had recalled enough detail of the episode, or if I had uncovered all the details, I entered the next stage to view the entire episode to check if this was the story that I had recalled. In this step, the play and pause button are enabled, so that I could click the “play” button to play all the SenseCam images in this event in chronological order. The automatic display could be paused or manually advanced using the scroll bar. While viewing the images, I needed to select the images which helped me to recall more information about the episode, so that I could examine the features of images that made them useful memory cues.

4) Rating of recall: Finally, I rated the correctness and vividness of recall for the episode on a five-point scale (with 1=recalled nothing, to 5=fully and vividly recalled).

Since this was a self-study and pilot study, reflection during the experiment played a very important part. I regularly took notes of my thoughts.

7.2.3.2 ***Results and Discussions***

Initially, I planned to compute quantitative results for the features and types of good memory cues based on the frequency of features and the types of cue information that had been selected, and the rating score for the vividness of recall. However, this turned out to be very difficult to do for the following reasons:

1) Some SenseCam images taken at adjacent times could be very similar in content and quality. Therefore, it was usually a difficult decision to select absolutely the best image from among them. It could also be misleading if an automatic keyframe selection algorithm is developed based on the difference between the selected images and others (including the very similar images). On the other hand, some types of items with certain features may not be presented as frequently as others. Therefore, these features, which might have contributed to the strength of a memory cue, could have been ignored. For the above reasons, I suggest that a list of features and types of objects, which are likely to act as good memory cues should be listed, so that both items with these features and those without them can be sampled, in order to test if these features contributed to the strength of the cues.

2) The rating scale was very subjective and unreliable. It was not always easy to give a very certain score for my cued-recall. Displaying all the SenseCam images in the episode could not guarantee my "total recall" and mental travel back to re-experience it.

3) There were no questions which could distinguish "know" and "remember". In many cases, I could understand all the episodes and infer what was happening. Yet, I had little vivid sensor-perceptual memory recollection for that specific episode, nor did I have a feeling of self-involvement, it felt as if I was watching a stream of photos of familiar places taken by others. For example, when I saw the images of the path from my home to my lab, I could infer that I was walking back home if these pictures were mine. Of course, some of the instances were due to a lack of detail in the images (low resolution and clarity). Yet, most of the "known" but not "remembered" episodes were about daily routines, e.g. sitting in front of my computer in the lab. If it were due to the fact effect, *distinctive events, or even routine events with distinctive aspects may be more easily recognized* ("remembered").

4) For episodes dominated by computer activities, I usually felt a need for much higher resolution images to show me the texts and images on the computer screen.

5) The episodes were segmented at varied lengths, ranging from a few minutes to a couple of hours. It did not really make sense to judge how complete the recall was if the length of the period was not given. I found it very difficult to guess the length of a segmented "event", therefore, it is difficult to evaluate how completely or correctly the subject recalled this "event". Actually, the cues can trigger memories of events of very different duration. Some items reminded me of the specific moments when the picture was taken, some items are more representative of a longer-term event, e.g. when I was in Paris. Therefore, instead of providing pre-segmented "events" and testing their recall, more flexibility should be allowed for the duration of an "event".

Limitation of episode selection: Since all episodes in this study were randomly selected, too few distinctive events were included. Therefore, it was difficult to know from this study if memory for distinctive events could be different from other events. Also, due to the design of the event segmentation algorithm (Doherty & Smeaton, 2008), the episodes included in this study could only be those time periods for which SenseCam images were captured with intact sensor data.

Due to all the above reasons, instead of attempting to develop quantitative conclusions, I focused on my free form notes and report my qualitative findings:

1) What objects tend to trigger memory of events?

All the types of cues included in the experimental application were more or less useful for triggering memory.

a. Similar to the findings in other studies, e.g. (Sellen et al., 2007), SenseCam images did trigger my memory of what I was doing during the episode for which they were captured. In many cases, there was no particularly important content (such as a person, significant object of location) present in it. After viewing some photos, I suddenly recalled lots of details which were not captured in the image.
b. Digital photos were good cues for events. This may be due to the fact that digital photos were usually taken in interesting events, and that intentionally taken photos usually cover a better view or more meaningful content than passively taken images. If this is true, the SenseCam images which were taken manually by pressing the shutter button should tend to be more memorable than others. In addition to the above reasons, some of the photos were explicitly viewed after they were taken. Thus, memories of the

photos and the corresponding events may have been re-enforced and more tightly associated.

c. Some titles of computer activities which I was focusing on over an extended period (usually several days) tended to be good cues for that period. One possible reason is that the items (e.g. a document) that I spent much time on were important, and the repeated or extended exposure to the name of the item made it a stronger memory trace, and provided it with more opportunities to be associated with rich context and events in that specific period of time.

d. Location names seemed to be useful only when the city was seldom visited. For example, the name of a city in France where I stayed for a couple of days for a conference immediately reminded me of the general event this episode was in. Yet, the name of places where I spend most of my time, or the places I hardly know (e.g. some places I passed by) did not function well as memory cues.

e. Needs for other types of information:

   - Quality of SenseCam images: SenseCam images are not always taken from the angle of what one saw. In addition, sometimes they are not clear enough to see the details that are needed to understand the event.
   - Day of week: is sometimes desirable information, although I could find it on a calendar based on the date.
   - Place names: may be useful for episodes which happened indoors, or in a vehicle.
   - Records of conversations: sometimes it is difficult to figure out what exactly was going on without knowing the details of a conversation when the images shows that I was talking to some people that I frequently chat with. Unfortunately, conversation was not captured in our lifelogs due to ethics concerns.

f. Finally, I found that well-remembered events are not always good landmark events, which is different from my hypothesis. The episodes that I could vividly recall were not necessarily good cues for other events that happened around that same period. This may be due to the fact that these events are not very relevant to their temporally adjacent events from any aspect apart from time. For example, in one of the episodes, there was a short moment showing a friend talking to me, and the other episodes of her visiting during the two weeks came into my mind. But I could not recall other events during that two weeks, or temporally locate it, e.g. which year and month it was, what happened before or after it.

7.2.4 **Conclusions and hypothesis**

To summarize the findings from study above, the following types of items were found to serve as potential memory cues: digital photos, SenseCam images, location and time of event, as well as certain types of textual information such as content of computer activities. A feature should be representative for the target which is distinctive. In short, for an object to be a good cue, it should: i) be easily understood and recognized, ii) strongly associated with the target events that it represents. Based on psychological theories and empirical studies, I hypothesis the following items tend to be good memory cues:

1) Intensely exposed information or engaged activities should be better remembered. Yet, for it to be a good cue for an item, an episode, or a period (general event), it should be distinctive to them. For example, the more time one spends on a document, the better the document (as a single entity) should be remembered (although not necessarily the details in it, e.g. the textual content), and therefore the more easily it should be recognized. According to theories of associative memory and findings from empirical studies, distinctive objects tend to be better cues. Thus events should be more easily recognized based on their distinctive facets. Therefore, facets that were exposed longer and more often (so they could be better remembered), but are exclusive to the target (item, episode or period) or at least distinctive from the most of rest of the items or time, tend to be good cues. I suggest that the strength of a cue item or facet is negatively related to frequency of encountering the facets, and positively associated with the duration of the facet in a single period. Therefore, the cue strength of facets can be expressed by a function of the two factors as below:

   $$\textbf{Cue Strength} = \textbf{a}*\ f(\textbf{duration}) - \textbf{b}*\ f(\textbf{frequency})$$

   * f(duration) and f(frequency) refer to a transformed value of duration or frequency, e.g. Ln(duration), where a and b are weights for the transformed values. Of course, the value of a, b, as well as how to transform the values has to be explored.

2) For images with similar content, or captured around the same time: According to the generation effect (Slamecka & Graf, 1978), manually taken photos tend to be better cues than automatically captured photos. This suggests that digital photos and manually captured SenseCam images should be recognized more easily and better cues for automatically captured SenseCam images.

a. Since memory tends to be re-enforced through rehearsal, the more often a photo has been viewed, the better cue it should be, as it can be more strongly associated with the event after viewing the image and reminiscing about the event a few times. This also implies that digital photos should be better cues than manually taken SenseCam images, as the former are viewed at the time of events when it was taken.

b. The better the quality of the image, the better the cue it could be.

In short, I hypothesize that: i) digital photos are better cues than SenseCam images, and manually taken images may be better cues than passively captured images (which were not taken around the time of manually taking a photo); ii) the more often a photo or image has been viewed, the better cue it tends to be.

3) Items tend to be better remembered if they are emotional, more specifically, if the event photographed increases the arousal level of the person. Besides, high arousal level facilitates the encoding and consolidating information in memory. Since the arousal level can be roughly estimated by Galvanic Skin Response (GSR), I hypothesize that *photos captured around the time of higher GSR tend to be better memory cues for an event than other photos*.

7.3 Experiment1: Towards automatically extracting memory cues from lifelogs

Finally, two quantitative studies were conducted to generate a data set for developing an algorithm for automatically calculating the strength of cue items (section 7.3) and testing the algorithm (section 7.4). In the first study, photos and facets were sampled according to the hypotheses that were derived from the self-study (as described in the end of section 7.2.3.2) to test how much memory can be triggered by each of them. Regression was used to generate formulas that predict strength of each types of cues in triggering event specific memory and memory of general events, as well as memory of landmark events.

7.3.1 Methods

7.3.1.1 *Materials*

1. Experiment platform

I designed and developed an experimental application that ran on the participants' own computers. It randomly presented cue items one at a time to the participants and required them to answer questions such as if they could recognize the item, if the item reminded them of a general events, and their reflections on the event. It also processed the resulting data automatically and sent the extracted numbers and values to the investigator, without including any exact details such as the images or the exact name of the place, in order to protect the privacy of the participants from the investigators.

2. Selection of "Cues"

Equal numbers of items were sampled for each experimental condition from the database, as described in Section 5.3, using the application described above. The samples were usually evenly extracted from the whole spectrum of values for the tested factor. In most cases, unless specified otherwise, this was done by dividing the entire range to up to 10 levels, then an equivalent number of items were randomly sampled from items in each level. The following types of items were selected:

1) **Images:**

Images were initially selected as evenly as possible within the constraints of the data for each of the following groups to make sure that a sufficient number of photos were sampled to investigate the influence of each of hypothesized factors (they are shown in italic below):

Group 1: In section 7.2.4, I hypothesized that *the more often a photo has been viewed, the stronger memory cue it will be*, as it should be better remembered and more closely associated with the event in which it was taken. The first group (number of accesses) of photos and SenseCam images were selected to guarantee a similar number of photos were sampled from each level of visiting frequency. Up to six levels of visiting frequencies were defined according to the participants' maximum number of visits (0, 1, then randomly sampled from each range which were divided by ¼ maximum, ½ maximum, ¾ maximum). To ensure the images were selected evenly from the entire lifelogging period, the program performed at least two rounds for the selection process. In the first round, one image for each level was randomly selected from the database. The occurrence of the month in which an image was selected was counted. In the second round, the months with less sampled images or no image samples had priority to be sampled.

Group 2: SenseCam images and photos taken around the same time (5 minutes around the time of taking a photo) were sampled, to explore if *the images that have been viewed more frequently tend to improve the memory of corresponding events, and make all the photos taken within that time recognized more easily*.

Group 3: As people tend to have better memory of information which is encoded at the time of high arousal levels, I hypothesize that *images captured or taken at the time of higher GSR value tend to be better memory cues for the episodes and general events*. To test this hypothesis and investigate the influence of emotion (as indicated by biometric data), Group 3 sampled images which were captured during the month when the biometric information was captured.

Groups 4-6: In section 7.2.4, I also hypothesized that photos taken at important moments are more likely to be better remembered and more closely associated with the events. Images in Group 4, 5 and 6 were sampled based on three of my hypothesized criteria for indicating importance of the event, as follows:

i. Since many people review the photos that they took during interesting events, the memory of these events could be further reinforced. Therefore, I hypothesize that *episodes with more photos tend to be more memorable*. In Group 4, images were sampled according to the numbers of digital photos during the hour when the photo was taken. Since the majority of the hours do not have any digital photos taken (most people do not take pictures every day), the application selected half of the sample from hours without any digital photos. For the other half in which there was at least 1 photo in the hour, the images were selected across up to 10 levels according to the number of images in the hour.
ii. *Events that happened at rarely visited locations tend to be more novel, distinctive or interesting, and therefore they tend to be more memorable*. The number of visits to a location refers to the number of location blocks, which is a period of time where a person stayed in a city without any breaks that longer than 24 hours. More details of segmenting location blocks are described in Chapter 8. Half of the samples were images captured at the most frequently visited location (up to one for each month per location), and the rest were captured at least frequently visited locations (one for each location).
iii. Since all three subjects spend large amounts of time working in front of their computers, I hypothesize that *interesting events are more likely to occur when they are away from their computers*. Therefore, there is a higher possibility of memorable episodes when the person spends less time on computer for the day. SenseCam images and digital photos were evenly selected from days with different levels of total duration of time in front of their computers. This duration was calculated by the sum of duration for all computer-activities based episodes (see Chapter 8, section 8.3.3.3). The levels' ranges are divided by every tenth of the maximum value from 0 minutes.

Table 7-3 Initial pool of images cues

Group No.	Factors	Digital photos	SenseCam	Total
1	Number of accesses	30	30	60
2	Image taken within 2 minutes of the time the other types of image from the Group 1 was taken	30 (1 for each SenseCam images in Group 1)	30 (1 for each photo in Group1)	60
3	GSR	30	30	60
4	Number of digital photos during the hour	30	30	60
5	Location	30	30	60
6	Duration of computer activities	30	30	60

* The number in the table refers to the maximum number of images for the group, which could not always be achieved. For example, not many SenseCam images were viewed more than once. Therefore, there may not be enough SenseCam images selected for the high frequency of accesses group. In addition, since the GSR was only captured for a one-month period of time, and to avoid similar images from the same event, the program only sampled one image each (photo and SenseCam where applicable) per day.

A summary of the above groups is shown in Table 7-3. During the experiment, 60 items were randomly selected from the initial pool, including approximately 30 photos and 30 SenseCam images. The program tried to guarantee that at least 10 items were selected from each group.

2) **Text (facets):**

The textual types of cues (facets) were evenly sampled across all levels of two factors: density and distinctiveness. The following types of facets were explored:

a) ***Location:*** According to the psychology literature, facets such as where, what, who tend to be well remembered features of events. I hypothesize that the *name of a location (name of city, and name of place presented by name of some Wi-Fi signals) and names of people (which are presented by the name of Bluetooth devices worn by and named after the person) tend to be good memory cues*. Prior to this experiment, consecutive records of Location, Bluetooth and Wi-Fi were merged into “blocks” respectively. Each of these blocks contains values of the attribute, begin and end time of the “block”, and overall strength of signal for Bluetooth and Wi-Fi blocks. The distinctiveness is defined as *the reciprocal of the number of blocks for a given type of facet*. The density is defined as the maximum total duration (sum of duration for all blocks of the facet) in a week. Thirty items of each type were sampled across different levels of number of visits.

b) ***Name of computer activities:*** As all three subjects spend a considerable amount of their time on their computers for both work and leisure, computer activities may be good reminders for general events (e.g. what they were doing during a certain period of time). According to the density and distinctiveness rules, I hypothesize that *computer activities of long duration but distinctive (only frequently used during a single or very few periods of time) tend to be good memory cues for general events*. To explore the most efficient way of presenting computer activities, four groups of computer activities were selected. Items in each group were represented by terms extracted from titles, the full title, and terms or full title with activity type (e.g. web, excel, email) respectively. The experimental application sampled 20 computer activities for each group with even distribution of density and frequency, and randomly selected 30 of them at the time of experiment.

c) ***Search terms*****:** Apart from individual computer activities (writing a document), I believe densely and distinctively encountered information may also be a good memory cue for the corresponding period of time. I assume that people may use some repeated terms during a period when looking for information on some topics. For example, one may use the query term "hotel" or "flight" and the names of the holiday destination frequently when planning a holiday. Therefore, some search terms could potentially serve as good memory cues for a general event such as this. Thirty search terms were sampled across all levels of density (total frequency in a week) and frequency (number of weeks it occurred).

d) ***Name of contacts*****:** We assume that people may contact certain individuals frequently only during a certain period of time for a specific event. For example, one may co-operate with a few other people on a particular project, but rarely get in touch with them afterwards or beforehand. Therefore, I hypothesize that *names of contacts which appeared frequently only during a specific period of time tend to be good memory cues for certain general events* (e.g. a project or that period of time). Thirty contact names, which appeared both as sender and receiver, were sampled across all levels of density (total frequency in a week) and frequency.

3) **Assisted cues**

According to experience from the self-experiment in section 7.2.3.2, one single facet or item is sometimes not enough to determine the exact event that it represents. In particular, since this experiment needs some of the events to be rated regarding the importance, it is necessary that they could be recognized. Therefore, for image type of cues, the following information was available for assisted recognition: location at the time the image was captured (city or address), other images, computer activities and photos, and even dates and time of the event. As for textual cues (facets), the distribution of the facets, and titles of key computer activities during the selected slots are available. Examples of assisted cues are shown on the left side of Figure 7.3 and Figure 7.4.

7.3.1.2 ***Procedural***

Different types of objects were tested separately. The process of the experiment is controlled by experiment tool show in Figure 7.2. For each cue that was presented, the participants needed to indicate whether they could recognize it (for textual type cues) or the activity during which it was captured (for image types of cues), by selecting "Yes" or "No (not sure)". If they could, they were asked more questions:

- If it makes them recollect the specific episode or general event.
- Whether the cue item reminded them of any other events before or after it, and the approximate month (e.g. 2009-05). This question aimed to explore the features of landmark events which help the user to recall and locate the temporal position of other events (e.g. target events).

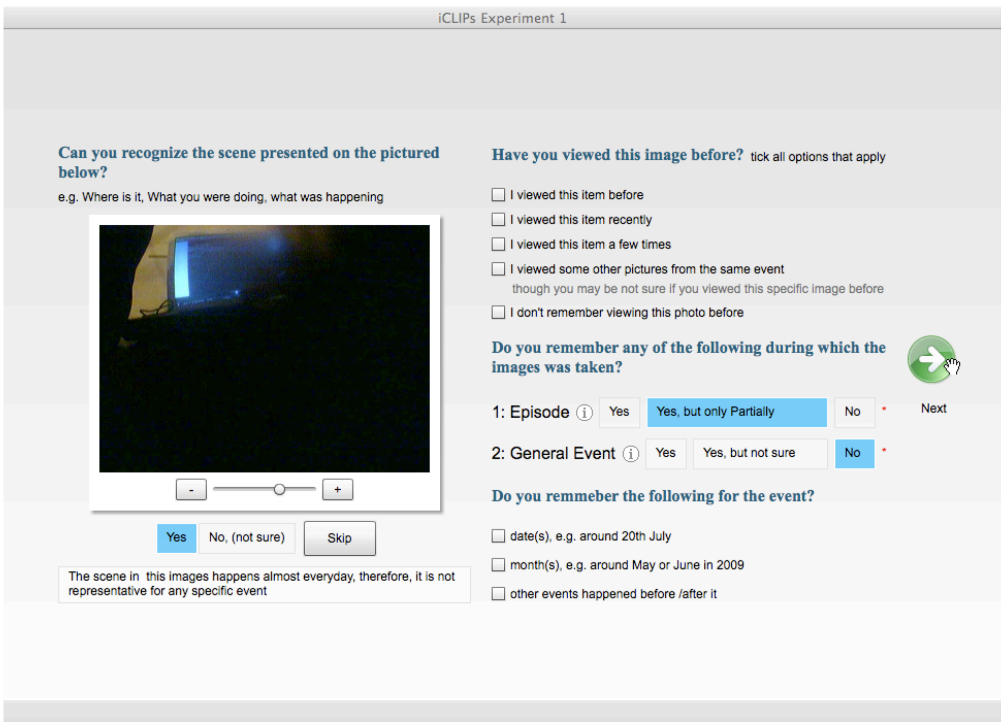

Figure 7.2 Screenshot of the experiment application showing an image cue item and the first group of questions for experiment 1

After the initial judgement of the strength of the cues was made, the participants could view some additional information (combined cues) to try to further identify the presented events, as shown in Figure 7.3 and Figure 7.4.

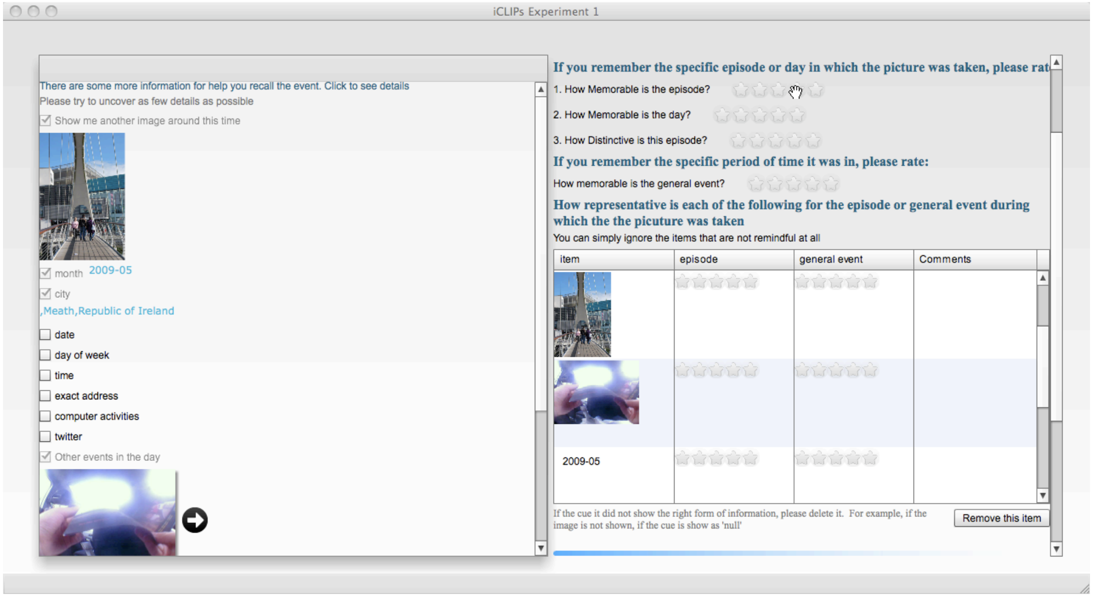

Figure 7.3 Screenshot of experimental application showing assisted cues and questions for image-cue type task

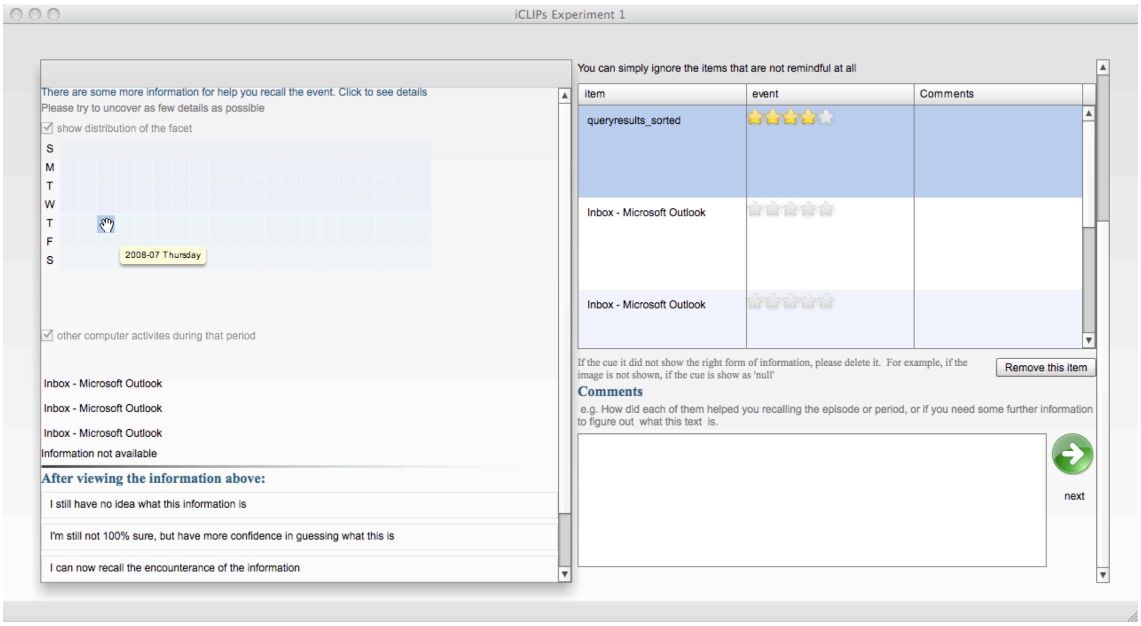

Figure 7.4 Screenshot of experimental application showing assisted cues and questions for textual-cue type

To view the details, the subject needed to click the name of the type, the detail information was then added to the list on the right side. The participants were required to rate how much each of these pieces of information contributed to their recollection of the episode /activity or general event. The participants were encouraged to use as few cues as possible, so as to avoid a ceiling effect in which every cue option is frequently used. For image-types of cues, if the participants claim to remember the approximate month or date, the details of month or date were automatically displayed at this step for them to check if their recall was correct.

For image types of cues, the subjects were also asked to select the frequency of visiting the image recently and previously. This is because the calculation of the visits to the images was not very accurate from the records in the lifelog, since it only included the user's visits during the lifelog period. Even during the lifelogging period, not every visit to the photos was recorded, due to the recording mechanism. For example, if the subjects viewed it on their cameras or on another computer, or if the software used to view the images provided no information to the capturing software as to which image it was, the visits could not be recorded. Therefore, the count of total visits was only an approximate measure.

7.3.2 Data analysis and results

Since there is not a single direct measure of the strength of the cues, it is calculated from several measures (ratings), as described in section 7.3.2.1. After this, regression method was used to find factors that influence cue strength and the proper weights for each factor.

7.3.2.1 *Overview of cue strength*

1. *Defining Cue strength*

Good memory cues are those items which not only provide the content (what it is, what was going on), but also easily recognizable episodes or general events that they are attached to. Since there was no direct measure of "how strong" the cue was, the score of cue strength was calculated as a combined measure. The **scores for strength of cues** for specific episodes, general events and landmark event were defined (calculated) as shown below:

1) Strength of cues for specific episode

In this study, the **strength of the cue for a specific episode** (*Cue_episode*) was calculated as:

$$Cue\_episode = Known \text{ x } (recognize\_episode + 0.4 \text{ x } (representativeness\_episode))$$

(a measure of the strength of the cue item for triggering memory of the corresponding episode)

- *known:* whether the user recognizes encountering of the scene in the cue image or encountering the cue facet (text), no=0 and yes=1
- *recognize_episode*: recognition of the episode (0=not at all, 1=partially or not sure, 2=yes)

- *representativeness_episode*: the rating of representativeness of the item for the episode (0=not at all, 5=extremely representative).
- Since representative episodes have a maximum value of 5, while recognized_episodes only have a maximun value of 2, to give them equal weight, a parameter 0.4 (=2/5) was used.

2) Strength of cues for general events

Similarly, the **cue strength for a general event** (*Cue_general*) was calculated as shown below, and an adjustment parameter of 0.4 to equalize the weight of scores from two questions.

$$Cue\_general = Known \times (recognize\_general + 0.4 \times (representativeness\_general))$$

(measure of strength of cue item for triggering memory of corresponding episode)

- *recognize_general*: recognition of the general event (0=not at all, 1=partially or not sure, 2=yes)
- *representativeness_general*: the rating of representativeness of the item for the general event (0=not at all, 5=extremely representative).

Both cue strength scores range from 0 to 4.

3) Strength of cues for landmark events

Landmark event can be either a specific episode or a general event (e.g. a holiday in Greece). As a landmark event, it should trigger the memory of approximate temporal position of the event and temporally adjacent events. Therefore, the **strength of a recognized event (which the cue item represents) serving as an landmark event** (*Landmark_score*) is the expressed as:

$$Landmark\_score = recall\_date \times 3 + recall\_month \times 2 + recall\_adjecentEvent$$

(measure of strength of an event to act as a landmark)

In this equation, *recall_date*, *recall_month* and *recall_adjecentEvent* refer to whether the subject recalls the date, month, adjacent events of the episode or general event in which the image was taken or the facet or information was encountered (0=no or the recalled information is not correct, 1=yes and the recalled information is correct). The three answers were weighted differently according to the preciseness of their temporal location. For example, if the subject remembered the date of the event presented by the cues, it is more precise than if he or she only recalled the approximate months. If the date was remembered, the month should also be remembered, therefore, the score for the situation that the date of event was recalled should be 1+2=3. If only the month was remembered, the score was 2. The landmark_score ranges from 0 to 6.

The strength of a cue item to trigger a landmark event should therefore be calculated as:

$$Cue\_landmarks = known \times (Cue\_general \mid Cue\_episode) \times landmark\_score$$

(measure of the strength of a cue to trigger memory of a landmark event)

That means, the strength of a cue item to trigger a landmark event depends on: i) whether the cue item can be recognized, ii) whether it can trigger the memory of the event (=0 if both scores =0, or =1 if either score>0), either episodic or general, and iii) how likely it is that this event can act as a landmark event.

2. *Results: overview of cue strength*

The three subjects conducted a total of 578 tasks, including 248 tasks on cue images, and 330 on cue texts (facets). Table 7-4 shows the average score of each type of cue for the three subjects.

Table 7-4 Average score of each type of cue items /information

Participants	**A**			**B**			**C**		
Scores	**E**	**G**	**L**	**E**	**G**	**L**	**E**	**G**	**L**
SenseCam Images	2.28	2.69	0	1	1.36	1.59	0.18	1.33	0.41
Digital Photos	2.75	2.87	1.17	3.42	2.67	2.18	3.70	3.34	1.42
Location	0	1.73	0.26	0	1.82	0.97	0	2.25	1.45
WiFi	0	0.50	0	0	0.64	0	0	0.62	0
Bluetooth	0	1.01	0.08	0	0.10	0.66	0	0.13	0.48
Search query	0	0.16	0	0	0	0	0	0.22	0.10
Contacts	0	0.18	0	0	0.17	0.27	0	0.13	0.03
Computer terms	0	1.4	0	0	0	0	0	0.58	0.13
Computer titles	0	0	0	0	0.71	0	0	0.88	0.38

*Note: E: cue strength for episodes, G: cue strength for general events, L: landmark score

As can be seen from this table, there are large personal differences in the ratings. It can be observed in general that photos are dramatically better at representing episodes than the other types. As for general events (longer period of time), name of location and computer activities are also demonstrated to be strong cues. Among the textual cues, location tended to be most likely to be a recognized facet, and the Bluetooth information the least likely. The full titles of computer activities were much better recognized, and more likely to be recollected than terms extracted from the title or terms used for online search.

The rest of this section explores the factors that contributed to the strength of the cues for general events. That is: what features make a facet representative and remindful for an episode?

7.3.2.2 *What makes facets good memory cues?*

To develop algorithms that automatically extract facts that tend to be good memory cues, I first investigated the factors that contribute to the strength of a cue. Again, for a piece of information to be a memory cue, it is important that it should be recognized (as previously encountered information or an attribute of a past event), and it should be able to remind the subject of specific general events or periods of time when this facet occurred. Regression algorithms are used to generate an equation to predict potential good memory cues. According to the hypotheses in section 7.2.4, the cue strength of a facet for a general event should be a function of density (total duration or frequency) of encountering the facet during that general event and the overall frequency of encountering it for the entire lifelogging period. In order to test this hypothesis, these two factors are used as independent variables in the prediction algorithm.

Due to the multi-stream and diverse types of general events, they were not pre-segmented into general events. Therefore, instead of calculating the density (total duration or frequency) of facets in a "general event", it was measured for a "period of time", which was chosen to be one week in this study. Either reciprocal or logarithm was used to normalize the density value where appropriate.

Regression method used data from all three participants rather than individual subjects. This was because the algorithm used in the prototype system was not trained dynamically for each user before they used the system. Therefore, I used this general static user model for all potential users. Equations were designed to predict the "**relative cue strength"**, which is a linear transformation of the cue strength score.

$$\mathit{Relative\ cue\ strength} = \mathrm{a} \times \mathit{Cue\_strengh\ (general\ /episode/landmark)} + \mathrm{b}$$

*Both a and b are constants

The remainder of this subsection reports results towards formulae to calculate the strength of cues from each of these types of facets:

1) Location

Location is the most likely feature to be recognized across the three participants. I found that when the participants could not recognize a specific general event that happened in a rarely visited location, they usually commented that they did not know exactly which trip it was as they went to the place several times, and suggested that images might be helpful for them to identify the exact occasion, e.g. "this is 'Cambridge' so would need SenseCam images and date information to know which trip to Cambridge it is". Linear regression was used to generate an equation that predict the *Cue_gen* score with the reciprocal of the number of the visits to a place (*r_totoalcount*) and the reciprocal of the maximum total number of hours they stayed in the place in a single week (r_maxWeeklyduration). The original equation based on all three lifelogers data is:

$$Cue\_gen\ (location) = 0.9 + 2.14 * r\_totalcount - 2.82 * r\_maxWeeklyduration$$

The equation for relative cue strength of a name of a location is transformed by removing the constant in the equation, and multiplying the parameters for *r_totalcount* and *r_maxWeeklyduration*, and is presented as:

$$Cue\ strength\ of\ location = 3 * r\_totalcount - 4 * r\_maxWeeklyduration$$

The correlation coefficient (Pearson's r) between the value predicted by this equation and the measured score is 0.62 ($p<.01$)

2) Computer activities

In general, the full titles of computer activities are significantly easier to recognize than extracted terms from computer activities ($p<.01$). Yet, for both feature types, subjects usually commented that more details of the file would be needed in order to see exactly what the activity is about, e.g. "would need to be able to see file content". Therefore, only 16% of all these computer activities were recognized. Logistic regression only found the maximum weekly duration to be a significant predictor for the cue strength score for general events. Therefore, the **title** of remindful computer activities can be roughly selected by choosing those with the **longest maximum weekly duration during the time of a general event**.

3) Search terms

Search terms are generally not very good cues for general events. Participants commented, “I know I searched for it, but I have no recollection of other things related to it. I don’t know why I searched for this information”, “it reminds me of the fact that I was looking for normalization techniques when I was coding! But I’d need the item content to see what this item was about”. Although neither factor was found to be a significant predictor of the likelihood of recognizing the general event, search terms that reminded people of general events usually occurred only in a single period of time (occurred in only one week), and have significantly longer maximum weekly frequency (frequency of using this search term during a week) than others ($p<.005$). Therefore, most remindful **search terms** can be selected by ordering them by the **total weekly frequency (the more frequently used in a single week, the better cue it tends to be), and that only occurred in no more than two calendar weeks**.

4) Contact names

Similar to some of the above types of facts, contact names are seldom rated as good memory cues for general events. For the contact names which reminded subjects of general event, some only appeared once, some occurred more than once during multiple (sometimes more than 20) weeks. Therefore, I could not derive a general rule to predict the remindful contact names based on the result data collected in this study.

5) Wi-Fi and Bluetooth names

There were a considerable percentage of Wi-Fi names recognized, but only a few of them were marked as representative of specific events or periods. The Wi-Fi names that were recognized were usually of overall high frequency of exposure. These include the Wi-Fi in the subject’s home or in the university. Almost all the Wi-Fi signals that were marked as representative for a general event, were named after a place. For example, “it is the name of the hotel that I stayed when I was in …”. As for Bluetooth names, only some of the pre-tagged ones were recognized. Most of the Wi-Fi and Bluetooth names which acted as a reminder for general events occurred on less than three separate calendar weeks. Therefore, the cue-strength could be roughly predicated by: **the highest weekly total duration where the Wi-Fi or Bluetooth signals occurred in less than three separate calendar weeks**.

7.3.2.3 *Investigating factors that make an image a good cue*

According to Table 7-4, both photos and SenseCam images tend to be much better cues than textual facets. Besides, they are also cues for specific episodes, and are more likely to represent landmark events. This sub-section explores the factors which make a photo or SenseCam image a good cue.

The number of accesses, the GSR value, the total number of photos in that hour and on that day, distinctiveness of location (reciprocal of the total visits, and months to the place) were retrieved from a database for all the images as potential cues. They were used for the following analysis.

1. **Are photos better cues than SenseCams images?**

As hypothesized in section 7.2.4, actively taken photos tend to be better cues than passively captured SenseCam images. An independent sample *T-test* was used to compare the average score for cueing strength of SenseCam images and that of manually taken photos. A significant advantage was found for photo cues over SenseCam cues ($p<.001$) for specific events, general periods and to represent landmark events. This advantage (actively taken digital photos over passively taken SenseCam images) of cue strength is more obvious for short time periods (episodes) than long time periods (general events).

2. **What makes an image a better cue?**

I have proposed several reasons and corresponding hypotheses to account for the advantage of manually taken photos as good memory cues. These hypotheses are examined using *Spearman correlation* to see the correlation between the following information relating the cue to the strength score for episodes, general events and landmark events:

a) *Number of visits to photos*: The number of visits is the total number of accesses to the images on the subject's computer (captured by Slife). However, the records of visits calculated by computer do not fully reflect the actual visits to the photos. For example, the subject may have visited the photo after the lifelogging period or viewed the images as soon as they were taken on their cameras. Therefore, I adjusted this value by adding the value from the subject's description of "visits" in the experiment. The description was coded on a 4 point scale, with "visited a few times" = 4, "visited recently" = 3, "visited before" = 2, "not sure if visited, but visited similar images in the event" = 1, and "don't remember any visits" = 0.
b) *Temporal distance:* The number of days between the time when the image was taken and the time of doing this experiment

c) *Rating of memorability and distinctiveness of episode: from not memorable/distinctive=0 to most memorable/distinctive=5*
d) *Average GSR value:* The average GSR value during the episode.

Unfortunately, only a few images which were tested were accompanied by biometric data, and these images, which were all SenseCam images, were not recognized. Therefore, only three factors can be explored: number of visits, temporal distance, and memorability/distinctiveness of the episode. The Spearman's correlation coefficients are shown in Table 7-5.

Table 7-5 Correlation of factors to the cue scores

Factors (predictors)	**Cue for specific episodes**	**Cue for general events**	**Cue for landmark events**
Number of visits	R=0.68, p<.001	R=0.55, p<.001	R=0.59, p<.001
Temporal distance	R=-0.12, P=0.27	R=-0.08, p=0.32	R=0.06, p=0.21
Memorability	R=0.65, p<.001	R=0.76, p<.001	R=0.75,p<.001
Distinctiveness	R=0.74, p<.001	R=0.73, p<.001	R=0.68, p<.001

Congruent with my hypothesis, the number of visits is strongly associated with the cue strength of the image. I also conducted an independent T-test to explore the differences of the number of visits between recognized and unrecognized, general events recollected and not, and temporal location recollected and not. Significantly more visits were paid to the photos of images that are recognized ($p<.001$). Therefore, I believe that the number of visits to an image can be treated as a significant factor contributing to the cue strength of an image.

As for temporal distance, the finding is congruent with the forgetting curve (see the review in section 4.2.5.2), i.e. even though the events happened more than one year ago memory of them does not decay significantly as time passes. Therefore, there is only a very weak and insignificant correlation between the temporal distance of from when the images were taken and the cue strength of the images.

Significant and strong correlations were found between memorability of events, distinctiveness of episode and the cue strengths. A Mann-Whitney test was used to compare the average rating of the memorability of the event between those represented by photos and those represented by SenseCam images taken at other times (not adjacent to the moment when a digital photo was actively taken). Significant advantage was again found in digital photos over the SenseCam images ($p<.001$). This suggests that digital images were usually taken in more memorable events, which are also more distinctive than episodes in which most of SenseCam images were taken. The distinctiveness of the content in the photo is also important. That is, photos that were taken at less distinctive events tend to be less strong cues. For example, "I could tell that it was on my regular route to work, but I took quite a few pictures on that route, I don't remember when it was, and I can't see what's special in this picture". The importance of the episode and the importance of event and its distinctiveness seems to be highly correlated ($R=0.88$, $p<.001$). Thus, it can generally be assumed that events which are distinctive tend to be memorable. Although it seems that subjects usually rate photos higher, no statistically significant advantage were found of photos over SenseCam images which were taken around the same time. This further supports the hypothesis that the advantage of photos over SenseCam images is due to the importance of the moments or events during which the photos were taken.

Of course, the quality of the image is also very important. One participant commented, "The images are too dark for me to see the details and figure out what it was about. The photos around that time were of much better visibility". On the other hand, not all the photos are found to be good memory cues. For example, some of the photos did not show the background or context (where it was taken) clearly, and the participants could not figure out what specific event it was in, e.g., "it looks like a museum item description, but I don't remember seeing it. So I can't figure out which museum it was in".

In short, digital photos generally tend to be better cues than SenseCam images. The reasons include that they are usually clearer and taken at more memorable and distinctive moments. In addition, photos were viewed at least once or more times, while SenseCam images were usually not viewed at all. All these factors contributed to the strength of cue images.

3. Algorithm to predict cue strength of images

To develop an equation to predict the strength of image as a memory cue, the regression method was used, taking these factors as predictors. Since the memorability and distinctiveness of events were only subjectively rated, some automatically measurable factors should be used to predict these values. I hypothesized that the distinctiveness of the location, number of photos in the event are positively associated with the memorability and distinctiveness of the event, while the total duration of computer activities is negatively associated with the importance of the event. The location score is calculated using the equation introduced in section 7.3.2.2.

Table 7-6 Correlation of factors and importance of events

Factors	Memorability	Distinctiveness
Location score	R=0.38, p=.003	R=0.45, p=.002
Digital photos	R=0.56, P<.001	R=0.55, p<.001
Duration of computer activities in the day	R=-0.37, p<.001	R=-0.39, p<.001

This hypothesis was generally supported by the result from Spearman's correlation between location score, number of visits, total duration of computer activities in the day and memorability, distinctiveness of events, as shown in Table 7-6. Although correlation calculated from the data of all three subjects is not very strong, the strength exists in individual's data. For example, the rating for memorability and distinctiveness of an episode is particularly strongly associated with location score for subject C, and with the duration of computer activity is particularly strong for participant B, but considerably less so for the other two participants. Therefore, I decided to take all three factors in the equation to predict an image's strength as a memory cue for episodes, general events and landmark events. The equation is expressed as shown below.

Cue_strength = Nv * *f(Number of visits)* + Np * *f(Number of photos in the event)* + Ls x *f (Location)* + Hc x *f (hours of computer activities in a day)*

*Nv, Np, Ls and Hc are constants.

To get the values for Nv, Np, Ls and Hc, a regression analysis was conducted on data from all three subjects to form equations. Similar to the way that the equation was created for predicting remindful location names, I also removed the constant from the equation and rounded the parameters. The parameters (weights) of each factor in the equations are shown in the Table 7-7.

Table 7-7 Weightings of factors in equations for predicting

Cue strength	Weighting of attributes in equation				Spearman's correlation
	Nv	Np	Ls	Hc	
Episode	5	0	1	-1	R=0.57
General event	4	0	1	-1	R=0.65*
Landmark event	5	1	2	0	R=0.78

Note: the equation is formed by regression directly on all three subject's date. Nv, Np, Ls, Hc are the weightings for the following values:
Nv: Number of visits

Np: natural logarithm of the (Number of photos in the event+ 0.1). natural logarithm is used to normalize this value.
Ls: Location score
Hc: hours of computer activities in a day

7.3.2.4 ***Assisted cues***

As for assisted cues (textual), the number of each type selected was counted as a measure of the importance of this type of information in representing events or computer activities. For 26.7% of the tasks, the participants looked for further support from combined cues. Among 23.3% of the tasks with image cues, the subjects looked for support from "another image" around that time. 16.7% of them looked for information of city, and 11.5% of them acquired information for the "month" of the event. The cues functioned to help the subjects figure out the event that the cue represents. The most often used cue is "another image" as a cue.

7.3.2.5 ***Conclusions***

In this experiment, I statistically explored the factors what contribute to the strength of cue images and facets for specific episodes, general events, and landmark events. I developed the following equations and algorithms to predict the strength of the cues:

1) For specific episodes, the cue strength of an image equals to:

   Cue_episode (image) = 4 * *Number_of_visits* + *location_score* – *hour_computer*

   *hour_computer: *hours of computer activities in a day*

2) As for general events, both images and several types of facets can act as memory cues. The algorithms to predict cue strength for each type of item are listed below:

- **The cue strength of an image:**

  Cue_general (image) = 4 * *number of visits* + *location_score* – *hour_computer*

- **The cue strength of a location:**

  Cue_general (location)= 3 * *r_totalcount* - 4 * *r_max_Weekly_duration*

- **The cue strength of a computer activity:**

  Cue_general (title) = a * *max_Weekly_Dration* (a is a constant)

- **The cue strength of a search term**:

  Cue_general (search term)= a * *max_weekly_frequency* (a is a constant)

- **The cue strength of a Wi-Fi or Bluetooth name:**

  Cue_general (Wi-Fi/ Bluetoth)= a * *max_weekly_duration* (count <3)

  * count : the number of separated months where the facet occurred

3) As for landmark events, it is not only that the events presented that can be recognized, but it should trigger memory of temporal location of the event, to help the person to locate other events that happened before or after it. Only some images were found to serve as memory cues for landmark events. The likelihood that an image can trigger the memory of a landmark event can be estimated by:

Cue_landmark (image) = 4 * *number_of_visits* + Ln (*number_of_photos_in_the_day*) – hours_of_computer_activities

Sometimes individual images or terms (facets) could not enable people to recognize the exact event, unless some other information was given to make the situation clearer. Such information includes: another image, location (e.g. city) and date/time (e.g. month) of the event.

7.4 Experiment 2: How good are these automatically extracted cues?

To evaluate the algorithms summarized above, they were tested with another set of data through two measures: i) the percentage of correct predictions, and ii) reaction time, that is, the time taken to recognize the cue item or recall the temporal features. Evidence has been found that the stronger the memory, the faster it is recognized (Sternberg, 1969). I assume that the faster one recognizes the cue item, the stronger cue it is. If the algorithms are effective, the items predicted to have strong cue strength should be more likely and quickly recognized than items that are predicted to have less strong cue strength.

7.4.1 Methods

The three lifeloggers participated in this study with their prototype lifelog data. An application was developed for the participants to conduct the study on their own computers. The application selected items with the highest weight (cueing strength) together with an equal number of items with average or lower weight. None of these items were presented in the previous experiment. The types of items included in this experiment are: images (including both actively taken digital photos and passively captured SenseCam images), location, computer activity titles, search terms and Wi-Fi or Bluetooth signals. There were three sessions. In the session 1, the subjects were to answer if they could recognize the specific episode or activity presented by the image or text. In session 2, the subjects also needed to recognize the period of time (general event) that the cue item represents. In session 3, they needed not only to recognize the items, but also to try to recall the approximate year, month and date that the cue image was taken or the activity the cue text represents took place. Figure 7.5 shows a screenshot of the task interface from session 3, with a textual cue. Before each session, they were given instructions for what to recognize or recall, and asked to answer as quickly as possible. To avoid clicking the "no" button by mistake and allow them more time to recall, the "No" button was disabled for 5 seconds after the cue item appeared.

Figure 7.5 Experiment interface for session 3

7.4.2 **Data analysis and results**

An independent sample T-test was used to measure if effective cue items tend to have higher predicted strength. The effective cues are the cue items that enabled the subject to recognize the type of event for each session (specific episode for session 1, and general event for session 2). This is indicated by the subject's response of clicking the "yes" button. For session 3, the effectiveness is defined by the subject's correct recall of "month". Pearson's correlation test was used to measure the correlation between the response time of positive answers (selecting "yes") and the score.

In general, the results suggest that the algorithms that I developed in the previous study can effectively select items as memory cues; details are shown in Table 7-8. For most types of cues, there are significant advantages of predicted stronger effective cue items compared to cue items that were not effective. A comparatively strong correlation can also be found between the response time and the predicted strength of image cues for both specific episodes and general events. Although the remainder of the correlations are not very strong, they are all positive.

Table 7-8 Result from T-test and Spearman's correlation

Predicted values	t-test	Correlation
Image cue for episodes	p<.001	R=0.53 ,p<.001
Image cue for general events	p<.001	R=0.66, p<.001
Image cue for landmark events	p<.001	R=0.42,p<.001
Location cue for general events	p<.001	R=0.32, p<.001
Title (computer activity) cue for general events	p=.026	R=0.23, p=.008
Search term cue for general events	P=.024	R=0.34, p=.012
Wi-Fi cue for general events	p=.028	R=0.27, p=.041
Bluetooth cue for general events	p=.043	R=.23, p=0.23

7.5 Conclusions

This chapter explored the types and features of personal lifelog items that could potentially serve as good memory cues. It started by collecting ideas of the types of personal lifelog items that could act as good memory cues from both lifeloggers and non-lifeloggers. Then I further explored the factors that may influence the strength of these cue items in a single subject experiment, based on the subject's self-reflection. After this, I made one further step towards an automatic algorithm to extract memory cues through an experiment which explored the likelihood of recognizing different personal lifelog item samples from different levels of hypothesized factors. I generated algorithms to predict the likelihood that a facet or an image can act as a good memory cue for a specific event, a general event or to represent a landmark event. These algorithms were further tested on a separate set of personal lifelog data. The result of this final experiment suggested that the algorithms are effective. Therefore, I use these algorithms in my prototype system described in the next chapter to dynamically extract good memory cues for presenting events and supporting browsing or navigation in personal lifelog archives.

Part 3

Evaluation

Chapter 8
The iCLIPs LAB: a Prototype PLL Search System

In the previous chapters, I reviewed potential user needs which might motivate individuals to seek information in their own personal lifelogs (PLLs), the information behaviour that is likely to be conducted to retrieve the information that they need, and the role of the user's memory during their information behaviours. I hypothesized that *better support to the users' memory can improve the efficiency and user experience in tasks of finding information from PLLs*. I also suggested potential approaches to realize the memory support based on my review of psychology literature of human memory, and conducted a number of empirical studies to further explore the support that could be included in a prototype personal lifelog search system. This chapter introduces the prototype system which was built based on my suggested memory supporting functions. This system is used to test the hypothesis

8.1 System Overview

The iCLIPs Lifelog Archive Browser (LAB) system is the prototype system that I built to support the following functions in accessing information from a PLL:

1) Retrieving digital items and information that they have previously encountered.
2) Recollection and recalling specific information or details encountered in either the physical world or digital world, or related to one's past experiences.
3) Reminiscing and mentally re-experiencing the past, with extracted data from one's PLL providing memory cues.

The system aims to free people from keeping and managing data, and to provide advanced information finding functions that enable people to locate (through searching, navigating and browsing) information that they desire from a PLL with what they can remember to make use of the above functions. The design of the system is based on the framework (guidelines) that I developed from literature reviews in Chapters 3 and 4 and the empirical studies described in Chapters 6 and 7, including:

1) ***Initiating*:** it should help users to quickly clarify their information needs and begin the first step in the searching process, e.g., by presenting them with high level cues of the content in their lifelog collections, or reminding them of the functions that the system provides.

2) ***Flexibility of approaches*:** it should allow users to switch tactics during the information seeking task. For example, it should let the users navigate and browse after a search action, and provide search functions when the target information is among a very long list of other result items.
3) ***Formulations of query:*** the search interface should allow users to "tell" the information system the details that they know about the target, and if possible, as close as possible to the form that the knowledge exists in the user's mind, e.g. visual-spatial, verbal. Proper questions should be asked to trigger the user's memory of information for corresponding fields. For a cue to be effective, it needs to be attended to, and above all, the cue should fall into the user's field of vision. Therefore, these questions or labels of search fields should be displayed in a way that is always easily visible to the users.
4) ***Presentation of results:*** the presentation of a target should be easy to recognize and to use. For example, representative features such as titles should be presented for a document rather than just using any random words in it. If a user searches for a file to use, the system should enable the user to directly open it for use with their preferred applications.
5) ***Cognitive load:*** a distinctive and small number of items should be presented on a single view to avoid working memory burdens.
6) ***Navigation:*** the presented structured of the directories should be easy to interpret and understand, so that the user can quickly learn about the current directory, and recognize or guess the correct directory to navigate into. The presentation of the folders should cater for the user's different levels of uncertainty of the target and the source of the target, with appropriate cues at different levels of details.

This chapter is structured as follow: section 8.2 introduces the functionality of the iCLIPS LAB system, describing each of the above components in more details, after this section 8.3 explains the background mechanisms of some of the interface functions.

8.2 Interface components and functionalities

This system has four main components for conducting finding tasks: search panel, navigation panel, result browsing panel, and faceted browsing (which also serves the preview function). Figure 8.1 shows the interaction between the main components in this interface. The result list is the main panel, which displays the computer items or episodes. The content in the results list can be created through search from the search panel, filtered through navigation (navigation panel), explored through faceted browsing (faceted browsing panel) and otherwise examined using options located above the result list, including item type based filter and time based filter (on a timeline). Both navigation and search actions can update the facets in the faceted-browsing panel as a previous or newly updated result list.

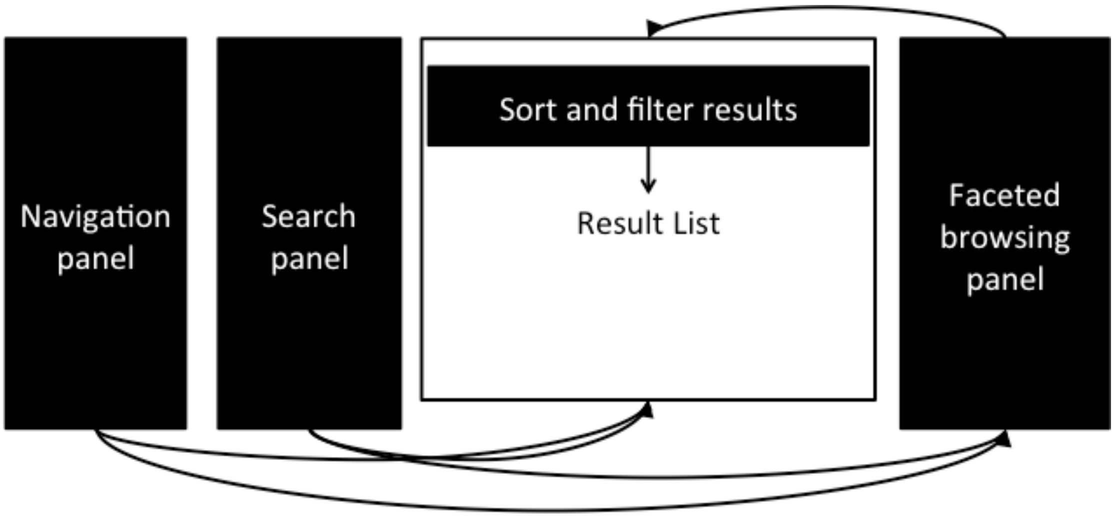

Figure 8.1 Main components of the LAB interface

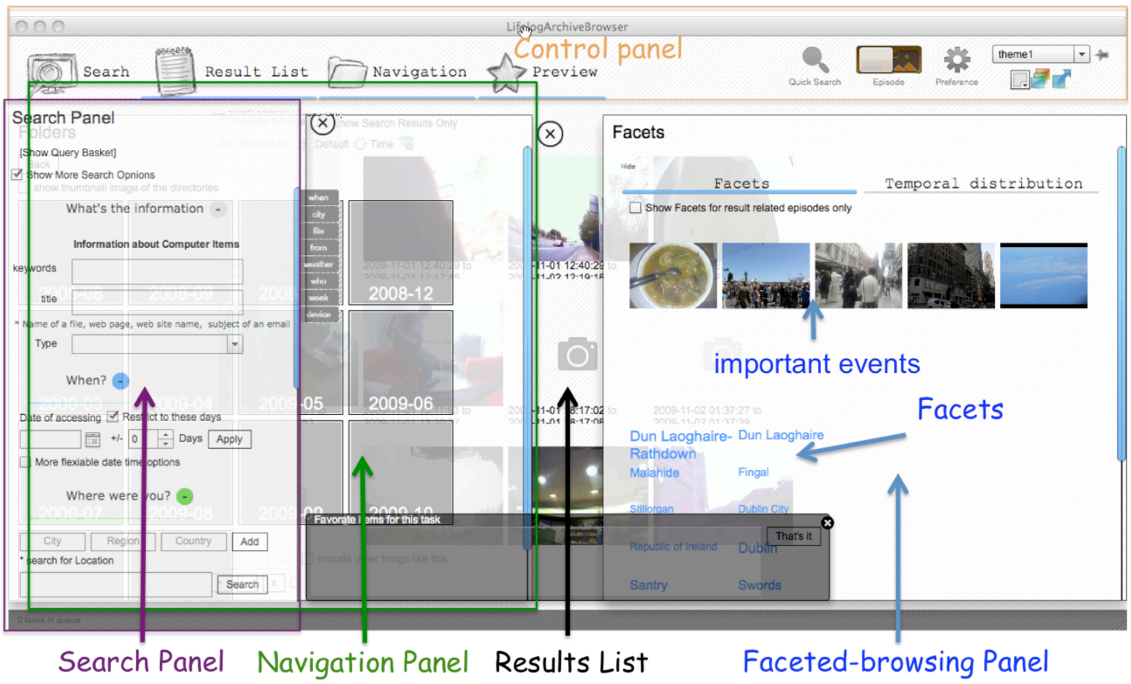

Figure 8.2 Screenshot of prototype system captured during a task searching for events

* The thumbnail images for each folder are hidden for privacy reasons. The overlapping panels can be hidden or shown one by one in practical use, they are all shown in this figure for the purposes of illustration.

Users can start with any of the following four approaches: i) search and locate the target in the search results, ii) navigate through automatically structured directories, iii) faceted browsing, and iv) browsing the entire collection of either events or computer items ordered by time. If the user starts with search, the search results can be browsed in a traditional list-view where the items are usually listed according to certain orders, e.g. alphabetically ordered by title or file name, ranked by relevance score, or ordered by timestamp of last modification of the file. Alternatively, users can also start their finding tasks by navigating or browsing in their entire lifelog collection.

8.2.1 Search interfaces

The system has two search panels for inputting queries (S1, S2), and a "query basket" for viewing and manipulating multiple search terms (S3).

8.2.1.1 *Formulating search queries: the search fields*

The search options are designed based on the literature, findings from my empirical studies, and feasibility taking into account the current data collection and available technologies. There are two groups of search options when search for an electronic item: i) attributes of digital items and ii) episodic context of any instance of access or interacting with the target items. The same search options are provided when searching for events. That is, the user can search by the attribute of an event (group 2) such as time and location, as well as related computer activities that happened around the time of the event (group 1).

1) The first group includes the following search fields: keywords, title, filename, item type, extension, path for files and URL for online items, and author ("received from" and "send to" for emails and text messages). These options only concern the digital items themselves, and are typical search options for personal information management (PIM) systems, which provide search functions, e.g. Spotlight[17], Windows search[18] and many email clients.
2) The second group of search fields are extended features in this system, including:
    a. Date and time: users can search by different parts of date and time, including: year, month(s), part or day(s). According to the review in Chapter 4, people seldom remember the exact numbers of date and time, which they did not necessarily pay attention to. Yet, they can "perceive" or estimate the date and time according to their relation with other important events, e.g. one may recall that a event happened shortly before Christmas as there were many Christmas decorations, or that it was in the

[17] http://en.wikipedia.org/wiki/Spotlight_(software)

[18] http://en.wikipedia.org/wiki/Windows_Search

evening since it was dark outside. People may remember or be able to infer the numbers for the approximate month, year, day of week (e.g. Fridays as they always have such a meeting on Fridays), or part of the week (e.g. weekend). They may also be able to indicate the approximate time based on their own schedules, e.g. after coffee, so that's around 3-4 pm as the person always have coffee at around 3pm. Yet, people seldom remember exactly how many hours ago from now something took place or the full set of the time information. For this reason, flexibility is needed for search options on date and time. Range sliders are available as an alternative to text format input for people who remember the approximate range rather than numbers.

b. Physical context: location, weather, light status and people appearing at the time of any instances of accessing or interacting with the target items.

Although there are many more types of information that people can remember related to target information or episodes, not all of them can be captured or are suitable for querying digitally.

8.2.1.2 *Manipulating search queries*

The search queries can be added and edited in two places: a traditional multi-field search panel (baseline search interface) (S1), and a one-text-field pop out search window (S2). The query terms within one search session can be further combined and re-used in a search basket (S3).

S1: Multi-field search interface

S1 (shown in Figure 8.3) is similar to most traditional multi-field search interfaces, in which each query field (e.g. keyword, time) has an independent input component (such as a textbox to type in the information, a dropdown list to select a correct option, a calendar to select the date, and sliders to select a range).

Of course, not every element in this interface is traditional. One of my design features is a foldable search option and a number of side labels. To maximally make use of the user's remembered details for search, proper questions need to be presented as memory cues to trigger the user's memory for corresponding search fields. Since there are a considerable number of the search options, it is difficult to present all the search options in a single view (without scrolling up and down). Even if the screen is large enough to accommodate all of them, users are unlikely to scan all the options if they are in a hurry or if they are lazy. Besides, limited working memory capacity (7±2 items) may not allow the scanned information to be fully processed and trigger all related memories. For this reason, the options for similar type of the attributes were grouped together, and represented with an easy-visible title, such as "where were you", "when was it". I anticipated that these labels could help the users recall corresponding content. By clicking the labels (buttons), the search options in that group are unfolded to accept input. In this way, it can save space and reduce the amount of information presented to the users. When several options are unfolded, it can become similar to a traditional multi-field search interface, which lists all the search options and requires the user to take time to browse for specific search options. To avoid this, the side labels were used. These labels, representing individual or groups of search options, stay at the same position and are always visible. When clicking a label, the search panel scrolls to the corresponding search option(s).

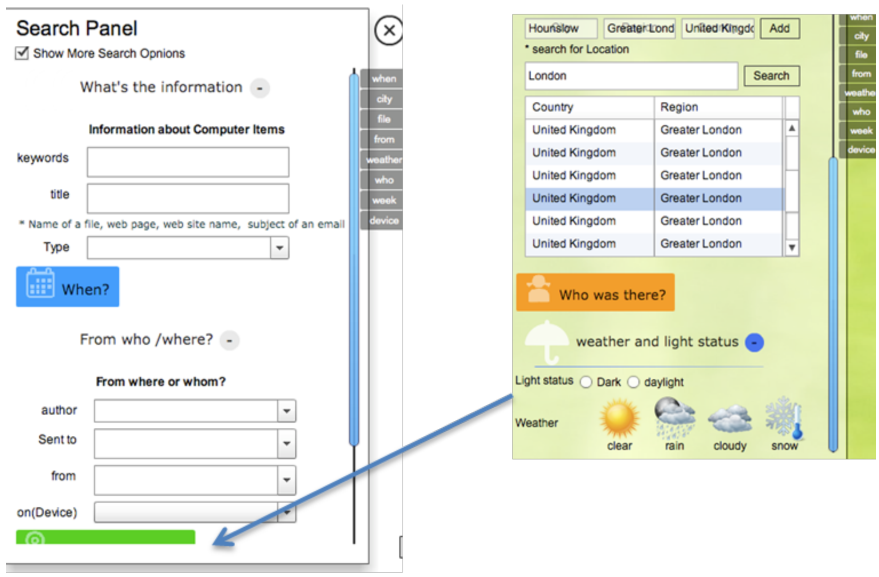

Figure 8.3 Screenshot of search panel (S1)

Search options Group 1 shown in the image on the left, and some Group 2 options on the right

*The two screenshots here captured while using different themes

As discussed in Chapter 4, one problem people usually encounter is the difficulty of recalling the exact information such as the name of a file or exact spelling of a city. The system tries to enable the users to recognize presented information rather than to recall the exact details. Some search options were equipped with "automatic completion", such as file type, name of locations and people. These "auto-completion" searches for matching names in the database with what the users entered (partial value).

S2: One-field query interface — don't like to move around?

The other query interface (S2) is a popup window with a single input box (shown in Figure 8.4), users can move to the next search fields by pressing the "enter" key or jump to any search options by clicking on its name (e.g. title, path, city). The difficulty of moving from field to field in a traditional multi-field search interface usually drives users away from using multi-field search. Therefore, I believe that *if the interface can allow users to add query terms for multiple* *filed without moving from place to place, users may add more queries in more search fields if they know the answers.*

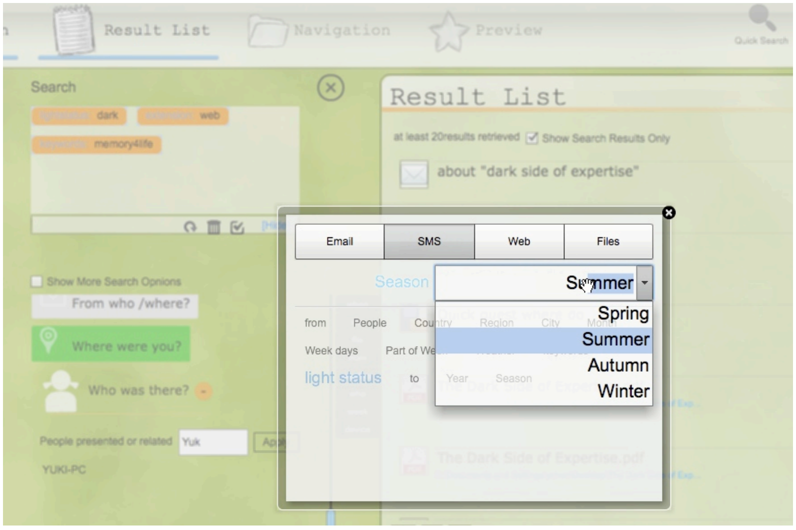

Figure 8.4 Pop-Up Window of One-field query interface

Unlike S1, since there is only one search field in S2, it is difficult to present the “cues” for each of the query options like in S1. In this search panel, the names of all the search options are displayed together. These labels are expected to be scanned easily so as to act as proper cues. The “current” search options are presented beside the text input box. If a user is too lazy to move his eyes to browse the search options in the tag clouds, he or she can simply click the “enter” key to move to the next search options which will appear at the same place. Similar to S1, auto-completion drop-down lists are provided for some search options (e.g. months, day of week, name of people), to overcome the problem of recalling the details of each field.

S3: Query Basket—reduce working memory burden

The query basket is designed to reduce the burden on working memory in search tasks which involve multiple terms or search sessions. In a traditional search interface, users have to clear and refill a search field in order to change the query. One reason that such activities cause cognitive load is that users need to remember (in working memory) what query they used in their previous searches during this session.

With the “query basket” (shown in Figure 8.5), users can be exempted from remembering such information. Each query term (a phrase or single fact of an attribute), added through both search panels (S1 and S2), is maintained as an object in the query basket which are visible at all times.

The query basket can be cleared manually by clicking a button (presented with a trash icon), or automatically when one entire task completes. The query terms currently in use are always highlighted so that the user can clearly see what they are currently searching with.

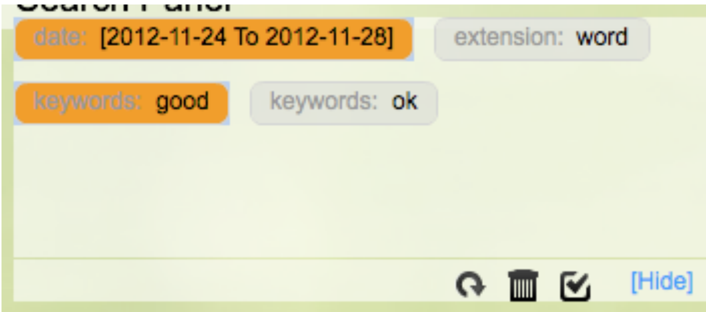

Figure 8.5 S3: Query basket

* Buttons heighted in orange indicate the terms that are selected for use in the current search

8.2.1.3 *Feedback to search action*

According to the principles of user interface design, it is essential to provide users with instant feedback after they make a significant change to their query. Ideally, the entire results set can be updated according to their latest submitted query. However, due to the slow background processing speed in the prototype system, it was generally not possible to make updates more quickly than within 5 seconds. The following methods were designed to provide fast feedback.

1. Update to the top results in the result list:

In fact, the users are not usually able to view the entire results set (if there are hundreds of items) in a few seconds. Similar to many search settings, they only view the first few results on the first screen. This means that updates to these few results can be enough to show the user the changes. Therefore, instead of fetching a full result set again, the system only updates the results listed on the first page, that is, the top 20 or less (if there are less than 20 results in total).

2. Number of results:

Indicates when the total number of result items has been updated as the result of change to the query. This is a quick indicator suggesting any changes to the result set because of updating the queries.

3. Update to the context:

Apart from the changes made to the result list, the contextual information such as the time range of the results, the total number of results and summary facets of the results are also updated accordingly, reflecting the changes to the current results data sets. Due to the algorithms of retrieving these pieces of information, this update is much slower than for the previous two features. The algorithms of the above functions are described in section 7.3.

8.2.2 Result interface

The results panel displays search results as well as detailed items in specific directories or result items filtered through faceted browsing. In this system, I categorize two types of result items: i) digital items that were encountered on one computers or mobile phones (e.g. documents, emails, text messages, and individual images), and ii) episodes (a short period of time in a range from a few minutes to a few hours, in which the person is focusing on a single activity, e.g. having lunch, driving to work). Due to the different retrieval mechanisms and the elements involved in displaying these two types of targets, only one type can be displayed at a time.

1. Representing digital items

Apart from image type result items, each digital item in the result list is represented with the following elements where applicable, as shown in Figure 8.6:

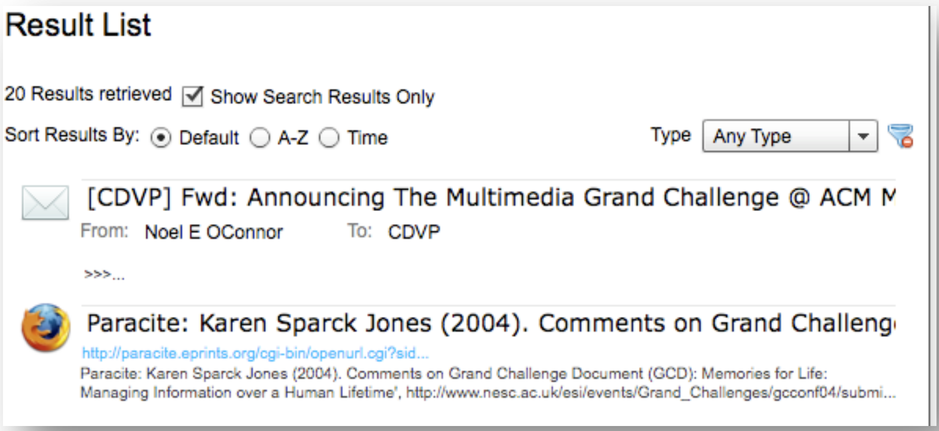

Figure 8.6 Result list for digital items

i) Title: title of activity, subject of emails or filename where applicable, this was captured by Slife from the window where it was originally presented.

ii) Icon: representing the types of the result item, with a tooltip showing the type of the item (e.g. email, web, document), and the application which was used to visit it previously (e.g. mail, Chrome, Microsoft Office Word).

iii) Contact names: for emails, SMS and IMs, the contact's name (username of IM applications, email address or phone number, whichever is available) of the message's receivers or senders.

iv) Path of the file or URL of the web page.

v) Content: First 200 words of its textual content if there is any.

The image items, mostly photos, are represented by a thumbnail of themselves, with the date and time of taking the photo below the thumbnail.

2. Presenting Episodes

In this system, *episodes* are defined as a short time frame of a single focused activity, e.g. a meeting, having dinner. The presentation of episodes is based on my investigation in psychology literature and a cued recall experiment (see chapter 7). Elements that are used in presenting episodes include:

i) A key image from that episode: these are usually photos or screenshots captured during the episode. When there was no photo or screenshot captured, a default placeholder image is presented. The algorithm for selecting the key image is described in section 7.3.

ii) The begin time and end time of the episode.

iii) Location in which the episode took place, including the name of the country, region, city and street level location wherever applicable.

The details of an episode can be viewed in a pop out window, as shown in Figure 8.7.

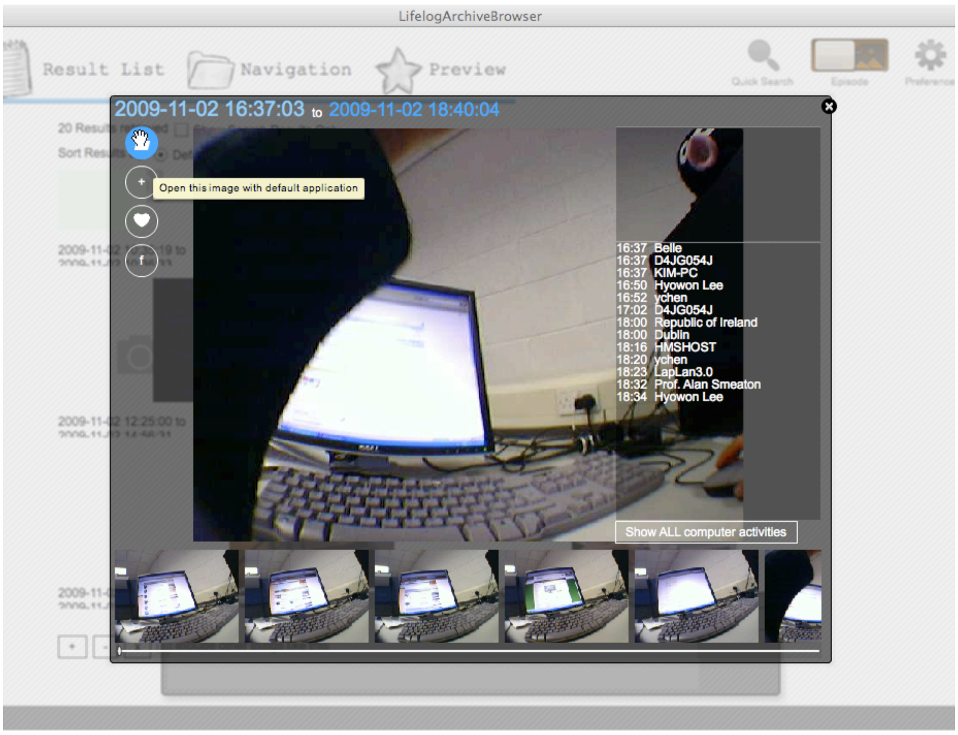

Figure 8.7 Pop out window showing details of selected episode (episode display window)

This presents all the images, context and computer activities within the episode. In this window, the user can manually select the keyframe image of the episode, open photo files, and upload their photos to Facebook.

3. Manipulating result list

It is quite common that among the many results returned by search engines, that relevant items are not listed at the very top of the list. In fact, in many cases the targets can be far from the first page typically showing the top 10 ranked items. In order to help users locate target items, both sorting and filtering functions are provided. The results can be filtered in a variety of ways, e.g. filter by time or location of events through "navigation" in dynamically generated directories, by facet from the faceted browsing panel, by the type of target items, by time range defined on the timeline or selected time slot on the temporal distribution grid, shown in Figure 8.8.

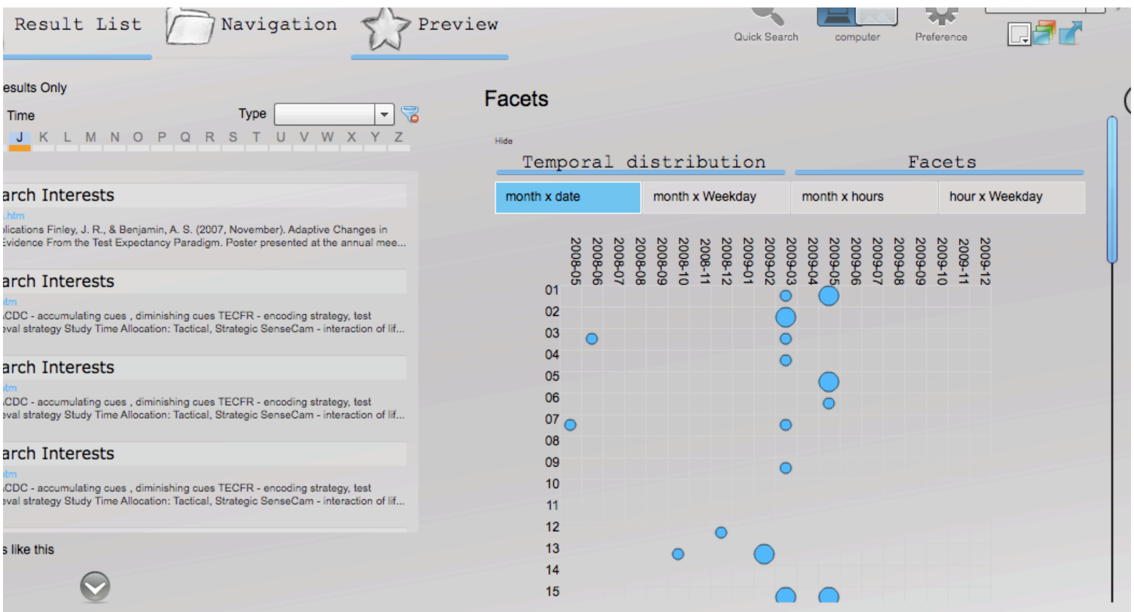

Figure 8.8 Temporal distribution of results

The temporal distribution grid shows the time slots where there are one or more results. The user is provided with the flexibility to "recognize" the appropriate timeslot from any of the four combinations of date and time information: date x month, month x day of week, month x hour of day, hour of day x day of week. For example, if the user only remembers that the event happened in an afternoon, on a Sunday, he can switch to hour of day x day of week view. Or if he only remembers that it happened in November 2008, he can switch to any of the three: date x month, month x day of week, month x hour of day, and hopefully only one of the slots under the month "November 2008" has a round dot (has results).

While browsing the results, the system allows the user to order digital items alphabetically, and order episodes and digital items by time. When sorted alphabetically, users can quickly jump to result items whose titles starts with selected letter (A- Z) by clicking the corresponding letter, as shown in Figure 8.9.

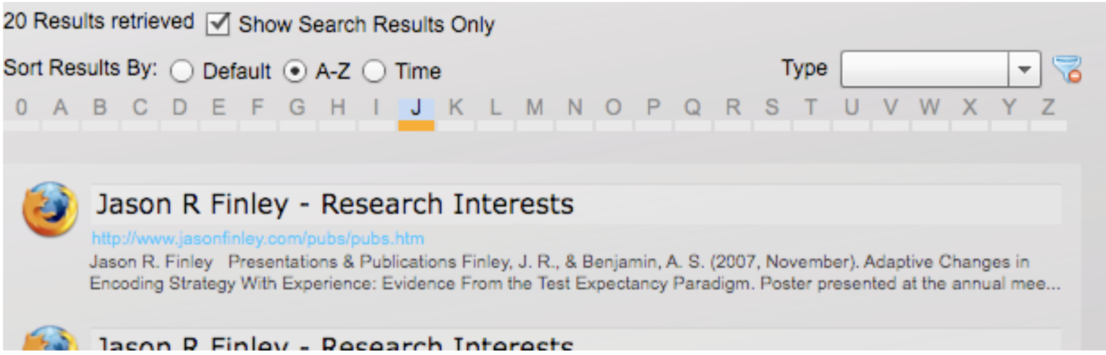

Figure 8.9 Result list ordered by alphabet

8.2.3 Timeline based Landmark-event Assisted Browsing

When the results are ordered by start time, a timeline is displayed with a function to adjust the time range of result items. In this situation, another type of landmark "label" is provided: the "landmark events", as shown in Figure 8.10.

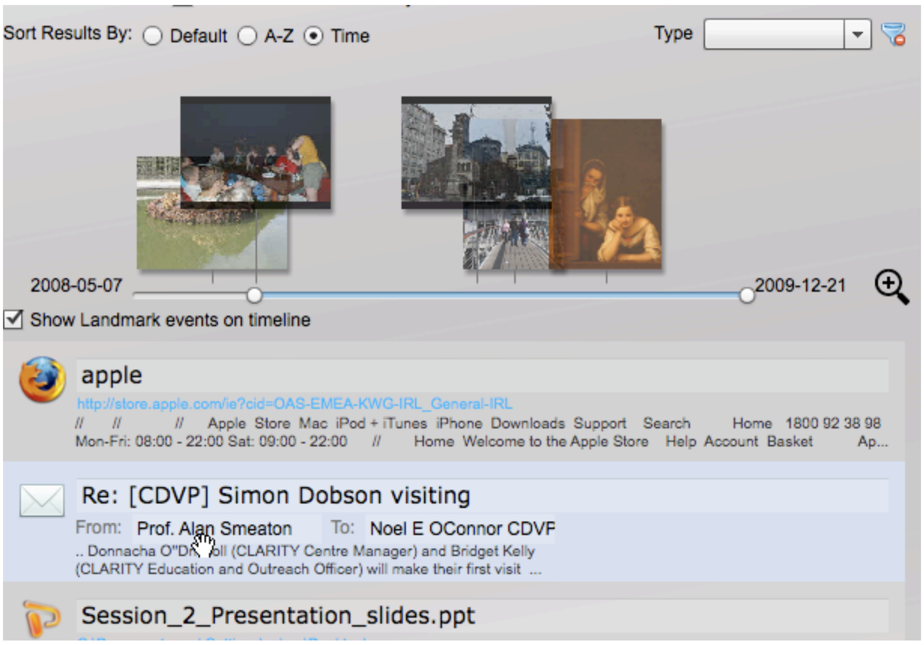

Figure 8.10 Timeline with landmark event

Up to 10 important episodes are displayed (with a key image of the episode) above the timeline as reference events, for the user to locate events adjacent to them, I call these “landmark events”. These landmark events are also represented by thumbnails of keyframe images in the episodes. The algorithms for selecting the landmark events and their keyframes are described in section 8.3.5. The user can filter their results by selecting a time range (between two thumbs on the timeline, with highlight). To do this, the user either clicks or drags a thumb to a time point on the timeline, or clicks the image of a landmark event. In the latter case, the results are filtered by the starting time of the earlier selected landmark event and the end time of the later selected landmark event. While moving the thumb along the timeline, the date information is shown above the thumb so that the user can determine where to place the thumb.

8.2.4 Navigation and Faceted Browsing

Apart from filtering results by result type and time range, users can also narrow the collection or results by navigation and faceted browsing.

1. Navigation with “Smart folders”

The design of the iCLIPS LAB system mimics the folder metaphor, and allow users to locate items by double clicking and “opening” folders. The folder based navigation panel is shown in screenshot in Figure 8.11.

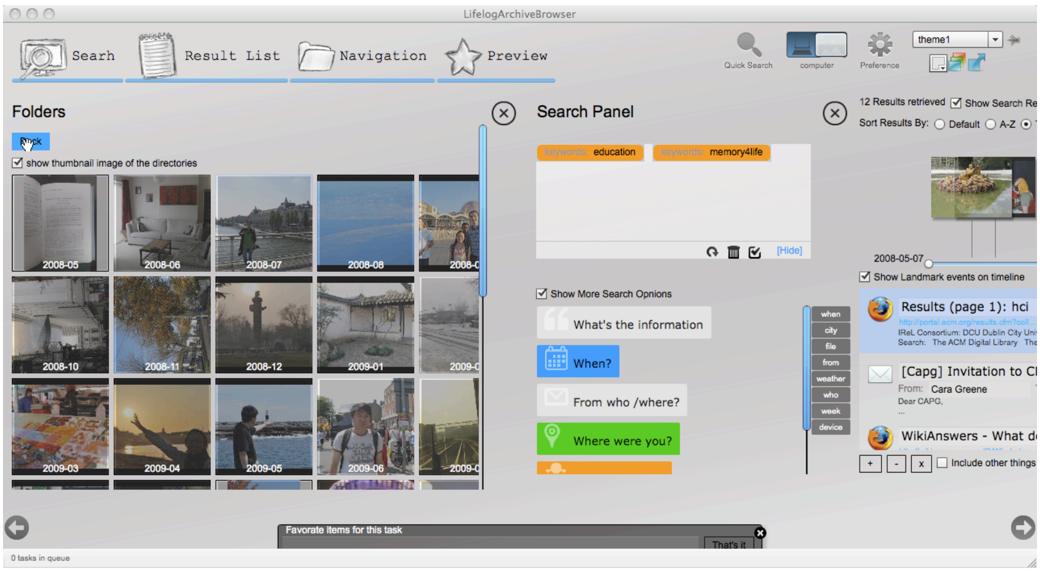

Figure 8.11 iCLIPs LAB interface showing folder navigation panel on the left side

Unlike the traditional tree structure for a folder hierarchy, folders and items in this system can belong to multiple parent folders. These "folders" are created dynamically for navigation. Two groups of folders are created based on the time and location of events (or computer activities) respectively. The first group of folders are hierarchically generated by the month, week, and date of events. Since people cannot always remember the exact month or date, surrounding items (week, dates) are also displayed in selected folder. For example, when the user clicks into a month, it shows the weeks in the month, together with smaller icons showing weeks in the month before and the month after. When the user opens a week folder, the days before and after the week are presented in smaller forms. The second group of folders are generated according to the location of events, also hierarchically by country, region (county), and city. Since the time spent in each location can vary dramatically, not all the locations on the same level (e.g. country, city) can contribute equally to segment meaningful groups of events. For example, a person may pass through several countries in a single trip (a couple of days), while staying in another country for years, and have different lifelog periods in different cities in this country. Therefore, only locations where one stayed for a considerable period of time are taken as separate folders, while the rest are grouped together with other short-stay places that are temporally adjacent to it, with a joint label (e.g. "Liverpool-Chester-Birmingham " for the folder containing episodes in these three cities). I believe that it could be easier for the users to interpret unknown names of locations when they are in a "context" (with name of places they visited before and after this location).

Every opening of a sub folder leads to the updating of result list as well as re-generation of folders in both groups. If the folder is a location-based folder, the time-based folders in it will be the months, weeks or dates during which the person stayed in the selected location. Similarly, if one dives into a time-based folder, the location folders will only include those places that the user stayed in during the selected time slot. Each of the folders is displayed with a thumbnail image and a title (e.g. name of the city, name of the month). The thumbnail image is either a key frame SenseCam image or a digital photo. The algorithm for selecting the key frame images is described in section 8.3.5. When clicking on the smart folders, the results in the result list are also updated according to current folder.

2. Faceted browsing

Of course, people do not always remember the name of the location or exact time (e.g. month, date) of events. Faceted browsing allows the users to navigate and browse their collection as far as they can recognize some correct properties of the target episode. The faceted browsing panel is shown in Figure 8.12. Users do not even need to think of any search query or to recall the correct time slot. There are a number of properties which users can utilize to filter the collections, e.g., name of people involved, name of places (city, country), or keywords of computer activities the lifelogger frequently engaged in during a period of time. Of course, since every click (selection of a facet) can change the current collection (the range of qualifying items), the displayed facets change accordingly. The types of facets include:

a) Images: Keyframe images of important events in this collection.
b) Location: Representative country, region and city names are displayed.
c) People: Names of people who appear much more frequently in the current collection period than he or she does in the rest of lifelogging period
d) Contacts: Name of contacts who were in frequent communication with the user (lifelogger) during a certain period of time in the current collection.
e) Computer activities: Terms (titles and search terms) extracted from key computer activities.

The algorithms for selecting these facets are described in section 7.3.2.

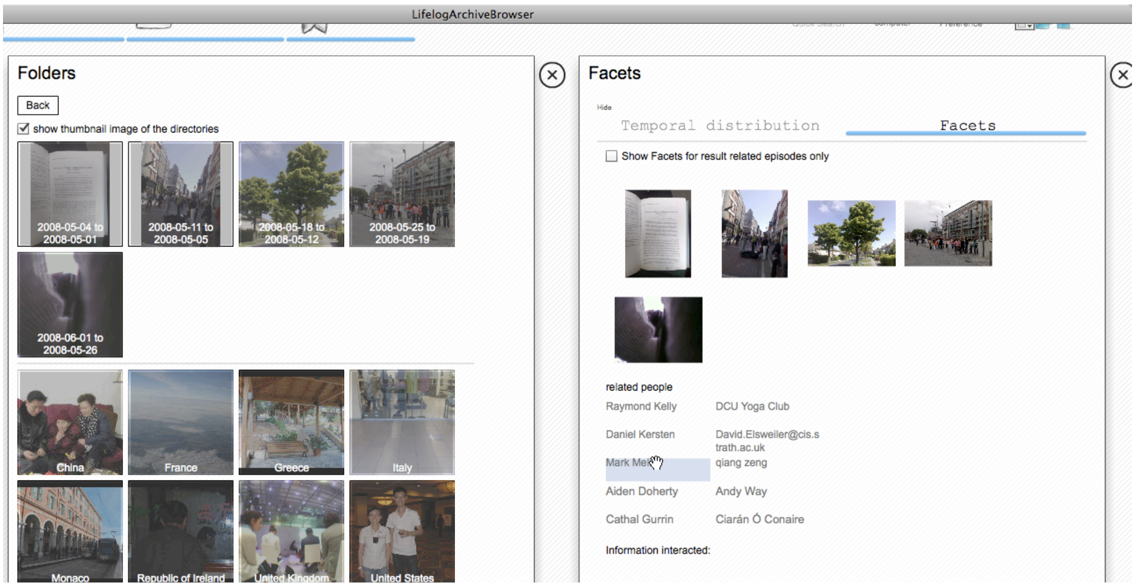

Figure 8.12 Interface with faceted browsing panel on the left

8.2.5 Other functions

Apart from the above main functions for finding information in lifelogs, I also designed the following functions to improve usability.

1. Switching between episodes and digital items

In case the user wants to view more computer activities in an episode, or more episodes associated with computer activities, the system provides the capability to switch between two types of targets. It allows users to view all the episodes associated with a computer item by right clicking the item, or to view the computer items visited during selected episodes by clicking a button in the episode display window. With the switch function, users can also browse for computer items by locating an episode in which the computer item was visited, or find an episode by searching for computer items which were encountered during that episode.

2. Saving favourite results and Finding again

Sometimes, people may want to review some interesting findings from their lifelogs again. They can save the results they found to collections. A collection is created every time the user "saves" the selected results. The selected item box can contain computer items, images and episodes.

3. Facebook Sharing

Sharing personal experiences in social networks has become increasingly popular. It was also been suggested by some people that they want a lifelog system to provide social sharing functions (Chen, 2012). This system allows users to upload photos from their lifelogs to Facebook by a single click.

4. Hiding unwanted content

Not everything in the lifelog which satisfies the query or filters is interesting to the user. Some events or items may even bring unhappy memories to the user. For this reason, the system allows users to "Trash" selected episodes, electronic items or all the episodes happened in a specific city, so that they will not appear until they are recovered from the unwanted list again.

5. Accelerate Initializing

As discussed in Chapter 3, users can have different levels of uncertainty regarding the potential targets, and different levels of knowledge of the information system and the information corpus. The overview function is expected to be particularly useful for first time and intermediate users who may have some problem planning a finding strategy due to failure to gather enough information (knowledge) about the function of the system, and types of data or potential targets in the data collection. The default screen (when opening the application) displays the faceted-browsing panel showing key facets of their entire collection, and the navigation panel showing all the months and countries in their collection. The default start screen is shown in Figure 8.13.

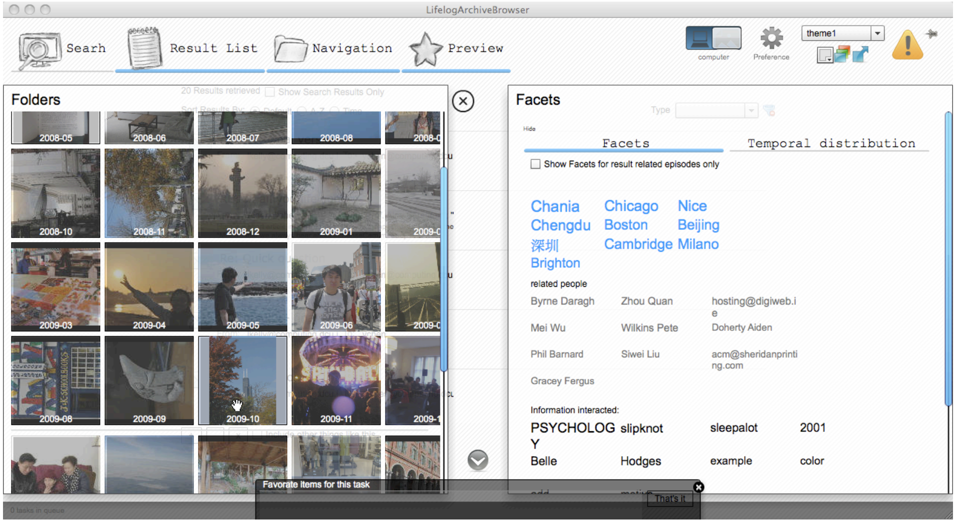

Figure 8.13 Default (initial) Screen when opening this application

Information and images in these two panels are expected to act as good memory cues which remind users of potential targets in the collection. The menu bar is displayed at the top with buttons corresponding to each of the main function panels: search, navigation, faceted browsing (preview). These buttons are planned to remind the users of possible functions they can employ, and help them to more efficiently plan their strategy for finding the information that they need.

6. Customized themes

Finally, 5 themes are available for the prototype system. So the users can used the colour themes are layout forms that they like. They can also use their own photos as background, and they select a full-screen mode.

8.2.6 **Function Summary**

To summarize, the system enables people to find either episodes or individual digital items in their personal lifelogs. It provides following functions:

1) It enables people to search for episodes or digital items with a wide choice of search options, ranging from attributes of electronic items to location or weather of an episode. Users can not only search for digital items with features of the episodes in which the digital items was encountered, but can also search for episodes by attributes of digital items visited in corresponding episodes. The flexible layout of the search options and floating labels for these fields were designed to minimize the effort in finding the search options themselves and to keep the users reminded of (or cued with) what they can try to recall, see the Figure 8.3 and section 8.2.1.2 for more details.

2) Users can sort results alphabetically or by time. When sorted by Time, a timeline component appears, and allows users to filter results by time range (e.g. 04-01-2008 11:04:00 to 03-02-2008 13:10:00) or jump to results after the selected time point on the timeline. Landmark events are also displayed along the timeline as reference points to help users to locate the time range of the target events (as described in section 8.2.3 and Figure 8.10).
3) The navigation function enables users to navigate and browse for information and episodes by time and location. The user can utilize this navigation function to narrow the current result set or dive into a "smart folder" which contains episodes during the time slot (a month) or location indicated by the name of the folder. Thumbnails of digital photos or SenseCam images are selected as the "cover image" for each folder (where applicable) to provide richer cues to the content in the folder (as described in section 8.2.4 and Figure 8.11).
4) The faceted browsing panel serves both preview and faceted browsing functions. It displays extracted summary of the selected collection (e.g. current result selection, selected folders). Users can narrow results by selecting a facet (see Figure 8.12 and description in section 8.2.4).

8.3 Data Structure and Background Algorithms

To realize the interface functions of this system, some background processing is needed. This section describes the structure of our data and background algorithm needed for the interface functions.

8.3.1 Data Structure

The raw data are processed, stored in database and indexed. Three main storage locations are used for the lifelog data in this system, including an SQLite database and two Lucene indexes. SQLite[19] is a self-contained database for local or client storage and embedded in application software. Unlike other database management systems, it does not have stand alone process to be communicated through a "server". It stores the entire database (definitions, tables, indices, and the data itself) as a single cross-platform file, which can be read and written by local software. Lucene[20] is an open source information retrieval (IR) library. At the core of its logical

[19] http://www.sqlite.org/

[20] http://lucene.apache.org/

architecture is the idea of a document containing fields of text, which are independent of the file format. The data in the databases on indexes is as follow:

1) The SQLite database stores records of all the interactions with computer items (including timestamp of opening and closing the window of the electronic item, full content, and its attributes), details of episodes, details of images including timestamp and path of the images, and other pre-processed information to facilitate rapid response on the interface.
2) A Lucene index for all the accesses of computer items and their associated context information such as location, name of people (Bluetooth device) and weather.
3) A Lucene index for all the episodes, including timestamps (hour, date, month, year, weekday), location (city, region, country), name of people nearby during the episode, weather, light status and so on.

8.3.2 System Structure

The system has two main programmes: a Java programme which takes care of the IR processes from the Lucene indexes, and an Adobe AIR[21] application which is responsible for the interface, interactions with the SQLite and communicating with the java programme. Both programmes are cross-platform, so that all our three lifeloggers could use the system (two of them were using Mac OS, and one of them was using Window XP at the time of the experiment). The queries generated from the search panels are sent to a background application to retrieve from Lucene Indexes. The retrieved results are temporally stored in the SQLite database. There, the data are processed before they are displayed on the interface. The rest of elements in the interface (e.g., filters, sorting) interact with data in the database without querying the Lucene indexes. The high level interaction of the components in the system are depicted in Figure 8.14.

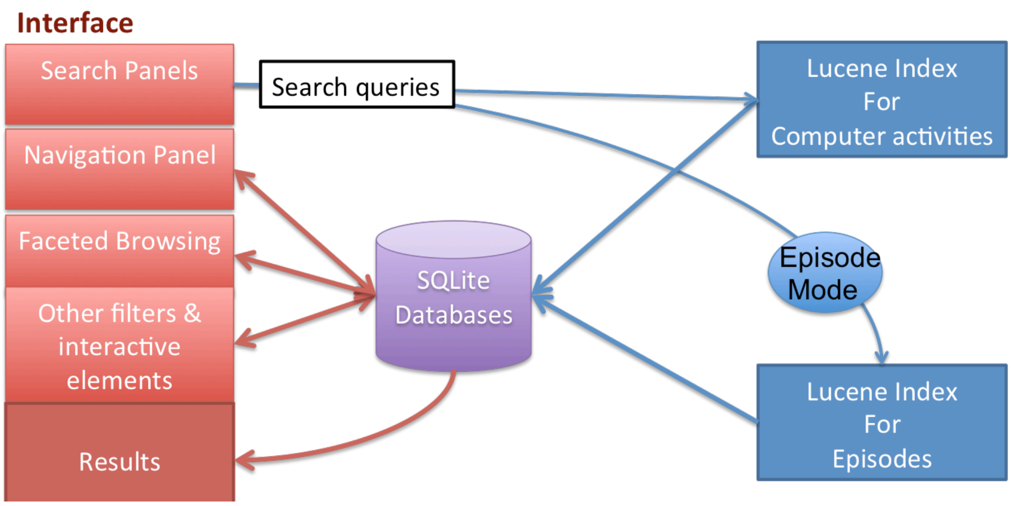

Figure 8.14 High-level structure of the system

[21] http://www.adobe.com/products/air.html

The rest of this section describes the mechanisms of IR from the Lucene indexes, and algorithms that realize the interaction between the data in the database and the interfaces.

8.3.3 Creating Episode

To enable users to find events and episodes, it is ideal that the data can be grouped into meaningful episodes for presentation.

8.3.3.1 *Related work*

It was found that the way people segment events affects what they remember later. The segmentations, which automatically carries on in human brains, are usually based on the bottom-up processing of sensory features such as movement and the top-down processing of conceptual features such as actors' goals (Zacks & Swallow, 2007). Doherty (2008) explored the segmentation of a visual lifelog into events based on image features and sensor data (e.g. light status) automatically captured by a SenseCam. However, the times when SenseCam images are missing cannot be segmented. With richer types of data in our prototype lifelog collections, other types of data can be used to assist the segment episodes. For example, Kang (Kang, et. al, 2005) used a time-based clustering (TBC) method to identify significant places that a user visited during a journey. When the duration spent at a place exceeds a certain time threshold, it was considered a new place (episode).

8.3.3.2 *Real life episode segmentation*

In this project, I used the approach of segmentation based on multiple information sources. The algorithms were developed by Byrne (2012), and clustered events at four levels. In the first level, contextual data were clustered with the TBC method. When a person is travelling, the context can change from time. Therefore, episodes which lasted less than the time threshold were temporally maintained and further processed to check if they belonged to an "interval" episode in which a person was moving from place to place (level 2). Since a person can engage in several activities in the same detectable location, a further segmentation is needed. For example, a person can watch a TV programme, prepare dinner, have dinner, and meet friends without leaving his house. In Level 3, sensor data (mainly accelerometer data which captures the movement of the camera) from a SenseCam was used to perform the segmentation. Since there are periods where both the SenseCam and mobile phone were turn off, explicitly captured content can be used. In Level 4, a short episode of 5 minutes was created for every point where an explicit content item (including Twitter tweet, digital photo, text message) was created, where no other episodes were available from the other three methods.

8.3.3.3 *Computer activity episodes segmentation*

Apart from the episodes created by above methods, computer activities can also be used for creating computer activity centred episodes. A time-based clustering method was used. Instead of judging the time of the duration of each activity, the interval between two clusters of computer activities was used as a criterion for segmenting computer-based episodes. This is because activities captured by the Slife software were defined by the opening and closing of a window. A person may switch between multiple windows around the same time for one task. This means that an activity defined by Slife may not be equally considered as a single activity by a person (the user). I assume that computer activities can be clustered into two episodes if there is a long-enough period between them without any computer activities. Since the events segmented based on SenseCam images are usually around 30 minutes (Doherty & Smeaton, 2008), I set the threshold between two computer activity episodes as 30 minute. Therefore, computer-activity-type episode is defined as a time period where there are computer activities, with no intervals longer than the threshold time (30 minutes). Figure 8.15 shows an example of how the activities are clustered.

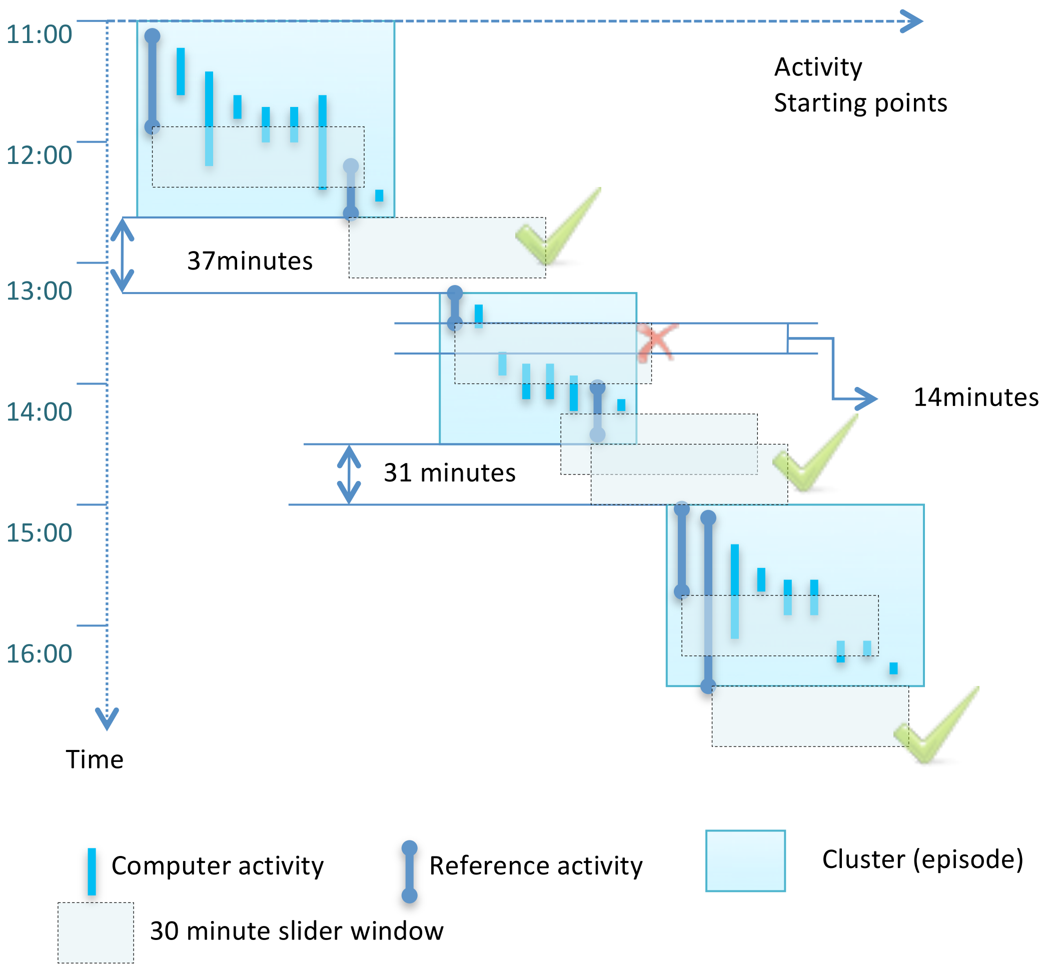

Figure 8.15 Cluster of computer activities

8.3.3.4 *Selecting key frame images for episodes*

Keyframe images were pre-selected to each episode. If there were no digital photos, screen snaps, or manually captured SenseCam images, the highest quality SenseCam image near the middle of the episode was used as a keyframe image from that period. For episodes of certain computer activities, the first clear image was used as the keyframe, as people may switch to other windows or have a short break during the task, the middle images may not be representative.

8.3.4 **Information Retrieval**

This system allows the users to search for either digital items or episodes using a variety of search options. The queries are sent to a background search engine developed in java based on Lucene. This section describes the retrieval algorithms for computer items and episodes and the other methods used in the retrieval functions.

8.3.4.1 *Information Retrieval algorithm*

The same algorithm was used to retrieve episodes and electronic files. It was a BM25F (Robertson et. al., 2004) extension to the standard Okapi probabilistic IR model on Lucene. BM25F is designed to most effectively combine multiple fields from documents for improved retrieval accuracy. The search engine accepts queries for the date, time, and day of week, month, and location, context (name of Bluetooth or Wi-Fi names) that occur during an episode. It retrieves all records which match at least one of the search criteria. This means that not all the items in the results match all the criteria that are included in a search query. For example, sometimes a user may just want an email which was received in May 2009, but the result also returned other types of items such as documents and webpages that were accessed during May 2009. The reason that I prefer best match to exact match is that people do not always recall all the exact terms that were recorded or indexed for search. For example, sometimes people only remember part of a filename, or sometimes they fail to correctly recall some aspect of the target, e.g. recall a wrong month of encountering it. With this algorithm, the target may be retrieved even if part of the query does not match the facts of the item. Of course, sometimes users may be very sure about some information and want to find things based on exact match. Thus, filter functions are provided to enable the users to narrow down the results set with exact match processes. With the BM25F retrieval algorithm, users can search for all fields without telling the retrieval system that the query is for any specific field, the algorithm processes this automatically. Therefore, it does not matter if a user puts a query for one indexed field in another field. For example, the retrieved results would not be influenced if the user filled in the field of “title” with content terms which actually belong to the “keyword” field.

8.3.4.2 ***Retrieving Digital Items***

To allow users to more conveniently manipulate the results by filtering and sorting them, retrieved results are temporally stored in an SQLite database during a task. As more results are retrieved, it takes longer to write all the retrieved items to the SQLite database, and longer for retrieval from the database, I decided to split the retrieval process into three steps in order to reduce the response time on the interface. Firstly, up to 20 episodes or digital items are retrieved and sent back to the Adobe AIR application for an instant update to the result list. At the same time, it starts to retrieve all relevant episodes or computer activities (up to the user defined maximum number), and sends the ids of the episodes or computer activities to the SQLite database for further processing. Immediately after all the results are retrieved and while the system starts to write them into the database, it also sends the total number of results to the Adobe AIR application as quick feedback to indicate the changes or the update of the result set.

8.3.4.3 ***Retrieving Episodes***

Episodes are retrieved using a similar method as the retrieval of digital items, but the retrieved results are from a combination of different sources, including: i) direct retrieval from an index of episodes, and ii) indirect retrieval from a database of all episodes whose time range overlaps with that of retrieved computer activities (retrieved with the same query, but from the Lucene index of digital items). The reason is that the index of episodes does not include all details of computer activities such as the full text of the computer files accessed during each episode, users are not able to search for episodes based on what they remember about the textual content that they read during the episode. In this situation, implicit and indirect retrieval is carried out at the background to retrieve these episodes with potential relevant computer activities. It is implicit as no user action is required, and indirect as the episodes are retrieved based on the timestamps of retrieved computer activities. The directly retrieved episodes are processed first, followed by the indirectly retrieved episodes. When no fields in the query involve computer activities, i.e. if the fields for keywords, type of the digital item, path/URL and so on, are left blank, the retrieval algorithm will ignore the process of indirectly retrieving episodes from related computer activities to reduce processing time.

8.3.5 **Cue items generation**

Cue items are generated for previewing current collections, e.g. the result set or a sub collection of the results set of the entire lifelog collection. There are two types of cues: representative features of general events, and representation of landmark events that were involved in the to-be-previewed collection. Instead of defining rigid boarders for general events and selecting information to present each segmented event, thematic facets were extracted to represent any general events they belong to. The algorithms were described in Chapter 7 (end of section 7.3).

8.4 Chapter Summary

This chapter introduced the prototype personal lifelog IR system, the iCLIPs Lifelog Archive Browser (LAB) which enables the lifeloggers to search, navigate and browse their lifelogs. The next chapter will report the evaluation of this system to test my hypothesis that a better support to user's memory can make their information finding tasks in a PLL more effective and efficient.

Chapter 9
Evaluation

9.1 Overview

In chapter 3, I concluded that the user's memory plays a very important role in information behaviour when interacting with his or her own personal lifelog (PLL). Therefore, I hypothesized that support of the user's memory could produce an improved user experience and efficiency for accessing data from their lifelog. Based on my review of psychology literature in Chapter 4, and the findings from my empirical studies described in Chapter 6 and Chapter 7), I designed and developed a prototype system, described in Chapter 8, which is expected to support the user's memory in several stages of the information finding process. This chapter reports the study that I conducted using this prototype system to test the hypothesis.

In Chapter 4, I hypothesized that the following solutions would support a user's memory in the information finding process for a PLL:

1) People are more likely to retrieve a target from an IR system if they are allowed to generate a query with information from autobiographical context.
2) Browsing and locating target would be more efficient if the user generally knows where the target is. My specific hypotheses are that:
    a. A lifelog collection should be organized by where (city, country) and when (month, week, date), since people usually remember the *where*, *what*, *when* and *who* of events
    b. Since thematic features of general events could act as good memory cues for general events, faceted browsing with extracting representative facets can improve effectiveness and efficiency of information finding tasks in PLLs.
3) Important events can act as reference points for users to more easily locate target events when the collection is ordered by time.

These hypotheses correspond to the following features and components of the prototype interface:

1) The search panels in which users are allowed to search with multiple attributes of electronic items and events, such as title, type, place, weather. (Hypothesis 1)

2) Time-based and location-based folder structure and faceted browsing which allow the users to filter results or the entire collection, by the thematic features of general events and lifetime periods. (Hypothesis 2-a)
3) Both the landmark events and thematic features are provided as cues for representing the content of the current collection. Faceted browsing is also available by clicking any of these facets. (Hypothesis 3)
4) Result items (including computer activities and real life events) could be ordered by time, a timeline showing landmark events will enable people to locate episodes by location relative to landmark events. (Hypothesis 2-b)

9.2 Method

The participants are the three lifeloggers. They were required to conduct 8 types of information seeking or finding tasks in their own lifelogs with the provided prototype experimental PLL system.

9.2.1 Evaluation Measures

The traditional ways of measuring IR performance are usually based on two standards: *effectiveness* (the percentage of what a user wants is found by the system), and *efficiency* (the time and effort taken from the user to get the result). Another measurement for evaluating an interactive search system is the user's subjective satisfaction with their search experience. In this study, I adopt all three measures. However, due to the complexity of the finding tasks in PLLs and the design of the prototypes system, I defined more precise standards for each measurement:

1. **Effectiveness**
   1) The method is effective if the initially planned target is found.
   2) In the case that the information need changes during the course of task, how happy is the user with the final results?
   3) Since people look for information to use, the effectiveness also depends on how usable the result is, that is, the easy with which the user can make use of the result. For example, if the user looks for a file to transfer it to others (e.g. to send to another person, or run within an application), the result is more effective if it provides a link to the file that by clicking on it, opens the folder containing the file or the file itself with the desired application, than if it only provides all the detailed information, textual content and a path which is not clickable.
   4) As for reminiscing and reflection type of tasks, the targets are usually subjective and not specific. For example, people may just want to view photos from the past to kill time or

get some emotional comfort. In reminiscing tasks, the effectiveness of the task is measured qualitatively through yes/no questions and open ended questions: “did you learn anything about yourself during this task”, “did you have any emotional feelings during the task”.

2. **Efficiency:**

In most IR studies, efficiency is measured by the time spent, or the number of steps taken to locate the result. However, these measures are not very suitable for our prototype system. For example, the time for each task may also depend on the current status of the user’s computer (if it is busy, it may take longer to get a result). Similarly, it is also difficult to give a clear definition of the ‘steps’. Different actions take varied levels of physical and mental effort from time to time. Scrolling down to browse for results may or may not require more effort than clicking some options to filter or sort the results. Typing a longer word may require more physical action and more time, but the word may take less time to recall.

Instead of measuring the “efficiency” quantitatively, I assess it based on the user’s subjective rating of “how easy is the task”. Since tasks start with different levels of difficulty, I measure the extent to which the functions in the prototype system help to reduce the difficulty of each finding task. Of course, it should be noted that the subjective measure from a small sample size may not be reliable or generalizable. Apart from the ratings, more focus of the current study is on understanding how and why it reduces or increases the difficulty of the task and efficiency of the task, e.g. is it because of the difficulty of recalling some feature to generate a query, or is it due to the difficulty of browsing for results, or is it a problem of the program’s speed.

3. **Satisfaction**

Satisfaction with the prototypes system is measured by the “helpfulness” of components that are used in each task. Again, the single subjective rating from a small sample size is not reliable or generalizable. More focus is on their comments regarding their experience of how a component or function helped them in the tasks and so on.

9.2.2 Material

In order to test the individual contributions of each feature and component, which are designed according to my hypotheses (9.1), I used a modified version of the prototype system, described in Chapter 8, as the experimental platform. In this modified version, the features and components were selectively enabled. Pre-task and post–task questionnaires were attached to the system for each finding task. Apart from this, the components were selectively enabled in different testing conditions in order to investigate the effects of the corresponding components. There were seven combinations (conditions) of components as shown in Table 9-1.

Table 9-1 Interface components included in each testing condition

Features	B1	C1	C2	B2	C3	C4	H
Basic feature options	Y	Y	Y				Y
Extended search options		Y					O
Basic result list	Y	Y	Y	Y	Y	Y	Y
Sort results by time	Y	Y	Y	Y	Y	Y	Y
Sort results by alphabet	Y	Y	Y	Y	Y	Y	Y
Alphabet landmark	Y	Y	Y	Y	Y	Y	Y
Temporal landmark events			Y			O	O
Folders				Y	Y		Y
Folder with key image					Y		O
Facets summary					Y	Y	O
Faceted browsing						Y	Y
Total tasks	6	6	6	6	6	6	24

Note : Y=included by default, O=optional, that is, the user can choose to enable the function during the task.

1. **Baseline search interface (B1):** The baseline search interface tried to mimic a typical search interface, and therefore, it only included some typical search options in the search panel, e.g. keywords, titles, contact names, and the date range (e.g. 10 days around 05-06-2008). The result interface only included a list view together with basic sorting and filters (item type, year, month, day).
2. **Search interface with extended search options (C1):** In this condition, extended search options were added to the search panel. These options included the name of the location, people, and weather and so on. The presentation of results remained the same as in the baseline system. There is an [unlock] bottom under the basic search panel, which expanded the interface to show the full list of search options. The subjects needed to click this button in order to use the extended search options. This small step aimed to discourage subjects from using the extended search options unless they really needed to. In this way, I could estimate how often subjects really needed to use the extended options.

3. **Search interface with landmark assisted result browsing (C2):** This condition enabled the function of using temporal context to assist the search result browsing. This condition was compared with the basic timeline-assisted browsing. In the baseline condition, the user could only jump to result items (which were previously encountered as recorded in their lifelog) according to calendar date on the timeline. It was expected that showing landmarks may help users to recall or recognize the approximate time point to jump, and as a result, the users could more quickly locate the target in the result panel. Since the landmark events could act as good memory cues for autobiographical memory, the presentation of the landmarks may also trigger more memory of the past for refining search queries.
4. **Baseline folder view (B2):** This baseline interface included the labelled folder and a list view of results. The result panel, which presents all the items that belong to the folders and their subfolders. Users could either look for their targets in the result list with other assistive tools such as filtering by item type and sorting by time, or go further down the folder structure to see content in a more specific sub-collection (e.g. opening a month folder, or to open a week folder to view all events which happened in the week). This condition was compared to the baseline search interface. The advantage of folder based navigation was expected to be in the consistency and people's habit of location based storage and finding in the real world. Also, users could get rich contextual cues for recognizing and recalling the correct path.
5. **Folder with contextual cues (C3):** On top of the baseline folder view, richer contextual cues were included in this condition to assist with location-based navigation. These cues included the cover photos (key images) of each folder, and the faceted browsing panel which displays key images of events and a textual summary of the activities in the selected folder. In this condition, the facets could not be clicked to "open" the collection which contains events with the facet as the theme. This condition is compared to condition B2. I expected that these cues could remind the subjects of the content in the folders, and more efficiently find the correct folder to navigate into.
6. **Faceted browsing (C4):** This condition included a faceted browsing panel and a list view of items. The facets were dynamically generated to represent the currently selected collection, instead of the fixed hierarchy of the folder view (condition B2, C3), in which the user could only narrow down events by calendar units (month, week) or location (city, country).
7. **Hybrid systems (H):** This condition included all the components in the prototype system. The search panel, folder view and faceted browsing panel were presented by

default. Other memory assistant functions, such as extended search options, landmarks, and cover photos of folders, were also available with a single click.

9.2.3 Procedure

9.2.3.1 *Task generation*

There are basically two types of information finding tasks according to how they were generated: assigned (required by others) and intrinsic (from the user's own need). With the naturalistic method (intrinsic tasks), the participants usually look for a target out of an intrinsic need, within a real world context which is usually related to the target and influences the information finder's strategies and performance in finding the target. Studies with naturalistic methods usually take a long time due to the limited frequency of occurrence of finding tasks. Due to the 2 year gap between the data collection and the time of conducting this evaluation, the experimental prototype PLL data was less likely to be needed by the users (the three lifeloggers) for their current life and work, it would be even more difficult for studying the finding behaviours in a naturalistic way, that is, logging the user's activities in finding tasks when they do need to use this system to find information in their PLL archives.

An alternative approach is using assigned tasks, that is, the examiner requires the users to search for specific things. This approach usually lacks the context of the task (e.g. how to use the information after it is found), but can be more efficiently conducted as it does not need to wait for certain events (in this case, finding tasks in PLLs) to happen. Also, with assigned tasks, it is easier to control the types of tasks. However, using this approach, it is difficult to evaluate a system for finding information in the user's personal information space (PIS), as the examiners can hardly know what is present the subject's (a person's) PIS. In a study which evaluated a personal email management system, the participants were from the same organization, so they have received some same emails. Thus, the examiner could pick up some of these group emails as assigned search targets (Elsweiler, et. al, 2008).

There is another approach that is in-between these approaches, it does not wait for a task to happen naturally, nor does it make up tasks and assign them to the participants regardless of the context or personal difference, it requires the subject to create the tasks by themselves. Of course, there could be other types of bias if all the tasks are freely recalled or imagined by the subjects. According to the mechanism of human memory, information that is likely to be recalled is usually what has recently been visited, frequently viewed, or strongly associated with the current context. To reduce the likelihood of such biases, some instructions should be given as a guide and cues to trigger an equal number of tasks for each type that are needed in the experimental design.

In this study, I decided to require the user-generated scenario in which certain lifelog data were needed. The tasks were then created in a comparatively natural way based on these scenarios of information needs. The participants were required to generate 10 tasks for each of the types listed below (excluding type 4 or 8, these two categories were used only if they were not sure what category the target belonged to):

1) Specific information: number, name of contact or papers, etc
2) Specific item: a file, an article, an email, an image, a YouTube video
3) Any information related to a topic: e.g. references on lifelogging
4) Other types of information or items encountered on computers
5) Specific information (attributes): e.g. time or location of and action or event
6) Specific episodes and general events for reminiscing
7) Information encountered in the physical world related to a topic: e.g. a person
8) Other things captured from the physical world

Six sample scenarios were given as suggestions for generating tasks, e.g. find some photos of you as profile images to upload to Facebook, find the name of the restaurant for the Christmas Lunch in 2009. The participants were encouraged to generate as many tasks as they could before they were given the prototype system. An application was developed and given to them to add tasks, shown in Figure 9.1. The number of tasks created for each type and the descriptions of tasks were displayed beside the main task-adding panel. For each task added, the subject was expected to answer the following questions:

1) Descriptions of the goal status: "A detailed description of the target without leaking any private information or information that you feel uncomfortable to reveal", "Describe in detail: What are you going to do with the target?". The above information was shown in the post task questionnaire after completion of each task, in which the subject was required to evaluate the result of the task based on the descriptions.
2) Reason: Since the data in lifelogs were a somewhat dated and not very much related to the subject's current life and work, it is difficult to ask users to think of tasks for finding information that are really needed. Yet, to make the tasks more natural, I expected the subjects to find their targets for a reason, by asking the subjects to describe how they were going to use the data, so that the last stage (use of results) could be evaluated.

3) Description of current memory status: This is to be compared with what the subjects remember priory to conducting the task, but using the system for other tasks, and compared with what the subjects remember after the task. In this way, I can learn if they learnt more of their past during the course of using the system.
4) Type of target: the choices are the 8 categories listed above. The selected type is used evenly in assigning tasks for each condition.
5) Planned approach of finding the target (before they have the lifelog system).
6) Difficulty of finding it with the approach described in the above question. This value is to be compared with the assessment in the post-task questionnaire, which asked the user about how difficult the finding task was when using the experimental system.

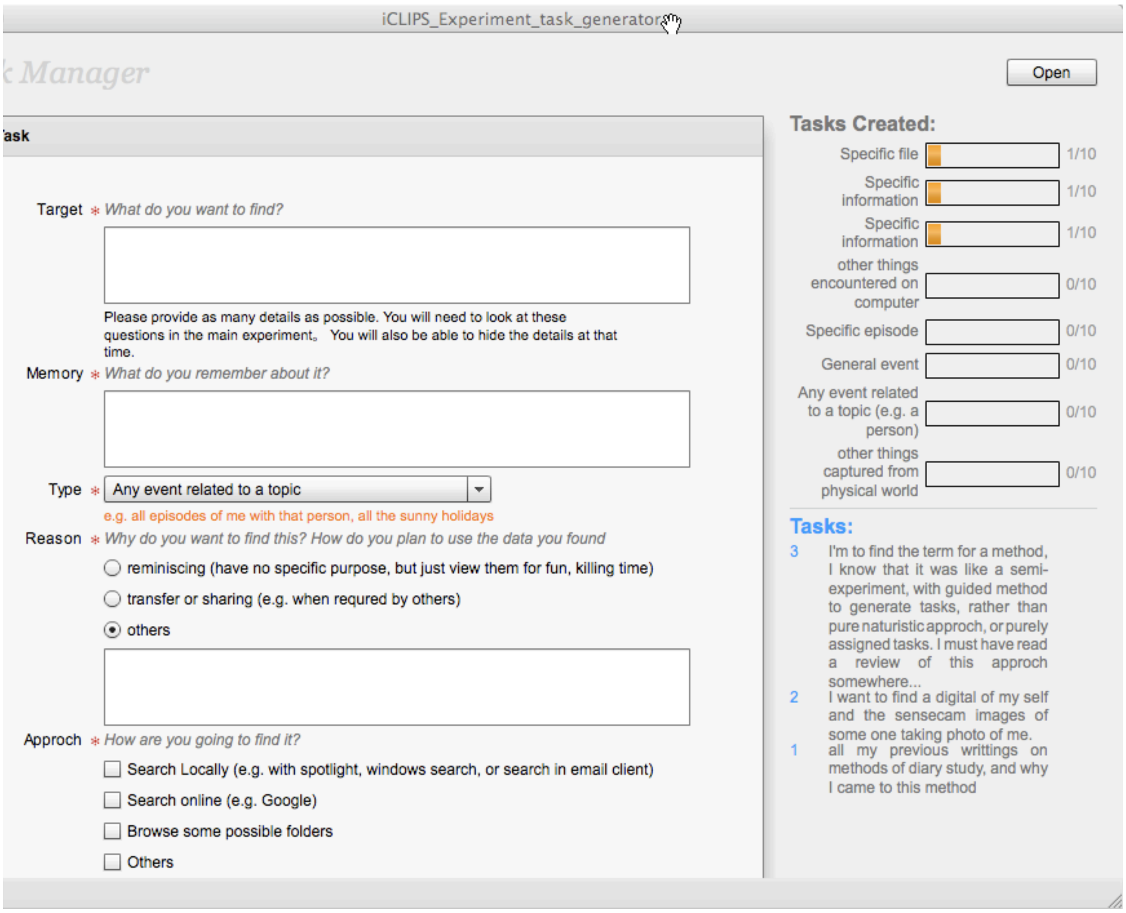

Figure 9.1 Task preparation application

9.2.3.2 *Pre-task questionnaire*

Before the user started the information seeking/finding process for each task, they completed the pre-task questionnaire, as shown in Figure 9.2. In this questionnaire, the goal status (task description) and the previous memory descriptions were collected.

1) The participants could edit the descriptions of the task to hide any details that they did not feel comfortable to let others see.
2) They could also add more information regarding what they remembered. The information added was used as a measure of improvement of the memory of things which happened during the lifelogging period after using this system.
3) They were asked to rate the anticipated difficulty of using the experimental system for the finding task.

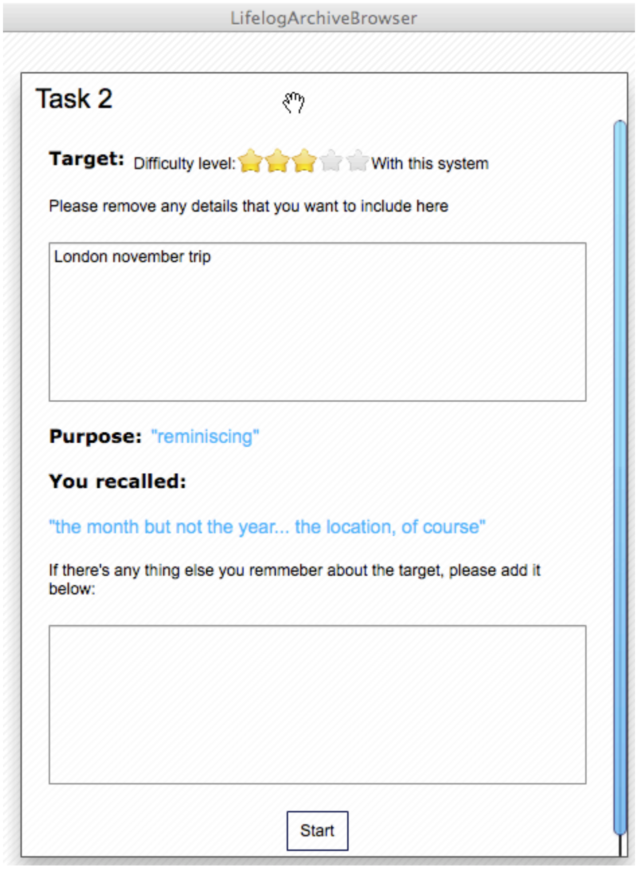

Figure 9.2 Pre-task questionnaire interface

9.2.3.3 ***Training***

Since the features of the system were "unlocked" bit by bit, the users were introduced to the functions step by step. Therefore, only one or two components, elements or functions were introduced at a time. The users (subjects) were allowed the opportunity to try each feature. Every time a new feature was unlocked (this happened before a task started), relevant instructions of how to use it appeared in a pop up window, with a link to a help file which introduced further details of the newly available functions. The subjects were encouraged to try the new features with an assigned sample task (assigned tasks were based on my knowledge of the items that should exist in all their individual personal lifelogs, e.g. received group emails).

9.2.3.4 *Information finding tasks*

In the information seeking or finding tasks, the users could use any available features in the experimental system to find the targets. They could select any amount of potentially usefully items into the results basket. On completing each task, they proceeded to the post-task questionnaire.

9.2.3.5 *Post –task questionnaire*

In the post-task questionnaire, the participants were asked to evaluate the task by answering the following questions, as shown in Figure 9.3:

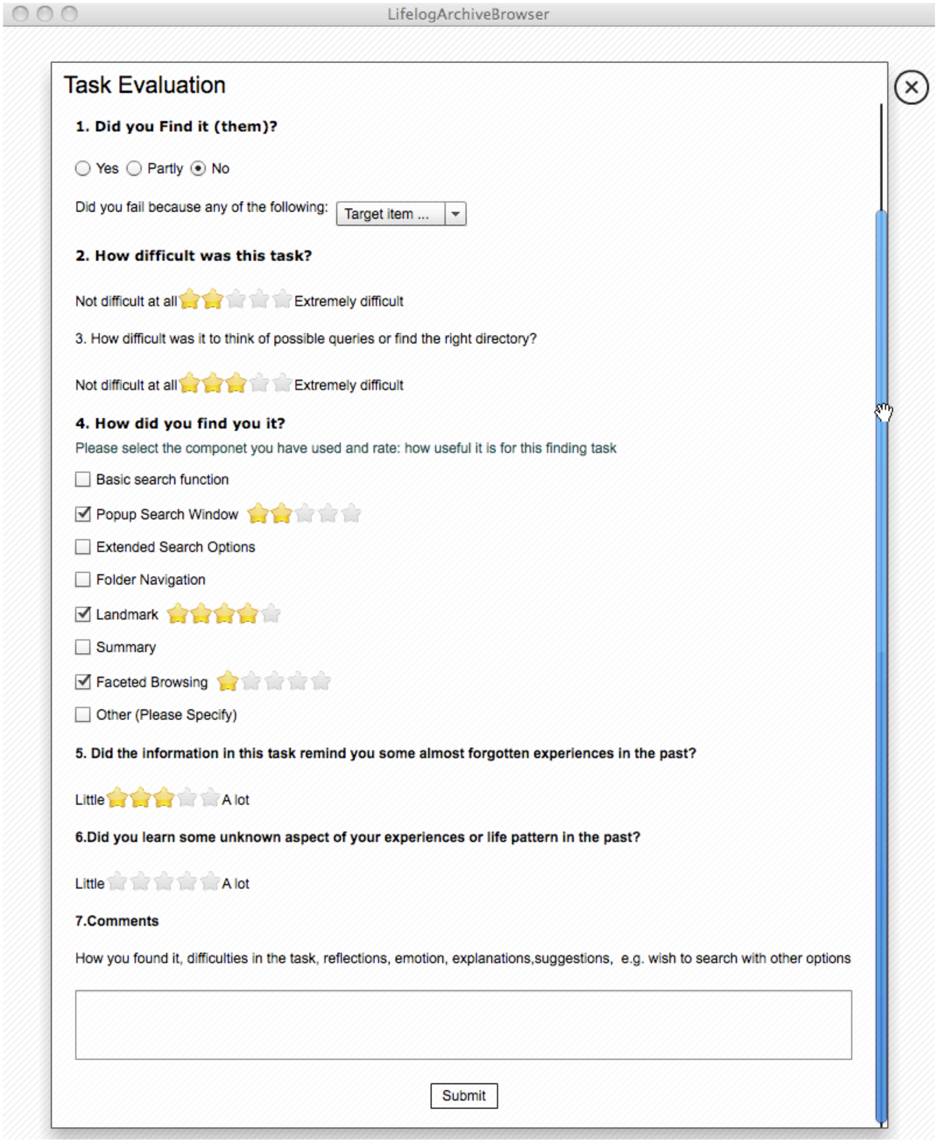

Figure 9.3 interface for post task questionnaire

1) If they found the target: they could select “yes”, “partly”, or “no”. They were asked for possible reasons for not finding the target; for example, the target is not recalled, the target was deleted, or if they needed more functions from the system.
2) They need to rate the difficulty level of task, from 1=extremely easy to 5 =very difficult.
3) How they found the target or conducted the information-finding task if they did not find any target.
4) They were required to indicate the elements that they had used, and rate how helpful each element was for this task. If they used the search function, they were asked to rate how difficult it was to formulate the query, and leave comments if they had any regarding problems encountered in formulating their query, how easy was it to convey what you know about the target to the interface, does the search interface allow them to input all they know about the target? If not, what else would they wish to enter as part of the query, and in what forms? If they want to, or have changed the query, how easy was it to change the query, and was the refined query based on some new information learnt from the results?
5) Reminiscing and emotional effects: did the information in the system remind them of any information or experiences in the past?
6) Reflection: Did they learn anything about themself, or their life patterns while carrying out this task?

9.3 Results

We analysed effectiveness, efficiency and satisfactory of each component compared to the baseline search interface. Table 9-2 shows the percentage of successful finding tasks and the reduced level of difficulty (compared by the rating of task difficulty with the subject’s other systems, e.g. email clients) of each type of conditions. A One-Way ANOVA test showed significant differences between the different conditions regarding the estimated difficulty level of the tasks (before carrying out the finding tasks and after starting using the system) ($p<.05$), reduced difficulty level for finding tasks ($p<.01$), and difficulty of recalling information to perform finding tasks ($p<.005$). According to Table 9-2 the subjects usually feel the tasks to be easier after using the system than their expected difficulty of finding them.

Table 9-2 Percentage of tasks in which each search option is used by all subject

Task condition *	Percentage of successful finding tasks within each condition	Amount by which level of difficulty is reduced**
B1	33.3%	-0.25***
B2	10.2%	0.12
C1	67.7%	-1.7
C2	56.7%	-0.42
C3	44.4%	-0.09
C4	23.6%	-0.38
H	57.8%	-0.88

Note:

* Please refer to Table 9-2 for the details of each condition

**Level of difficulty reduced by = post-task difficulty rating – ½(pre-task difficulty rating + initial rating of difficulty priory to using the system)

***Negative scores indicate improved efficiency for this finding task.

At the end of each task, the questionnaire required the subjects to select the features they used during the task, and rate how "useful" the features are for the task. Table 9-3 shows the frequency of using each feature and the rating of "usefulness" for each feature. The frequency of use refers to the total subject indicated use of the feature among all the tasks in which the feature is available. The usefulness value is the average score of the subject's rating after the tasks on a 5-point rating scale (1=useless to 5=extremely useful).

Table 9-3 Usefulness of interface features

Feature	Frequency of use	Usefulness
Basic search options	67.5%	2.3
Pop up search interface	6.2%	2.1
Extended search options	75.5%	4.1
Folder navigation	46.5%	3.5
Landmark on timeline	7.6%	2.9
Faceted browsing	12.2%	2.4

9.3.1 Autobiographical context as search options:

A Chi-Square test found that when the extended search options were used, the user was significantly more likely to find the planned target than when using the basic search options ($p<.01$). This finding supports my first hypothesis that "People are more likely to retrieve a target from an information retrieval (IR) system if they are allowed to generate a query with information from autobiographical context".

For the tasks where the subjects manually enabled the extended search options, I generally assume that they have given up finding the target with basic search options. This means that the basic search option, based on a standard search function, could not provide them with the information that they needed. For 57.3% of the tasks, in which the extended search options were enabled and hidden by default, the subjects clicked to show and use the extended search options. Eleven tasks which searched for computer items also manually enabled the extended search options, with the targets being successfully retrieved for seven of these. Although this number is small, it does suggest the importance of extended search options from episodic context.

The difficulty level of tasks was also calculated as a measure of the efficiency of the system, shown in Table 9-4. Although no significant differences were found between the values from the two conditions (with and without the extended search options), the tasks were generally rated as less difficult when the extended search options were available.

Table 9-4 Average rating scores for difficulty of tasks

Efficiency score	Basic search interface	Extended search options enabled
Difference of pre-task and post-task rating for difficulty of task	Mean=0.06 SD=1.88	Mean=0.92 SD=1.88
Post task rating of difficulty of task	Mean=3.32 SD=1.88	Mean=2.78 SD=1.64
Difficulty of recalling information to conduct search	Mean=3.00 SD=1.93	Mean=2.78 SD=1.64

Table 9-5 shows the percentage of search options used. When looking for computer items, keywords and extension (type of item) are the most frequently used search options regardless of the availability of the extended search options. This is partly because keyword-based search is usually more efficient with the background IR system. According to one subject, "I found the presentation easily through keyword search ... surprisingly it was one of the few results that appeared." When searching for events or photos, the basic search option (approximate date range of the event) usually tended to be difficult. Subject A commented "I cannot recall dates & in my searches here it is mostly events or groups of events that I am interested in finding. Geo-location filters and people filters might be." While the extended options were not used as often as the basic search options, such as keywords or items type when looking for computer items, they are occasionally very helpful. When searching for events or photos, these extended search options are much more useful and more frequently used than the basic exact dates based search.

Table 9-5 Percentage of tasks in which each search option is used

Search option	Percentage of tasks used (where the option is available)	Search option	Percentage of tasks used (where the option is available)
Key words	47.5%	Year	12.1%
Title/filename/subject	13.3%	Month	13.2%
Item type	42.5%	Day of week	5.4%
From /to/author	12.1%	People around	13.4%
File Path/URL	1.2%	Weather	3.4%
Date range	7.3%	Country	16.7%
Time range	1.2%	Region	11.2%
Light status	1.2%	City	16.7%

9.3.2 Hierarchical navigation

This system automatically generated two hierarchical structures of "folders" according to the time and location of events.

1. Navigation vs. search

Based on the findings of (Bergman, 2008), I expected that people would tend to prefer this "location-based" finding method than search. However, in this study, I found that this approach is only preferred when the target is an event or information encountered in the physical world (photos), but not for finding computer items. For example, when looking for a file under the experimental condition B1 (only folder based navigation is enabled), subject A commented that she would rather that the "folders" are grouped by item type.

This finding indicates that the mental "location" of events is more closely related to autobiographical memory, while the mental "location" of computer items is still more closely associated with where we encountered the item previously, or how we usually find it. For example, subject C commented for one of the tasks "I know where the file is on my computer, but I can't recall which month it was in", or in other words, the "mental categorization" of files is not usually based on calendar dates and physical locations of an individual.

2. Cues for hierarchical navigation

The cover photos are commented to be very helpful, e.g. "easily found using tools. Photos found using folder navigation (photo from the event appeared in folder view).", "folder navigation allowed me to find required photos, because I remembered the year and month", "folder navigation was great for this task because images from episode appeared in the folder". The tasks in which the cover images are available had a much higher successful rate for finding the desired targets than tasks conducted under the baseline folder navigation condition (B2).

9.3.3 **Faceted browsing**

The faceted browsing function was intended as a supplement or an alternative to the hierarchical navigation function. It displays the key facets and events in selected "folders". By clicking any of the facets, the collection is narrowed down to general events with the selected facet as a theme. Unfortunately, this function was seldom used alone, but usually as a filter function after search. Tasks in which faceted-browsing was used did not significantly improve the effectiveness of efficiency according to the post-task rating scores. Yet, the facets did successfully trigger more memory from the subjects, e.g. "the summary and photos brought that holiday back to mind".

9.3.4 **Landmark events on a timeline**

It is congruent to many other studies, e.g. (Cutrell et.al., 2006), that the subjects also liked to sort their search results by time. The timeline-based filter, which narrows results according to a selected time range, seemed to be a frequently used feature. Although I did not find an improved rate of finding the search target, nor did I find any significant decrease of difficulty level when this feature was enabled, the landmark events were commented to be useful. Among the 183 times that the timeline based filter was used (146 of them were under the task conditions that a landmark event is available), 127 of them were via a click on landmark events or when the landmark events were presented. This suggests that subjects do need the landmarks events to more easily filter the results by time range.

9.3.5 **Other findings**

9.3.5.1 ***Filter functions***

While the best-match search algorithm enabled the subjects to find many of their target items or events through searching, they usually commented that they required more filtering functions. Since the IR algorithms are not perfect enough to guarantee to retrieve the target items, and sometimes they return many results, which make it difficult to locate the target item within the first few pages of retrieved results, if it is retrieved at all. For example, “I browsed the episodes ordered by time, it’s much easier and more accurate than searching”. Therefore, the subjects sometimes commented that they have no way of finding the target via searching using this system, and prefer to use their email client, or to find it in their local file system. Of course, the filtering functions that the system provided are also commented to be useful “timeline function is useful”, “restricted the results by type and found it easily”. Yet, some additional types of filters are also needed, e.g., month, location, date, name of contact (who sent the email), and even keywords.

9.3.5.2 ***Finding events vs. finding computer items***

Interestingly, I noticed that tasks for finding episodes (finding specific episodes, finding information encountered in the physical world) were rated much higher than tasks for finding information encountered on computers (e.g. find an email) before starting the entire experiment ($p<.001$). The difference of difficulty level between ratings before using the system and after each task is greater for tasks with an episodic type of target, than for tasks with computer items as the target. In fact, 59% of the event types of targets were found, while only 34% of the computer item targets were retrieved. These figures suggest that this system is probably more useful for finding events in PLLs than finding encountered computer items.

9.3.5.3 ***Influence of memory after using this system***

While using this system, the images and other types of cues bring memories back to the subjects. Such information was expected to help the users recall useful information to perform the finding tasks using this system. Of course, what memory the cues trigger and what memories they re-enforce is not under the system’s control. I found that the information presented in earlier tasks helps later tasks which require such memories. For example, subject C commented for a task “I know the month and approximate date of the event, as I saw it in another task”.

In 49% of the tasks, the subjects reported that they had recollected memories that they had almost forgotten, or have learned new information of their past experiences which they did not know, although they only reported to have recalled a lot of information (rating 4-5) for 5 of the tasks. For example, subject C commented “it reminds of so many details, and enjoyable to review them”. Two subjects also reported to have to some extent made reflections of their life patterns during 29% of the tasks.

9.4 Discussion and Conclusions

This chapter reported a user study with three lifeloggers using the prototype iCLIPS LAB system to access their own lifelog data. This evaluated the hypothesized methods for supporting user’s memory during their information seeking tasks in their own personal lifelogs.

We found that search by episodic context (e.g. location, people) and flexible date time information (year, part of week) are particularly useful for tasks aiming at finding events or information encountered in physical world. In some tasks which aim to find information or items encountered on one’s computers, the subjects also needed the extended search options occasionally. The overall ratings of difficulty and the frequency of successfully finding target both supported my first hypothesis: *People are more likely to retrieve a target from an IR system if they are allowed to generate queries with information from autobiographical context*.

The navigation function with hierarchical folders, which were automatically structured according to time and location of events, was more useful for finding events than finding computer items. When coming to find computer items, the subjects usually preferred “traditional” search approach with this system, or to navigate and find them in locations where they had encountered or stored them, that is, folders on their file system or email boxes (which can be accessed with the email client that the subject usually uses). This finding did not mean that the subjects do not like navigation (location based search). Indeed, it suggests that there is a stronger association between the memory of the target item and its physical location on the file system or another frequently used management tool; and that the subjects are more familiar with the strategies of finding them from their file system or their information management tool. Another reason may be the absence of the manual organizing step, which can elaborates the user's understanding of the items and director, and may create a tighter association between the item and the location (directory) in the user's memory.

As for event-type targets, which the subjects did not manage or frequently access via other tools, are usually easy to locate with defined categories of time and location, unless the subjects remember neither of these types of information. The system automatically selected representative photos as covers of the "folders", and the combination of photo and date/time (name of month, date, week) or location proved to be very good memory cues for the subjects to recognize the right directory for locating the target events. In general, the results from using navigation functions supported my hypothesis that *People are more likely to retrieve a target from an IR system if they are allowed to generate queries with information from autobiographical context*, and that a lifelog collection can be organized by where (city, country) and when (month, week, date), as people usually remember the where, what, when and who attributes of events

The faceted browsing function was supposed to allow the users more flexibility in locating target items by different aspects (themes) of events. Unfortunately, for the few tasks that were conducted under the experimental condition in which faceted browsing was the only available function, the subjects did not manage to find their targets. However, the faceted browsing function was very useful as an additional filter to narrow down search results or items in "folders". Therefore, I conclude that faceted browsing with extracted representative facets can improve effectiveness and efficiency of the finding tasks in PLLs.

Similarly, landmark assisted timeline filters are usually used as additional features to browse search results. Although no significant improvement in effectiveness and efficiency has been found in task when this features is used, the subjects did comment that this feature is helpful.

Of course, this is only a small-scale evaluation of the system with three lifeloggers and each of them conducted only 60 tasks, and thus, it is difficult to always draw conclusions based on the statistics gathered from this study. As the system is a prototype built with Flex and SQLite, it is sometimes rather slow to respond and not very stable from time to time. These factors also influence the subject's choice of strategies (what features to use) and rating for the difficulty of the tasks.

To conclude, based on the statistics and the subjects' comments, the memory-supporting function in this prototype system did reduce the difficulty of finding tasks and improve the likelihood of the finding the information that they needed. This is congruent with my main hypotheses: "better support to user's memory can improve usability in accessing personal lifelogs". The findings of this study also imply that an information system can support people in accessing information from their PLLs and can help people to recall and learn information that they almost forgotten or did not know in the past. Last but not least, during the course of visiting their PLL, people can gain a better understanding of their life patterns in the past.

Chapter 10 Experiences based on two years of prototype lifelogging

With the unique long-term collections from three lifeloggers, I had the chance to do an in-depth exploration of the lifeloggers opinions of capturing personal lifelogs and their suggestions of technologies for lifelogging. This chapter reports the discussion during an informal focus group interview which was conducted with the three long-term lifeloggers after they used the prototype system. This interview was conducted in a quite room with casual settings, with sofa and coffee. Three questions were discussed: how they used the lifelogs before given the software, how they like the data collection, and what they do not like about lifelogging.

10.1 Use of lifelogs

Prior to installing the prototype information management system, the subjects seldom retrieved information that was stored in the lifelog databases, but just like any non-lifeloggers, find them from directories/folders or search for them through desktop search. There were only a few occasions when the lifeloggers had looked into their SenseCam collection or SMS messages to find specific information.

During the user study, subjects reported to be “so happy to see these things being captured”, and commented that they wished that they had continued capturing lifelogs, though selectively.

10.2 What drives people away from lifelogging?

The main reason that the lifeloggers did not want to carry on lifelogging is the physical and psychological burden. As for the physical burden, the wearable devices used were not light enough to be unnoticeable. For example, all the subjects were not willing to continue capturing biometric data due to the discomfort caused by the biometrical devices (heart rate monitor and the BodyMedia armband). Even for the Nokia N95 mobile phones, which were needed to capture location (GPS, Wi-Fi) or people (Bluetooth), was not small and light enough to be carried all the time, and was usually left on the desk when the person walked away.

One of the psychological burdens is caused by the wearing of the SenseCam. Since the camera is easy noticeable, many people inquired about it, and often tried to remain out of view from it once they learnt that it is a camera. There were also some embarrassing situations in which other people felt uncomfortable to be standing in front the lifelogger while they were wearing a

SenseCam, and required the lifelogger to turn it off, or even to delete the images that had recently been captured, containing the person in question.

Privacy is also an important issue with the lifelogging. Privacy concerns involve both the lifeloggers and third parties. This first point is quite obvious as the behaviour of the lifeloggers is recorded and can be replayed many times, if their data is leaked, information which they may wish to keep private could be exposed to others. As for third party privacy, examples are emails, text messages or conversations between another person and the lifelogger. Some of this information is only expected to be seen by the two of them. Therefore, the leaking of lifelog data, or if the lifelog data was given to others, would violate the third party's privacy.

10.3 Storing or Forgetting?

Another reason that some people object to lifelogging is their belief in the rights to forget unpleasant things, e.g. (Bannon, 2006). Yet, emotion of past experiences can change over time. For example, if we did something stupid and feel embarrassed about it, at the moment, we may wish to remove this moment from our life forever. But many years later, such experiences may turn into something we feel fun and cause for laugher, in which case we may regret permanently deleting from our personal lifelog. Gordon Bell described one of his experiences in the book Total Recall (Bell, 2010). When his dear friend passed away, every piece of information related to the colleague that was brought to his memory only added to his sorrow. However, a few months later, when his initial sorrow had passed, the "mementos" about his colleague turned into something Bell would like to look at and reminisce on.

Of course, not all the unpleasant memories become pleasant or neutral, and at least at the time when they are still unpleasant, presenting any of these things related to the user is not appropriate. Therefore, I suggest that a temporary blocking mechanism should be provided by lifelog management systems. Instead of permanently erasing the currently unwanted content, a function like a "sealed envelope" that hides unwanted content away temporarily, and can be unveiled when the time comes that the lifelogger needs to see them or when they are no longer unpleasant.

10.4 Total Capture?

In general, all three subjects expressed the opinion that they would like to capture as much information as possible for some interesting or significant event, but not on a daily basis.

Lifelogger A said that she would like all these data, but not from wearing things like a SenseCam to capture them. This is because of the effort of coping with the burdens of lifelogging were too great, compared with the “reward” it returns. However, we do not always know when a significant event will happen. Sometimes, they just felt lucky that a SenseCam was worn today because of some unexpected thing that happened. For example, one subject unexpectedly encountered an old friend whom he had not seen for years. Of course, he forgot to take out his camera to take a photo of the two of them because they had an exciting conversation. It was only after he went back home some time later, that he realized that although he did not take a photo, fortunately, his SenseCam recorded it for him, which made him very grateful that he had been wearing it.

The problem is: we cannot predict the chance of encountering interesting things that are worth capturing. Despite this, future studies can work towards reducing the burden and effort of doing lifelogging. If the capturing is seamless and unnoticeable by the lifeloggers themselves, maybe more people would be happy to accept lifelogging technology on a daily basis.

10.5 Suggestions for future lifelog capturing methods

In the course of using the prototypes lifelogs, I notice the importance and needs for capturing more information from the digital world and the physical world. I suggest the following.

1. **Information from the electronic world**

While using the prototype system, subjects usually found it disappointing that the original files could not be opened because they had either been changed or removed, or were on other devices rather than the computer on which they were using the prototype system.

In the prototype lifelog, most of the electronic items that had been encountered on computers were not stored in the lifelog dataset. Only the text extracted from the documents or emails was stored in the records in the SQL database. While some of the original files were moved or deleted, their textual information, although not in the original style and layout, remained in the lifelog database as plain text. This is generally fine for pure textual items such as text messages, tweets, or even most of emails and document. However, for multimedia items such as a video or software, the textual content stored in the database is of very little use. For example, for visited images or video, if the original files were removed, the textual representation of these items (usually only the filename) is almost useless. This type of problem is not unique for lifelog collections, but is common for many personal information collections and management tools. If all the original copies can be stored at a unique location, e.g. a lifelog device or on the cloud, this problem may be reduced. However, not every electronic item one encountered can be saved. For example, videos embedded in online webpages, or those streamed to play on a local client-side application usually have copyright restrictions and certain technologies to prohibit people from downloading them. In the online questionnaire that I conducted to explore the opinion of general public on lifelogs (Chen, 2012), some participants expressed their wish to record their activity playing computer games.

A computer screen recorder, which records the desktop activity in video form with both image and sound, could be a solution. The textual recording of activities (including attributes of activities and the textual content extracted from them) and copies of original files where available, should also be kept. In this way, the textual type of records could facilitate automatic management (e.g. indexing and searching) by computer programmes, as well as the re-use of textual content (e.g. for copying some texts). With the support of the textual information, the original files can be retrieved for re-using or transfer when needed in the future.

2. Video vs. Images

Video can usually preserve and convey more detail than static photos owning to its capture rate. Cameras can only takes images at certain intervals of at least a few seconds, and therefore usually miss some details. Besides, images are often blurred if the camera or target is moving. The reason that lifelog research, as well as many other desktop screen record tools choose to capture static images instead of videos is largely due to the concern of storage space. Although mainstream electronic storage space for personal computers has increased very rapidly in recent years, many computer users are from the ages of earlier 1 MB disks and 2 GB hard drives. The cost of several GB for an hour's video may strike many of them as excessive and drive them away from adopting video recording approach. However, I believe that with the continuing development of electronic storage and video compression techniques, limitations relating storage space should be removed in the near future.

Another reason that draws people towards using images instead of capturing videos is that images are generally easier to browse than videos using most current tools. It is generally easy to scan a hundred thumbnails of images in a few seconds. If the images were captured every half minute, then an hour's worth of images can be browsed quickly in a few seconds. If needed, users can select interesting images to take a closer look at more closely. With videos, even if they are played at a 20X real-time speed, an hour's video could take three minutes to view. Besides, rapid flashing (change of images in the sight of the viewer) could make the user's eyes feel uncomfortable. However, a simple modification to the video browsers may solve the problem. That is, to present key frames (images) of short episodes of video similar to the presentation of static image. In this way, videos can be browsed like browsing a collection of images. Keyframe based video browsing is not new, the technology has been under investigation since the 1990s for video retrieval applications and has developed over the years. Thus, it is desirable to use advanced video processing techniques to extract some representative keyframe images for easy browsing events in long-term personal lifelogs. However, despite on-going work, reliably identifying representative keyframes in videos remains the subject of ongoing technical investigation.

3. **Audio**

Audio is desirable information, especially during conversation. We have many episodes which have many images showing participants engaged in friendly chatting, but the images and the routine locations in which they are captured, are just not strong enough cues to remind us of any details of the conversation. Accurate automatic speech recognition techniques are obviously part of the solution. However, there are also significant privacy issues relating to spoken content. Failure to capture audio means that in additional to spoken material, the lifelogs do not retain sounds which are "evocable" and "emotional". Privacy concerns mean that capture of audio in PLLs will remain controversial unless all the audio records are under the control of the speaker him or herself, and either the voice or the transcripts are shared with people only with their permission, but it is not clear how this can be achieved in practical settings.

4. **Context**

To make Bluetooth or Wi-Fi signals more useful, it is desirable than they have meaningful names, or techniques to associate them with the wearer or location. Of course, many other sensors may be useful in addition to GPS and those used in these prototype lifelogs. For example, eye trackers embedded in the frames of glasses may be a good indicator for the precise information a person has seen. A wearable EEG, in addition to GSR sensors, may record brain wave to detect the user's intentions or what's happening in their mental world.

5. **Ownerships of the data**

In the context of this thesis, any data that is recorded by a lifelogger's devices "belongs" to this lifelogger. However, there are always issues regarding third party individuals. For example, people who were captured in a photo may want it to be seen by others or even the lifelogger. Accidently-recorded voices may contain highly confidential material, and must not be heard by anybody else. Indeed, either intelligent filter technology should be developed to allow people to "erase" unwanted images and other materials from other people's collections, or, as I discussed earlier, the information created by a person should be fully under his or her control even after it has been shared with others.

In short, content in continuous lifelogs are desirable, but the more advanced technologies are needed to make the capturing process weightless and seamless. More effort is needed on protocol of privacy of the collections so that more variety and detailed information can be included in personal lifelogs.

Chapter 11
Concluding Discussion and Future Work

11.1 Summary

In this thesis, I have described the motivation, development, and evaluation of a prototype system for long-term lifeloggers to access their own personal lifelogs (PLLs). Since there is little existing work describing work examining a user's information behaviour with a PLL information access system, I explored the potential processes and problems of information finding tasks for a PLL theoretically based on the existing literature on information seeking. I found that the user's memory plays a vital role in the information finding tasks in their PLLs. Therefore, I reviewed the psychology literature on human memory and conducted experiments to acquire a better understanding of questions regarding user's memory specifically related to finding tasks in PLLs. Based on existing theory and the findings of our studies, I designed and constructed a prototype system, called the iCLIPS LAB (lifelog archive browser). I conducted a user study based on the collections of three long-term lifeloggers, providing them the iCLIPS LAB system to access their own lifelogs with the prototype system. The findings from this study suggest that it is important to support users' memory for tasks of accessing their own PLLs.

This section reviews the questions explored in this thesis and my findings with respect to answering them.

11.1.1 Information finding Tasks in lifelogs

To develop a prototype system for accessing personal lifelogs, I needed to know what types of "things" people may want to find in a PLL. Since there are few examples of relevant information systems for accessing PLLs, nor is there a community of "users" of such systems, I could not explore the types of information needs or information seeking/finding tasks people may perform on an information system for PLLs based on existing work. Thus, I explored this topic through three steps:

In Chapter 2, I reviewed the potential application of PLLs, and discussed the role of information finding tasks in using these applications. I inferred the possible information needs and associated information finding tasks that correspond to some types of functions that people may want from their PLLS, including:

1) Events and facets of events for *recollecting*: helping people to recall specific information, facts encountered or experienced in the past, e.g. the date of an event.
2) Events for *reminiscing*: enabling users (lifeloggers) to reminisce on events which happened during the lifelogging period.
3) Computer items for *retrieval* and *re-use*: allowing users to easily find and open items in their "deposit", for example, finding an old document or information in an email.

Of course, there are also other types of information need, such as summaries of life patterns. In this thesis and my prototype system, this is treated as a by-product for other functions.

In Chapter 3, I reviewed models and existing studies on information seeking, finding and refinding behaviours, and proposed a knowledge-based framework for information finding. In this framework, I suggested that knowledge of "what" and "where" of a target significantly influences people's choices of strategies for an information finding task, including the conditions under which they would select their PLLs as the information source. According to this framework, there are 3 type of scenarios in which people may want to find information from within their personal lifelogs:

1) The information seeker (ISKer) has seen the exact information when using PLL system previously, and expects to find the same information again. She/he may trace the previous route in the PLL system to locate it.
2) The ISKer remembers encountering the target item, and knows that the PLL system captures and stores these types of encountered information or items, e.g. all their visited web pages.
3) The target is known to exist in their PLL system, e.g. photos, digital capture of events one has experienced, regardless of whether the ISKer has seen the target itself before, or whether they know exactly which item to look for.

Although I could not directly explore all the types of information needs and tasks in full PLLs with existing systems, I could explore part of the needs and tasks from people who looked for information that they have encountered before. I employed both diary study and online questionnaire approaches in our studies in Chapter 6, and concluded that there are the following types of information needs:

1) ***Specific piece of information***: small piece of information that the user needs to use directly. Examples include a phone number, an email address, or a reference of a paper.
2) ***Specific items (known-items)***: such as a specific document, email, application (software) and multimedia objects (e.g. YouTube video, images). These types of items

are usually used directly, transferred (given to others) or as a source for browsing and finding other information.

3) ***Specific source***: examples include a specific website, folder or document. These targets are usually a middle stage in an information-seeking task, from which the user usually proceeds to find other information in it. The information may or may not have been encountered previously.
4) ***Details from specific source***: examples include details of an article or exploring new information in a visited web page. This type of target is usually for a learning purpose.
5) ***Topic***: this type of target usually includes multiple pieces of information from multiple sources and is what one has seen before, but for which one cannot recall all the details. For example, all of my previously read papers on this topic, information of all recent movies, prices of the flights that I saw the other day.
6) ***Attributes of an event***: date, time or location of conducting some activity.
7) ***Information seen in the physical world***: these usually include a number, opening hours, a name of place and names of encountered people.
8) ***Details***: usually include details from conversations or talks, e.g. what was said in the meeting.
9) ***Physical Objects***: these are usually small objects that one often uses, such as a card or a key. In this case, images captured in lifelogs can act as evidence to show people where they left their key if it happened to be captured by the camera, or the images could act as memory cues to help the person recall the last time that they saw the key.

We concluded the following type of tasks based on our findings in Chapter 6. These types of tasks are used as a guide for generating tasks to evaluate our prototype system in the user study described in Chapter 8:

1) ***Look up tasks:*** for exact details (e.g. phone number, address, contact names), attributes of an object such as price, date and/or time of an event, etc.
2) ***Known-item search tasks:*** the targets of this type of tasks are usually specific objects that have been encountered previously, such as a file, email, specific article, or software, multimedia object (e.g. images or videos clips), online shopping items.
3) ***Exploratory tasks (topic learning):*** in these tasks, people usually do not have a clear idea of the exact information which they need. This type of task usually occurs after a known item finding task where the subject looks for some specific potential sources (e.g. a folder, a collection, a web site, or a document), and browses for interesting content.

4) ***Navigational tasks:*** The target is usually a website, folder or directory, or group of pages such as a person's home page or blogs. Targets of this type of task are seldom a final stop of a finding process. Any of the above three types of task, in particular an exploratory task, is usually followed after reaching the target, by navigating or browsing in it.

11.1.2 How to support user's memory in accessing PLLs

During my theoretical review in Chapter 3 and Chapter 4, I found that the user's memory plays a very important role in the process of accessing personal lifelogs using typical information finding approaches such as search and navigation. Memory is involved in:

1) Tasks: when the target information is not clear, people need to recall potential targets that could satisfy the information need of their current situation.
2) Generating search queries: people usually need to recall features or attributes of the targets (encountered information or events in the past) to perform the search.
3) Navigation and browsing: when items are organized into directories people need to recognize the correct directory and path towards the location where the target item is stored.
4) Browsing: when there are large amounts of data in a single directory or collection, users usually need to sort the results into a certain order. Therefore, it is important for the user to recall the approximate location of the target items in a list ordered by this aspect. For example, when events are ordered by time, users need to recall the approximate temporal location of the event, or recognize events adjacent to it.

Based on a better understanding of the mechanisms of human memory developed from my review in Chapter 4, I hypothesized that the following designs of an information system can support a user's memory in finding information in PLLs:

1) For search functions: people are more likely to retrieve a target from an IR system if they are allowed to generate a query using information from autobiographical context.
2) For navigation functions: Browsing and locating target would be more efficient if the user generally knows where it is. Therefore,
    a. A lifelog collection should be organized by where (city, country) and when (month, week, date), as people usually remember the where, what, when and who of events.
    b. Faceted browsing with extracting representative facets can improve effectiveness and efficiency of the finding tasks in PLLs.

3) Important events can act as reference points for users to more easily locate target events when the collection is ordered by time.

It is still not clear exactly which attributes or features from autobiographical context people tend to remember. Nor do I have a clear picture regarding which facets in personal lifelogs are representative. For the first question, I conducted empirical explorations through diary studies and online questionnaires as reported in Chapter 6. The findings suggest that among the rich varieties of attributes or related information that people tend to remember, the extension of files, name of contact who sent the email, country, location and part of week tend to be more reliably recalled.

In Chapter 7, I conducted a series of experiments to explore the types of facets that tend to be representative and the factors that make them good memory cues. I found that digital photos are particularly representative and tend to act as strong memory cues. In fact, any high quality photo (the content is clearly visible, not blurred) which is taken in an important event (or memorable day), or visited a few times is likely to be a good memory cue for a specific episode and or general event. Apart from this, the names of distinctive and significant locations, and titles of significant computer activities also tend to be representative memory cues for general events. Other information such as the month of an event, although not working alone as a good memory cue, largely improves the likelihood and accuracy of recognizing events represented by images and some other types of facets (such as name of city).

11.1.3 Prototype system

I developed a prototype system that provides the search options that people tend to remember, and automatically structures the PLL collection into events and directories of events. It also automatically selects images and extracts facets to represent time or location-based directories, landmark events and general events (for faceted browsing).

I conducted a user study for this prototype system, requiring three lifeloggers to access their own lifelog data with the system. I found it is particularly useful for finding events or photos. While it is also useful for finding electronic items or information encountered on computers, people usually have alternative approaches with which they find it easier to locate their targets. For example, when they know where a file is located, they would rather open that folder directly than search for it with the system. For some tasks, they would like more sophisticated tools if they could remember the information that these tools utilize to perform searching. For example, when the person remembers the subject and sender of an email, according to the comments of one of the subjects in the study, she could use her email client to filter the results by sender and sort the results by subject of email, she could then usually easily find it by browsing the sorted results. The main findings are listed below:

1) While keywords and attributes of electronic items such as item type (web, pdf) are still the most often used type of queries, queries from episodic context are also sometimes very useful. When looking for events or photos, subjects prefer to search by location, people, and more flexible part of time (e.g. month, year, and part of week) than using exact date range.
2) The hierarchical folder structure based on the location and time of events is useful for finding events and photos in events, but not very useful for finding computer items. This suggests that computer items or information encountered on computers are not mentally categorized by date / time or the location of the person.
3) Cues such as key images, representative locations or computer activities were suggested to be useful for filtering results.

11.2 Contributions of this thesis

To summarize, this PhD work has the following contributions:

- Explored the potential user needs of personal lifelogs from a wider population
- Proposed models for knowledge-based information finding behaviour, and applied it to predicting potential tasks, problems and issues in accessing personal lifelogs, which leads to my proposed a guideline for designing user-friendly information system for accessing personal lifelog
- Further investigated the role of user's memory in finding, refinding, and accessing PLLs, and proposed guidelines for memory-friendly search- interface design.
- Investigated the experiences of long-term lifeloggers in terms of the capture and use of lifelog data in their daily lives
- Developed a prototypes PLL system which can be used to explore requirements for an effective PLL search system by conducting user studies related to access from personal lifelogs

11.3 Future work

This work has developed a prototype system to support active information seeking in one's own PLLs. Of course, this is only a preliminary step to supporting information seeking in PLLs. Further work could be done to make this prototype compatible to a wider range of formats of current lifelogs collections, especially the growing amount of lifelog data captured by apps on smartphones. Such a system could be used as a tool for further explore user needs from lifelogs, and information behaviour with one's own lifelogs. As was discussed earlier, the ideal system could automatically detect a user's needs, and provide what they want. Of course, achieving this type of functionality is very difficult. One major step to realize this is to develop advanced machine learning algorithms to predict behaviour patterns for different types of situation that can be learnt from detailed PLL records of previous activities.

While PLLs have been found to be helpful to trigger episodic memory, it is still unclear how they can support the attenuation of unpleasant or traumatic memories. In Chapter 4, I suggested that traumatic memories may be positively distorted by re-enforcing the links between pleasant memories and elements of traumatic memories, so that previously strong cues for traumatic memory could gradually trigger more of the pleasant experiences instead. Of course, while practical investigation is needed to examine this suggestion, ethical concerns would pose challenges for design and conduct of such a study

In addition, there can be many more types of content in future personal lifelogs with the development of new technologies which capture and manipulate information relating to the daily lives of individuals. There are likely to be many new applications making use of such information which are not included in this thesis. For example, low level features of PLL data from a reasonable size of population can be utilized for social research, e.g. to explore how people in the world interact with each other, to detect interesting events in a crowd, to find new trends, or examine the butterfly effect of an individual's action.

Finally, the paradox between the level of detail captured in a PLL and the risk of privacy leaks is a hugely important issue in the field of lifelogging. Privacy concerns relate not only to the lifelogger him or her self, but may also involve third parties who are captured in a photo or an audio recording containing their voice and so on. Therefore, while it is desirable that new capture technologies or data processing methods can be introduced into lifelogs, it is worth thinking about how a protocol might be setup relating to the types of information that could be captured, and how and where they should be stored and controlled.

Appendix I. Questionnaire for diary study

The follow lists the textual content of the questions and options for the questionnaire used in the diary study. The format is slightly different from that is displayed on the web. The dynamic functions such as jumping to different questions based on selected option are not possible to be shown on this document.

Diary Entry: Information Refinding

You said you wanted to find some information, which you encountered on your computers sometime ago. Please answer the following questions for this diary entry

1. What did you look for?

____

2. Which category does it belong to?

- ○ A piece of information
- ○ A specific email
- ○ A specific file
- ○ A text message
- ○ A video / image/ music online
- ○ A specific web page
- ○ Other

3. What were you doing at that moment (when you had the intentions of finding this information)?

- ○ Working on relevant topic on computer
- ○ In a conversation about a related topic
- ○ I was not doing anything that is related to the information needs
- ○ Others please specify ____________________

4. How did you locate it (information or item)?

- ☐ Asked other people
- ☐ Browsed possible directories on my computer
- ☐ Searched on my computer
- ☐ Searched online for "any" article or resource that matches certain criteria
- ☐ I tried to look for it but did not find it
- ☐ I did not even TRY to find it
- ☐ Other please specify____________________

5. Did you find the specific items /information that you encountered previously?

☐ Yes, I found the exact item
☐ Yes, but a different version
☐ No, I found a similar one or another version of it
☐ No, I used something else
☐ No, I did not find anything

6.Which of the following is a more proper statement?

o "I encountered this item /information several time"
o "I only encountered this item /information once"
o "I used /visited it very frequently during a certain period"
o Other please specify

7. Where did you encounter it previously?

☐ Online
☐ In an email
☐ Someone told me in IM (e.g. Gtalk)
☐ I created it
☐ Somewhere on my computer
☐ I don't remember
☐ Others please specify____________________

8. Why do you want to find this item this time?

☐ Others require it

☐ I need to work on it

☐ I need certain part of it to continue my work

☐ I need to learn new information from it

☐ Others (please specify)___________________

9. Please what do you remember about it? (e.g. where and when you encountered it previously, what it looks like)

---

10. If it is information in an email, a document or on a webpage, what do you remember about that email, document, or webpage?

☐ Some exact text (words) in it
☐ Some visual elements in it
☐ Visual layout of the window
☐ The file name
☐ Where it is (URL, or the directory it is in)
☐ The name of the person who send you

- ☐ The email address which was used to send you the email, or which you sent to
- ☐ User name (or screen name) of the person who sent you the information or you sent to
- ☐ If you searched this online, the words you used to search
- ☐ None of the above
- ☐ Others________________________________

11. How long ago was the last time you encountered it (before you find it this time)

- ☐ Just now
- ☐ Recently (less than a week ago)
- ☐ Up to a month ago
- ☐ Up to 6 months ago
- ☐ Up to couple of years ago (but within the same life stage as you are now. e.g. in college)
- ☐ Several years ago
- ☐ I don't remember at all
- ☐ Other please specify _____________

12. What detail do you remember about the previous encountered

- ☐ year(s)
- ☐ month(s)
- ☐ date(s)
- ☐ day (s)
- ☐ part of the week (weekend, weekdays)
- ☐ time (e.g. around 5.00pm)
- ☐ part of the day (e.g. morning, dinner time, late night)

13. Were you in a country, region or city which you seldom go to?

- o Yes, in a different country
- o Yes, in a different region (County, Province, states), but in the country I reside
- o Yes, in a different city, but in the region I reside
- o No, but I'm in an area of the city I seldom go to (go to 13)
- o No, I was at one of my regular locations (go to 14)
- o I don't remember where I was (go to 14)

14. Do you remember the exact name of the country, region and city were you were in at that time?

- ☐ Yes, I remember the name of the Country
- ☐ Yes, I remember the name of the Region
- ☐ Yes, I remember the name of the City
- ☐ I don't remember the above, but I know where it is on the map
- ☐ I cannot remember any of the above

15. What do you remember about the location?

- ☐ The exact address e.g. street name
- ☐ I can recognize on the map
- ☐ I remember some landmarks near the location , e.g. a pub, station
- ☐ I don't remember any

16. For the last time or last well-remembered occasion that you encountered it, which of the following information do you remember?

- ☐ Names of people near you
- ☐ The Weather
- ☐ Light status (dark/ light)
- ☐ Your emotional status (e.g. happy, excited, depressed)
- ☐ I can't remember any of the above

17. If you were using your computers or mobile phones around that time, do you remember:

- ☐ The name of the application you were using around(inc. shortly before, after) that time
- ☐ The name of the items you were using around(inc. shortly before, after) that time, e.g. name of files or web pages, subjects of emails
- ☐ I can't remember

18. As for the period around last time you encountered it, which of the following do you remember?

- ☐ What was happening in the world, e.g. world cup; Or what were the popular news?
- ☐ Focused computer activities: e.g. working on an assignment, searching information about...
- ☐ Other personal events, e.g. holiday in Spain, preparing for a party
- ☐ None of the above

19. Is the topic of the focused computer activity related to any of the following?

- ☐ Public events
- ☐ Personal events
- ☐ Others please specify

20. How long did the focused computer activity last.

(Please select the most approximate option.)

- o A couple of days
- o A week
- o Couple of weeks
- o A month
- o I can't remember
- o Others please specify

21. For that personal event, do you remember the following information?

- ☐ People involved (attended)
- ☐ Location
- ☐ Other (please specify)______________

Appendix II. Questionnaire for online survey (refinding)

The following text only represents the textual content of the questions and options used in the online questionnaire. Some dynamic functions are not possible to be presented here, e.g. random ordering of options, jumping to different questions based on choice of previous question, and minimum time for different page.

This questionnaire aim to investigate your memory of previously encountered information. If in the last hour, you have looked for some information that you have encountered before, you are welcome to participate in this study. Below are some examples of finding previously encountered information:

" I want to find the phone number for a colleague. I'm sure that I saw her email address on the emails she send me. So I'm looking for the emails from her "

" I'm planning to go to town, and buy something in a shop, but don't remember the opening hours. I remember that I've seen it outside the shop sometime ago. "

" I want to know where and when I saw this scene previously. "

You can feel free to hide any information which has privacy concerns, but your answers should be true to what you know.

1. Did you look for any previously encountered information in the last hour?

- o Yes
- o No

2. What did you look for? (Please describe the type of information you looked for, why you looked for it.)

____

3. Which category does it belong to?

- o A piece of information
- o A specific email
- o A specific file
- o A text message
- o A video / image/ music online
- o A specific web page
- o Other (Please specify)____________________

4. What were you doing at that moment (when you had the intentions of finding this information)?

- o Working on relevant topic on computer
- o In a conversation about a related topic
- o I was not doing anything that is related to the information needs
- o Others please specify ____________________

5. How did you locate it (information or item)?

- ☐ Asked other people
- ☐ Browsed possible directories on my computer
- ☐ Searched on my computer
- ☐ Searched online for "any" article or resource that matches certain criteria
- ☐ I tried to look for it but did not find it
- ☐ I did not even TRY to find it
- ☐ Other please specify___________________

6. Did you find the specific items /information that you encountered previously?

- ☐ Yes, I found the exact item
- ☐ Yes, but a different version
- ☐ No, I found a similar one or another version of it
- ☐ No, I used something else
- ☐ No, I did not find anything

7.Which of the following is a more proper statement?

- o "I encountered this item /information several time"
- o "I only encountered this item /information once"
- o "I used /visited it very frequently during a certain period"
- o Other please specify
- o No, I haven't encountered it before

8. Where did you encounter it previously?

- ☐ Online
- ☐ In an email
- ☐ Someone told me in IM (e.g. Gtalk)
- ☐ I created it
- ☐ Somewhere on my computer
- ☐ I don't remember
- ☐ Others please specify____________________

9. Why do you want to find this item this time?

- ☐ Others require it
- ☐ I need to work on it
- ☐ I need certain part of it to continue my work
- ☐ I need to learn new information from it

☐ Others (please specify)___________________

10. Please what do you remember about it? (e.g. where and when you encountered it previously, what it looks like)

11. If it is information in an email, a document or on a webpage, what do you remember about that email, document, or webpage?

☐ Some exact text (words) in it
☐ Some visual elements in it
☐ Visual layout of the window
☐ The file name
☐ Where it is (URL, or the directory it is in)
☐ The name of the person who send you
☐ The email address which was used to send you the email, or which you sent to
☐ User name (or screen name) of the person who sent you the information or you sent to
☐ If you searched this online, the words you used to search
☐ None of the above
☐ Others________________________________

12. How long ago was the last time you encountered it (before you find it this time)

☐ Just now
☐ Recently (less than a week ago)
☐ Up to a month ago
☐ Up to 6 months ago
☐ Up to couple of years ago (but within the same life stage as you are now. e.g. in college)
☐ Several years ago
☐ I don't remember at all
☐ Other please specify _____________

13. What detail do you remember about the previous encounter?

☐ year(s)
☐ month(s)
☐ date(s)
☐ day (s)
☐ part of the week (weekend, weekdays)
☐ time (e.g. around 5.00pm)
☐ part of the day (e.g. morning, dinner time, late night)

14. Were you in a country, region or city which you seldom go to?

- Yes, in a different country
- Yes, in a different region (County, Province, states), but in the country I reside
- Yes, in a different city, but in the region I reside
- No, but I'm in an area of the city I seldom go to (go to 13)
- No, I was at one of my regular locations (go to 14)
- I don't remember where I was (go to 14)

15. Do you remember the exact name of the country, region and city were you were in at that time?

- ☐ Yes, I remember the name of the Country
- ☐ Yes, I remember the name of the Region
- ☐ Yes, I remember the name of the City
- ☐ I don't remember the above, but I know where it is on the map
- ☐ I cannot remember any of the above

16. What do you remember about the location?

- ☐ The exact address e.g. street name
- ☐ I can recognize on the map
- ☐ I remember some landmarks near the location , e.g. a pub, station
- ☐ I don't remember any

17. For the last time or last well-remembered occasion that you encountered it, which of the following information do you remember?

- ☐ Names of people near you
- ☐ The Weather
- ☐ Light status (dark/ light)
- ☐ Your emotional status (e.g. happy, excited, depressed)
- ☐ I can't remember any of the above

18. If you were using your computers or mobile phones around that time, do you remember:

- ☐ The name of the application you were using around(inc. shortly before, after) that time
- ☐ The name of the items you were using around(inc. shortly before, after) that time, e.g. name of files or web pages, subjects of emails
- ☐ I can't remember

19. As for the period around last time you encountered it, which of the following do you remember?

- ☐ What was happening in the world, e.g. world cup; Or what were the popular news?
- ☐ Focused computer activities: e.g. working on an assignment, searching information about...
- ☐ Other personal events, e.g. holiday in Spain, preparing for a party
- ☐ None of the above

20. Is the topic of the focused computer activity related to any of the following?

- ☐ Public events
- ☐ Personal events
- ☐ Others please specify

21. How long did the focused computer activity last.

(Please select the most approximate option.)

- o A couple of days

- A week
- Couple of weeks
- A month
- I can't remember
- Others please specify

22. For that personal event, do you remember the following information?

- ☐ People involved (attended)
- ☐ Location
- ☐ Other (please specify)______________

23. Please select you age group:

- ☐ <16
- ☐ 16-25
- ☐ 26-35
- ☐ 36-45
- ☐ 46-55
- ☐ 56-65
- ☐ >65

24. How often do you travel to another city or region?

- ☐ More than once a week regularly to one or two fixed places
- ☐ More than once a month regularly to one or two fixe places
- ☐ More than once a year regularly to one or two fixed places
- ☐ More than once a week regularly to various places
- ☐ More than once a month regularly to various places
- ☐ More than once a year regularly to various places
- ☐ I seldom travel to other places

25. What's your main purpose of using a computer?

- ☐ Work
- ☐ Entertainment
- ☐ Social networking
- ☐ Others _____________

26. Which of the following is more like you?

- ☐ I seldom organize my files on my computer
- ☐ I organize the files on my computer regularly
- ☐ I occasionally organize my files on my computer, but very thoroughly every time.

Appendix III. List of Publications

This Ph.D. research was carried out as part of the Science Foundation Ireland Research Frontiers Programme 2006 funded iCLIPS project. Further details of the iCLIPS project are available at: http://www.cdvp.dcu.ie/iCLIPS/. Part of the work reported in the thesis has been published or presented in peer-reviewed conference or workshops:

The work I reviewed in Chapter 2 (section 2.3.3.2) is reported in the paper:

> Chen, Yi and Jones, Gareth J.F. (2012) *What do people want from their lifelogs?* In: 6th Irish Human Computer Interaction Conference (iHCI2012), 20-21 June 2012, Galway, Ireland.

The work I reported in Chapter 6 have all been published, mainly in the paper:

> Chen, Yi; Gareth, Jones. (2013). *Utilizing episodic context in search of personal information archives* . In proceeding of 7th Annual Irish HCI Conference

The exploratory studies reported in Chapter 7 (Section 7.2.3) has been published in:

> Chen, Yi and Kelly, Liadh and Jones, Gareth J.F. (2010) *Supporting episodic memory from personal lifelog archives using SenseCam and contextual cues.* In: SenseCam Symposium 2010, 16-17 September 2010, Dublin, Ireland.

> Chen, Yi and Jones, Gareth J.F. (2009) *Exploring Digital Elements for Visualizing Time in Personal Information Re-finding.* In: 3rd Irish HCI Conference, September 2009, Dublin, Ireland.

The following publications arrive wholly or partially out of this Ph.D. research. However, much of their content does not appear in this thesis, rather they were explorations conducted in this space prior to writing the thesis and conducting thesis experiments.

2011

> Chen, Yi and Jones, Gareth J.F. and Ganguly, Debasis (2011) *Segmenting and summarizing general events in a long-term lifelog.* In: The 2nd Workshop Information

Access for Personal Media Archives (IAPMA) at ECIR 2011, 18-21 April 2011, Dublin, Ireland.

Jones, Gareth J.F. and Chen, Yi (2011) *A strategy for evaluating search of "Real" personal information archives.* In: The Evaluating Personal Search Workshop at ECIR 2011, 18-21 April 2011 , Dublin, Ireland.

2010

Chen, Yi and Jones, Gareth J.F. (2010) *Augmenting human memory using personal lifelogs.* In: AH 2010 - 1st Augmented Human International Conference, 2-3 April 2010, Megève, France. ISBN 978-1-60558-825-4

Chen, Yi and Kelly, Liadh and Jones, Gareth J.F. (2010) *Memory support for desktop search.* In: Desktop Search Workshop at SIGIR 2010, 23 July 2010, Geneva, Switzerland.

2009

Chen, Yi (2009) *Exploring Memory Cues to Aid Information Retrieval from Personal LifeLog Archives.* In: 23rd BCS Conference on Human-Computer Interaction, 1-5 September 2009, Cambridge, U.K..

Chen, Yi and Jones, Gareth J.F. (2009) *An Event-Based Interface to Support Personal Lifelog Search.* In: HCI International 2009, July 2009, San Diego, U.S.A..

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Kelly, Liadh and Chen, Yi and Fuller, Marguerite and Jones, Gareth J.F. (2008) *A study of remembered context for information access from personal digital archives.* In: IIiX 2008 - 2nd international symposium on Information interaction in context, 14-17 October 2008, London, UK. ISBN 978-1-60558-310-5

Chen, Yi and Jones, Gareth J.F. (2008) *Integrating memory context into personal information re-finding.* In: Second Symposium on Future Directions in Information Access (FDIA 2008), September 2008, London, U.K,.

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