Capture & Access Lifelogging Assistive Technology for People with Episodic Memory Impairment

Matthew L. Lee & Anind K. Dey
Human-Computer Interaction Institute
Carnegie Mellon University
{mllee,anind}@cs.cmu.edu

Abstract

Capture and access lifelogging technologies use a combination of wearable and environmental sensors to record people's experiences and then make the data available for subsequent review. These types of technologies can help people with episodic memory impairment (such as Alzheimer's disease) regain an awareness of the important experiences of their life and reduce the burden they impose on their caregivers. However, lifelogging technologies can produce an overwhelmingly large amount of information (in the form of photos, audio, videos, and sensor logs) that is too difficult for people with cognitive impairment to review. Our approach focuses designing systems that select and present only lifelog data that are the most effective memory cues for the person with memory impairment. To design such systems, we conducted two field studies to investigate the strategies people use to compensate for their episodic memory impairment and also what kinds of information are the most effective memory cues. Based on the findings from these studies, we discuss the design of a capture and access lifelogging system that passively records people experiences, selects out the most effective cues, and presents these cues to the person with memory impairment in an engaging cueing interaction that allows them to exercise their memory abilities.

Introduction

We depend on our episodic memory to help us remember our recent experiences. We can remember having a good chat with a close friend last week and can pick up where the conversation left off. We can remember buying milk and bananas from the market in the morning so we do not have go out and buy them again in the afternoon. We can remember having dinner at a new restaurant and can relive the experience of how delicious the food tasted by simply thinking of it. We remember spending an evening reading a favorite book in the safety and comfort of our home.

Recent experiences provide a rich, intimate source of information for making important decisions, planning out our future actions, thinking about the pleasant experiences of our lives, interacting meaningfully with others, and living in comfort and security. However, Alzheimer's disease (AD) subtly and progressively robs people of their ability to remember their recent experiences. One of the first symptoms of the disease is recent episodic memory impairment. Episodic memory is the memory of specific experiences that you can replay in your head, in contrast to semantic memory, the memory of facts about the world. AD affects not only the individual with the disease but also his caregiver, particularly family caregivers who provide support at home. Providing care for people with AD can lead to depression and other mood disorders, as it can be more emotionally and physically demanding than caring for other types of diseases that afflict the elderly [1, 18].

Technology can be used to support recent episodic memory. In particular, capture and access lifelogging technology is a natural fit for people with episodic memory impairment. Normally, people without memory impairments perceive their experiences through their senses, and their brains are able to record a representation of their experiences and make them available for reflection. People with AD, however, have cognitive impairments that result in faulty recording and thus retrieval of their experiences. Capture and access systems can perceive the user's experiences, record a representation of them, and make them available for subsequent user review. With this approach, we can capture effective memory cues that can assist the person with memory impairment to not only recall but also mentally relive the experience.

Background

Approximately 18 million people worldwide have been diagnosed with Alzheimer's disease, with this number expected to double within the next 20 years [2]. One out of every ten people over the age of 65 in the United States and half over 85 have been diagnosed with AD [8]. Recent episodic memory impairment can lead to feelings of

uncertainty, irritation, frustration, and fear in the person with Alzheimer's disease [20]. Living with constant uncertainty about previous experiences can lead to a frightening loss of control in people's lives. Increasingly dependent on a caregiver to help make simple decisions, they are forced to relinquish control of their life. They can become easily depressed as they struggle with failures due to the uncertainty and the loss of control that pervades their lives [17]. Recent episodic memory is also an important contributor to a person's sense of self. These memories allow people to reflect on their life and perceive themselves living and experiencing reality continuously through time [7].

Non-technical Solutions

Existing solutions that people with AD use to remind themselves of their recent experiences include: lifelogging memory aids, support from caregivers, and following routines. Support groups often suggest keeping a *lifelog*, a written journal or scrapbook of experiences as a memory aid so people with AD can look back on it and remember what they did [24]. However, the additional effort of writing things down or taking photographs with a camera can make this unappealing, especially for people who may not fully acknowledge their memory problems. Furthermore, representing experiences simply as written text may not be sufficiently rich enough to trigger an episodic recollection of the experience. Other obstacles for the use of memory aids are that people must *remember* to use them and *want* to use them [5]. People have trouble remembering to carry their memory notebook with them and, even when they do, may not want to write in it because it draws attention to their problems [9].

Caregivers also provide memory support for people with AD. They provide cues for remembering previous experiences and reminders for future tasks. We describe this process of how the caregivers provide cues and breakdowns that occur in the description of the results of our initial ethnographic field study discussed later in this paper. However, these responsibilities place great strain on them as they must repetitively support the increasing cognitive needs of episodic memory impairment in addition to the physical needs of normal aging. As a result, caregivers, especially those who are less emotionally capable of coping with a declining loved one, may also develop depression and caregiver burnout [4].

Following routines helps people better remember their experiences by essentially making all their experiences the same. With routines, people with AD do not have to rely on their episodic recollections of their experiences but can instead exploit the regularity of their activities to recall what they normally would have done. However, following structured routines requires a sacrifice in flexibility. Learning new routines may also be difficult for people with AD because of their cognitive limitations on learning [10].

Most existing forms of memory support aim to either substitute or completely replace the individual's memory. Caregivers can vividly describe the complete details of a recent experience so that the individual with memory impairment does not need to rely on their own memory at all. Routines can allow individuals to rely on their semantic or procedural memory instead of their episodic memory. Most existing non-technological techniques do not provide adequate opportunities for the person with AD to exercise their residual memory abilities to prevent further decline. Next, we discuss our technological approach and how it can benefit people with episodic memory impairment.

Approach

Capture and access technologies are a natural fit for people with AD and their episodic memory impairment. Capture and access systems can perceive the user's experiences, record a representation of them, and present them for subsequent user review. Technologies such as sensors [13] and natural input interfaces [26] are making it easier to capture people's experiences *more completely* and *more unobtrusively* than existing non-technological memory aid solutions can. For example, the Microsoft SenseCam system [13] uses a wearable camera to automatically capture digital photographs of the wearer's experiences from a first-person perspective. Reviewing photographs captured by SenseCam enabled a patient with episodic memory impairment remember her experiences better. The Personal Audio Loop system [12] explores how to record audio continuously using a mobile phone and to make the last 15 minutes of perceived sounds available to users. The Cook's Collage [21] was found to help people keep track of where they are in multi-step tasks such as cooking using real-time photographs of actions taken during the cooking task. People with episodic memory impairment such as Alzheimer's disease can benefit from the potential provided by capture and access technologies.

Our approach focuses on designing, building, and evaluating an intelligent capture and access memory aid system that:

1. *Passively captures* the content and context of people's experiences through wearable and environmental sensors such that memory-impaired individuals need not remember to explicitly initiate capture of their experiences.
2. *Selects and presents only the most effective memory cues* (both automatically and with the help of the caregiver) so as not to overwhelm the cognitively-impaired user with too much lifelogging data.
3. *Provides an interactive, engaging,* and *cognitively-stimulating interaction* that maximizes the opportunities for memory-impaired users to exercise their residual memory abilities and to activate their own recollection and mentally relive the original experience instead of simply passively being told about the experience.
4. *Reduces the caregiver's burden* to repetitively provide memory cues for person with memory impairment.

In order to design such a system, we conducted two formative field studies to understand the needs, abilities, and practices of people with episodic memory impairment and their caregivers. The first field study was an observational ethnographic study of people in the various stages of Alzheimer's disease to identify what kinds of experiences are difficult to recall, how they relied on memory aids, and how their caregivers provided support for recent memory. From our observations, we highlight opportunities for capture and access technologies to provide cognitive assistance to people with episodic memory impairment and their caregivers. The second field study explores what types of information people with episodic memory impairment consider to be good memory cues, that is, those that help trigger a mental reliving of the original experience.

Based on the findings of these two formative field studies, we will design and develop an intelligent capture and access system that uses wearable sensors to record photographs, ambient audio, and location information. This information will then be processed automatically by the system based on a combination of predefined heuristics and supervised learning based on input from the caregiver to suggest which pictures and audio may be good cues to help trigger recollection of the original experience in the person with memory impairment. These suggestions along with the all the lifelog data will be shown to the caregiver through an interface that allows the caregiver to select out the best cues. Our approach will leverage not only computer-automated techniques but also the expertise of the human caregiver to determine the best set of cues for the particular experience. The caregiver will use this interface to construct a slideshow narrative of the experience using the pictures, recorded audio, and any annotations that may help the person with memory impairment recognize and recollect the experience. This annotated slideshow narrative will be made available to the person with memory impairment through a simple tablet-style viewer device that is easily picked up like a book or photo frame to be reviewed. The viewer will not simply playback the slideshow like a movie but rather engage the user in a cueing process where the user has opportunities to pause and engage their own recollection before receiving more assistance through more detailed cues.

We will evaluate this capture and access system using a combination of field deployments and controlled laboratories studies to understand how it helps individuals with memory impairment remember their experiences better and how it can contribute to changing the burden on the caregiver and the dynamic between the caregiver and the memory-impaired care recipient. Before discussing the details of this design and the evaluation, we first describe the formative studies that helped inform our design choices.

Investigating the Memory Practices of People with AD

We conducted a formative ethnographic study to better understand the everyday memory practices of individuals with Alzheimer's disease and their caregivers. We wanted to identify what strategies they used to help compensate for episodic memory impairment, the role of the caregiver, and how these forms of support break down. We used an observational ethnographic approach where we conducted semi-structured interviews with five participants in the various stages of AD and their family caregivers and also observed them for two consecutive days as they carried out their normal routines in their homes and when they went out. We also attended caregiver support groups to gain additional perspectives on our investigation.

One finding from our field study was that people with AD were generally less aware of the extent of their memory problems. Having an awareness of memory limitations means knowing when to rely on one's own memory account and when it is necessary to rely on external support to recall an accurate account of past experiences. Clinical findings have shown that a lack of awareness of functional and memory deficits can lead to poorer patient outcomes

as well as higher caregiver burden [19]. We found that the people with memory impairments always claimed to have better memory abilities than what the caregivers described, often attributing memory failures to simply getting older. Situations where there is a difference between what people recall and what they actually experience give people an opportunity to become more aware of their memory limitations. Capture and access technology can help people become *more aware* of their limitations in episodic memory by providing them with an objective, veridical account of what they actually experienced. By becoming more aware of their actual limitations, people can more accurately determine how confident they can be in their cognitive abilities. Confidence is an important element of maintaining the self, but overconfidence can lead to repeated failures. There is an equilibrium point between hope (relying on one's own abilities) and despair (relying on external support) where people can operate to achieve the best outcomes [6]. The objective account provided by capture and access technology can allow people with memory impairments to self-assess their memory abilities and learn their limitations as the disease progresses.

However, there may be situations where gaining an awareness of limitations may lead to poorer outcomes. In the caregiver support groups we attended, caregivers of people in the more severe stages of AD often shared about telling "loving lies," where the caregiver agrees with the person's false reality because telling them the truth could result in unnecessary worry and discomfort. In later stages of AD, people with memory impairment may react negatively to learning about their own memory limitations. To that end, capture and access technology can also be used to make people *less aware* of their limitations. The representation reviewed by the person with memory impairment does not have to match what really happened, but rather it can be manipulated or processed by the caregiver to reinforce (possibly incorrect) perceptions of reality to make the person with memory impairment feel more comfortable. Thus, capture and access techniques can be used to help people manage their awareness of their memory abilities and limitations by providing faithful and/or comforting representations of past episodes.

We found that people with memory impairment mainly relied on the caregiver who often mediated their use of memory aids. For example, a common non-technological memory aid used was the calendar. However, our memory-impaired participants did not actively maintain or refer to the calendar to keep themselves updated. Instead, they relied almost entirely on the caregiver to remind them of what they had done and what was coming up. This illustrates the point that memory aids, while initially intended for the person with memory impairment, may ultimately require the intervention of the caregiver to operate it themselves or supervise or remind the person with memory impairment to use it. Therefore, the needs of the caregiver must be considered when designing a memory aid system. Operating the system should not impose a greater burden on the caregiver than the amount of burden it relieves. Caregivers mediate the use of memory aids so the benefits of these aids need to outweigh the increased burden they impose on the caregiver.

Caregivers not only mediate the use of memory aids, but they themselves also act as a memory aid for people with memory impairments. To help recall past experiences, we found that caregivers engaged people with memory impairments in a cueing dialog where the caregiver provided cues, small facts about an experience that help recall more of the memory. Caregivers usually reveal cues in a piecemeal fashion until the person with memory impairment can recall the rest of the episode with their own memory. The person with memory impairment responds to the cue by either recognizing it or not. The cueing process continues as the caregiver proceeds to give cues until the memory is recalled at an adequate level of detail. Caregivers shared that the people with memory impairment often find it rewarding when they receive just the right amount of cueing assistance so that they can recall most of the memory themselves. In fact, there is clinical evidence that engaging in such cognitively stimulating mental exercise can slow the progression of cognitive decline [25]

However, caregivers do not always complete the cueing process. We observed instances of *cue shortcutting* where caregivers gave only one or two cues, and when the person with memory impairment was not able to come up with the rest of the memory, the caregiver gave up and just told the person with memory impairment all the necessary details of the experience. Instead of going through the process of incrementally providing cues to aid recollection, caregivers prematurely terminated the cueing process, eliminating the opportunity for people with memory impairment to recollect the memory by thinking hard about the cues. Overburdened caregivers may be motivated to shortcut the cueing process because they are unable to think of appropriately rich, salient, or specific cues to trigger recollection. They may also be impatient and not want to take the time and effort to engage the person with memory impairment in a laborious cueing process that may have been repetitively performed many times before [16]. This leads to the question of whether technology can assist the overburdened caregiver in identifying and patiently presenting good cues. We conducted a second study to investigate what are good cues for triggering memory recollection to understand the role of technology in supporting memory impairment.

Identifying Good Memory Cues

We conducted a study to identify the best cues for triggering memory recollection. Current lifelogging systems use various capture techniques to automatically record memory cues such as digital photography [13, 15], video and audio recordings [14] [22]. These systems record an overwhelmingly large amount of data that is daunting to review. The caregiver is burdened with reviewing all the captured data and selecting out the best cues to present to avoid cognitive overload in the person with memory impairment. Automated summarization techniques [3] such as key frame extraction for videos and sets of images are helpful at reducing the amount of data to review. However, with an understanding of what good cues are, these extraction techniques can be better designed to automatically select good cues and reduce the burden on the caregiver. We can also understand where technological methods still fall short and when we must then rely on the person with memory impairment or their caregiver to select good cues.

Our participants included five memory-impaired elders and their caregiver and four memory-unimpaired elders and their spouse. They went on personally significant experiences wearing a SenseCam, a small wearable digital camera worn at chest level that automatically takes a snapshot every two minutes. After each experience, we had the participants sort through the photographs (Figure 1) to select out the photos that best helped them mentally relive the experience. The participants iteratively selected half the photos in the set, choosing those photos in each iteration that were better cues. The sorting continued until the chosen set contained only one photo that best represented the experience. This photo sorting task provided a tangible way for participants to articulate what are good memory cues. Based on the participant's descriptions of each photo from the think-aloud sorting task, we coded each photo with the information contained in the photo and any other details of the experience it reminded the participant of. From these sorted sets of coded photos, we can determine the types of information that are particularly good cues for memory recollection.

Figure 1. Participants sorted photos according to how well they reminded them of the experience.

We were able to categorize the cues in each photo into four categories: Person, Object, Place, and Action. A *Person* cue is a specific person(s) (*e.g.*, daughter, grandchildren) that was highlighted as important for their recollection. An *Object* cue is some significant object (*e.g.*, birthday cake, stained glass window). A *Place* cue describes the physical setting of the experience (*e.g.*, the façade of a visited store, the dining room). An *Action* cue describes some motion or physical action that may involve people, objects, and places (*e.g.*, driving home, playing the piano).

Based on the last few photos selected for each experience in our study, we can characterize each experience in terms of its majority cue type, for these cues are particularly well-suited to help individuals recollect the experiences. *People-based* experiences such as family reunions and weddings are best cued by the people interacted with. *Object-based* experiences such as a museum visit and a shopping trip are cued by the objects encountered. *Place-based* experiences such as a vacation to a new town are cued by the places the individual went. *Action-based* experiences such as attending a church performance and rehearsing a play are best cued by referencing the actions that occurred. Good cues for a particular experience need to match their type with what is expected from the experience. From a technology design perspective, knowing the type of experience can help determine what types of cues are most appropriate to be captured and presented to best support recollection of the experience. In other words, instead of weighing all cue types equally for all experiences, systems should automatically highlight or extract cues of a particular type that will most likely represent the important aspects of the experience and be good cues for recollecting the experience.

We identified one critical characteristic of good memory cues: *recognizability*, and two factors that contribute to greater recognizability: *distinctiveness* and *personal significance*. At a fundamental level, memory cues are only effective if they can be recognized as part of the original experience. Even in our first observational study, we noticed that the caregiver's verbal cues were effective at helping the person with episodic memory impairment

recollect more from the experience *only if* the person with episodic memory impairment first recognized the cue and could mentally situate themselves in the original experience. In our subsequent photo sorting study, we noticed that participants (both with and without memory impairment) often discarded or skipped photos that they did not recognize from the original experience.

Participants chose distinctive photos that uniquely represented the experience, so that when they looked at the photo, it would cue a recollection of that unique experience and not some other experience. Distinctive details, especially those different from people's normal expectations, are usually more memorable than less distinct details. This is consistent with psychological understandings of the distinctiveness effects in memory [23]. Good cues for recollecting the experience also tend to hold more personal meaning for the individual. Personal significance makes a cue more effective in triggering memory recall because it makes the cue more recognizable and memorable, a basic requirement of an effective cue.

Recognizability, distinctiveness, and personal significance are all difficult characteristics for computers to identify in cues. Some sensors can sense a proxy for these characteristics such as measuring physiological arousal and brain wave activity as a proxy for personal significance. However, these techniques are not particularly accurate nor are they particularly easy to implement. We observed that caregivers often used verbal cues that were more distinctive or personally significant when describing a photo. When using lifelogging technologies as a source of cues, the person with memory impairment or the caregiver must play an important role in identifying the distinctive and personally significant details. In follow up validation studies, we found that caregivers also used the same criteria to choose cues to help the person with memory impairment recollect the experience. Using the findings from our two field studies, we designed an intelligent system that captures people's experiences, leverages the caregiver's abilities to select cues, and presents cues to the person with memory impairment.

Capture-Process-Review Lifelog System

Based on our findings from our initial ethnographic field study and our cues study (both discussed above), we will design and build an intelligent system (Figure 2) that will allow people with memory impairments such as Alzheimer's disease and their caregivers to passively *capture* their experiences, *process* the lifelog data into a narrative, and *review* the narrative to help them mentally relive the experience.

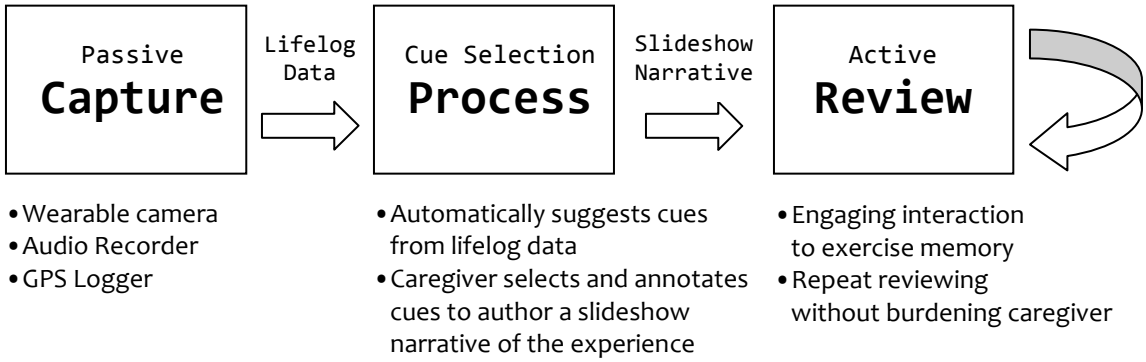

Figure 2. Experiences are captured using wearable sensors, caregiver selects and annotates cues with the help of automatic suggestions from the system to make a narrative, and the person with memory impairment can review this narrative and exercise her memory.

Capture

The system will use a combination of wearable sensors to passively record the content and context experience of the user. We will use the SenseCam [13] from Microsoft Research, a wearable digital camera that will automatically take photos based on time and various sensors. Based on our and experiences [13] from Microsoft Research using the SenseCam with memory-impaired individuals, SenseCam images are effective memory cues. In addition to photos, we will also use a portable digital audio recorder to record voices and ambient sounds from the user's experience. We will also record the location context of people's experiences using a portable GPS logger that can easily fit in the user's pocket or purse. Our passive capture approach eliminates the need for memory-impaired users to remember to explicitly trigger capture during the actual experience. However because the system will either be

constantly recording (as in the case with the audio recorder and GPS) or recording based on predetermined rules (as in the case of SenseCam), the system may capture many details, some of which may not be particularly good cues. The resulting lifelog will be "noisy," filled with many uninteresting or ineffective cues. Hence, our system must provide a means to process the data to extract out the most relevant cues.

Process

The processing phase of the system will be where the raw lifelog data from an experience (potentially hundreds of photos, many hours of audio, and associated location data) can be sifted through to select the best cues to include in the photo/audio slideshow narrative that the person with memory impairment will use to support their own recollection of the experience. The caregiver will use our custom-designed desktop software application to process the lifelog data and construct the narrative. Successful construction of a meaningful and non-overwhelming narrative will depend on the combined effort between the software's automated suggestions of good cues and the user's (in this case, the caregiver's) ultimate selection of cues. We will be exploring supervised learning techniques for adapting the software to make better suggestions for cues based on the caregiver's choice of cues. Based on the type of experience (as indicated by the caregiver), the software will use both content and contextual information to recommend a set of photos that match the appropriate type of cues. For example, if the recorded experience is a "people-based" experience (*e.g.*, a family reunion), the software will use various image processing techniques in conjunction with infrared sensor logs from the SenseCam to identify photos with people in them. From these recommended photos, the caregiver will select the photos of the more distinctive or personally significant people to include in the slideshow narrative as cues for this experience.

The caregiver will listen to various audio snippets (such as conversations) recorded when the picture was taken and will even be able to have this snippet playback during the review phase. The caregiver will also be able to add voice annotation to a photo to further describe the experience and to provide additional personally significant cues. We will also include a feature where the caregiver can draw on the photo to highlight important or significant content. The drawing and the voice annotation features of our design will be substitutes for physically pointing and verbally describing the photo in person. Leveraging the caregiver's expertise in selecting and annotating cues will result in a better narrative, but it will involve more work for the caregiver. The software's feature of automatically suggesting photos or audio will reduce the need for the caregiver to look through all the photos to find the best cues and will minimize the work they must to do find good memory cues to include in the narrative. Furthermore, we also expect that the caregiver will need to author the content only once and can refer the person with memory impairment to the review device instead of repetitively providing the same cues for the same experience.

Review

The review feature of the system will allow the person with memory impairment to review (on their own, at their own pace) a multimedia narrative of an experience as cues to help them not only to recall the experience but to be able to mentally relive the experience. Instead of repetitively asking the caregiver for assistance, they will be able to use this device as a type of "memory appliance" to help them trigger their memory. The idea of a "memory appliance" is similar to the information appliance described in [11] but instead of providing current information, the memory appliance assists the user with recollecting an experience. The actual viewer device will be a tablet PC that can be placed in a convenient location such as on the coffee table or on the nightstand. The user will be able to simply pick up the tablet and review the slideshow of the experience as if they were picking up a picture frame or a book.

The user's interaction with the slideshow will be designed to be interactive, stimulating, and engaging rather than passive. Instead of simply playing back the slideshow like a movie, the user must press the screen between each slide to see the next photo. Within each slide, the photo alone will be first presented without any annotation or callouts. Before pressing the screen to advance the slideshow, the memory-impaired individual will be given the opportunity to think deeply about this photo and exercise whatever memory abilities she still has. Pressing or tapping on the screen plays back the recorded audio from the scene. It could be ambient sounds or a conversation matching the photo. Again, the user will have a chance to process these sounds and the photo together and use them to as cues into her memory. Pressing the screen again, the caregiver's drawing annotation (*e.g.*, a circle around the face of one of the people in the photo) will be overlaid on the photo. The user will be given a chance to think deeply about who the circled person is. Pressing the screen, finally the caregiver's voice annotation will be played back, describing the scene and who the circled person is and what they were talking about. Pressing the screen will move

the slideshow to the next photo where the same interaction will be repeated, maximizing the opportunity for the memory-impaired user to recollect *on their own* the details of their experience. Within each slide, additional information is progressively revealed, much like in the caregiver cueing process. However, unlike the caregiver, the software will never grow tired and will not shortcut the cueing process but will instead provide many opportunities for the memory-impaired user to recollect details on their own, which the users will find rewarding and help their own confidence. The tablet form factor and the associated slideshow viewer software when combined with caregiver-authored content based on actual lifelogging data will provide an easy way for people with memory impairments to review experiences on their own and at their own pace without the need to burden their caregiver.

Future Work

We plan to deploy this system in with memory-impaired individuals and their caregivers. We will evaluate the effectiveness and usability of the capture devices, that is, whether users were comfortable using it and whether it captured an adequately comprehensive account of users' experiences. In addition to our field deployment with caregivers, we will use controlled laboratory studies to test the usefulness of the processing software's recommended cues. We will identify whether the suggested cues are actually what caregivers would select if they looked through all the data. In our field deployments, we also plan on evaluating the effect of the caregiver-authored content and the progressive revealing of cues provided by the slideshow viewer's interaction on the user's memory. It is our goal that this system will allow the memory-impaired user to better remember and mentally relive their experiences while reducing the overall burden on the caregiver.

We also plan to use and extend our system to further explore the design space for capture and access systems for assisting memory. We will investigate how the information from additional wearable and environmental sensors can help simplify the caregiver's sorting process and enhance the richness of the review experience for the person with memory impairment. We want to explore alternate representations of experiences such timelines and collages, in addition to a slideshow narrative, to determine how to best present multimodal cues. Based on the caregiver authored content, we will be able to look into different types of user interactions with the system such as games, quizzes, or storytelling to cognitively stimulate the person with memory impairment. In the longer term, after a substantial amount of lifelogging data has been captured, we can investigate how using machine learning techniques with large corpora of data can help improve the system's ability to determine what photos or sounds may be particularly distinctive or personal significant. Also in the longer term, we are interested in seeing how the use of assistive technologies change over time as people get older and experience further cognitive decline. We designed our systems primarily for those who are still in the early stages of cognitive decline because we hope that the benefits from early adoption of technological solutions can persist through the later stages of a person's life. Our proposed system will provide us a good platform to explore and address these technical, social, and cognitive challenges.

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