Human–Computer Interaction

ISSN: 0737-0024 (Print) 1532-7051 (Online) Journal homepage: https://www.tandfonline.com/loi/hhci20

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To cite this article: Masashi Crete-Nishihata , Ronald M. Baecker , Michael Massimi , Deborah Ptak , Rachelle Campigotto , Liam D. Kaufman , Adam M. Brickman , Gary R. Turner , Joshua R. Steinerman & Sandra E. Black (2012) Reconstructing the Past: Personal Memory Technologies Are Not Just Personal and Not Just for Memory, Human–Computer Interaction, 27:1-2, 92-123, DOI: 10.1080/07370024.2012.656062

To link to this article: https://doi.org/10.1080/07370024.2012.656062

Published online: 13 Apr 2012.

HUMAN–COMPUTER INTERACTION, 2012, Volume 27, pp. 92–123

ISSN: 0737-0024 print / 1532-7051 online
DOI: 10.1080/07370024.2012.656062

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Reconstructing the Past: Personal Memory Technologies Are Not Just Personal and Not Just for Memory

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Research has shown that personal memory technologies are a promising way to address the needs of older adults with memory impairments. In this article, we review three recently completed studies that evaluated technologies for personal memories intended for persons with Alzheimer's disease (AD) or mild cognitive impairment (MCI). In the first study, we worked with 12 participants with AD or MCI and their families to construct DVD-based Multimedia Biographies that depicted prominent events, people, and places from the participant's past. We then evaluated over a period of 6 months psychosocial effects that viewing the biographies had on the participants and their family members. These effects included

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stimulating reminiscence of past events, triggering predominantly positive emotions of happiness and occasional moments of sadness, and engaging conversations with family members. In our second study, we designed a home-based ambient display that allowed a man with AD to similarly review his past life, in combination with recent photos automatically captured by a lifelogging device called SenseCam. Psychometric tests and semistructured interviews revealed how the intervention appeared to improve the participant's sense of self and lower apathy. In our final study of 5 cognitively impaired participants we compared representations of recent experiences captured with SenseCam in 3 ways: with the raw image stream, with a slide show consisting of a selected number of SenseCam images narrated by a family member, and with a control reviewing no images. Results included evidence that reviewing SenseCam images improved episodic recall for personal events depicted in the images for 4 of the 5 participants.

Based on lessons learned from this research, we suggest that personal memory technologies should not just be framed as systems for augmenting an individual user's capacity for accurate recall of personal events, but instead should support groups of people such as members of a family in telling their life stories. This conception yields benefits beyond the

support of memory, such as fostering a sense of self and strengthening interpersonal relationships with family members. We conclude the article by presenting design considerations to help guide and inform the development and evaluation of future "personal memory" technologies.

1. INTRODUCTION

Our ability to capture, store, and share representations of personal experiences has been radically transformed by new possibilities afforded by digital technology. The ubiquity of camera phones, inexpensive and abundant digital storage, and social networking platforms are prime examples. An important resulting concept is lifelogging, which comprises nascent technologies and practices that enable pervasive capture and storage of multimodal data that represent the life experiences of users (Czerwinski, Gage, Gemmell, & Marshall, 2006).

Although lifelogging technologies can boost productivity for information professionals by providing easier access to needed information, these same technologies can play an important role in the personal sphere. Recording and archiving traces of our lives is a primary element for helping us reflect upon experiences and convey our life stories to others. The emergent practices and technologies for "digital personal memories" have critical implications for how we capture and relate our life stories (Harper, Randall, et al., 2008) and can deeply influence how we remember the past, share recollections with others, and interpret our identities. Identifying and investigating the ways that lifelogging provides value in the personal sphere can help to suggest directions for designers and researchers who are designing, building, and evaluating these technologies.

We investigated these implications through the Digital Life Histories research project—three studies that explored the psychosocial impacts of digital storytelling and lifelogging technologies on older adults with cognitive impairments. We chose to explore this space by working with older adults with Alzheimer's disease (AD) and mild cognitive impairment (MCI), a predictor of AD. These participants allowed us the opportunity to see how technology might support entire lifetimes of memories. Further, these individuals seemed likely to benefit from tools to help compensate for memory impairment. Finally, because they often required care from partners, siblings, children, and third-party caregivers, we were able to investigate how lifelogging impacted relationships among family members (and beyond).

Each of our three projects explores the use of narrative for structuring multimedia data that represent the life histories of our participants. In the first study we evaluated the impact of Multimedia Biographies (MBs) on 12 persons with AD or MCI (Damianakis, Crete-Nishihata, Smith, Baecker, & Marziali, 2009; Smith, Crete-Nishihata, Damianakis, Baecker, & Marziali, 2009). We worked with family members of AD patients and directly with the participants with MCI to collaboratively produce DVD-based MBs that told the life story of patients through various personal media such as photos, home movies, documents, music, and audio narration. In the second

study, we combined our MB method with SenseCam and ambient displays to explore via a single-subject case study the impact of these technologies on the identity of an individual with AD (Massimi et al., 2008). In our third, most recent, and previously unreported study (Baecker et al., 2012), we conducted a systematic evaluation of the psychosocial effects of two SenseCam media conditions that represent an episode in the lives of five individuals with AD or MCI and their partners. The first condition (*SenseCam remix*) presents a small selection of SenseCam images in a slideshow narrated by the cognitively impaired person's study partner. The second condition (*SenseCam reexperience*) presents the unprocessed log of all SenseCam images captured during the event. We compared these conditions to an active control in which participants viewed no SenseCam media.[1]

Across these projects we employed diverse methodologies including in-depth interviews, participant observations, and psychological instruments for measuring constructs such as memory, identity, and emotional well-being. We analyzed these results through disciplinary perspectives including human–computer interaction, social work, neuroscience, and psychology.

Our research revealed recurring themes. Narratives of the past captured by these technologies are not just collections of facts for users to record, store, and remember, but reconstructions of experiences subject to multiple interpretations and perspectives. Personal memory technologies are as significant to family members as they are to the person whose life is conveyed in the lifelog. Their impact includes, but goes beyond, the support of recall. Creating and viewing personal memory media is an occasion for reminiscence, joy, and sadness; they preserve personhood, start family conversations, engender feelings of togetherness, and provide a legacy for family members.

Our findings show that in order to understand personal memory technologies we have to better articulate what we mean by "personal" and "memories." We suggest that personal memory technologies should not be framed only as systems for augmenting an individual user's capacity for recall of personal events but rather as means for supporting the narrative reconstruction of life stories that can have multiple meanings and effects for different stakeholders.

We now review relevant literature, describe the three studies, and conclude with implications for the design and evaluation of future personal memory technologies.

2. BACKGROUND

Augmenting human memory with machines has been a central goal of computer science since the early beginnings of the field. Numerous accounts of the history of human–computer interaction, such as Baecker, Grudin, Buxton, and Greenberg

[1] Our first two studies have been previously reported, and only a selection of major results and lessons learned are included in this article. Our third study has not been previously reported, and results are presented here for the first time.

(1995), present and explain the importance of Bush's concept of supplementing human memory with the Memex. They also describe the visions of Engelbart and Nelson of the role of hypermedia in supporting group collaboration and individual creativity. We therefore proceed to outline the state of the art and debates on emergent technologies, and then discuss how personal memory technologies can support cognitively impaired persons by helping them remember the past, tell life stories, and connect with others.

2.1. Personal Memory Technologies

The rising capacity and decreasing cost of digital storage has made the prospect of saving a lifetime's worth of personal data a practical and inexpensive possibility. For example, in the MyLifeBits project, Gordon Bell has digitized all of his personal data including photos, documents, web sessions, conversations, and biometric data. This project first predicted that 1 terabyte of disk space would be adequate for logging all personal data (except video) over the span of 80 years (Gemmell, Bell, Lueder, Drucker, & Wong, 2002). Gemmell, Bell, and Lueder (2006) have since noted,

> We now believe that a terabyte will hold a lifetime at twentieth-century resolutions and quantities, but speculate that twenty-first century users may expect to record their lives more extensively and in higher fidelity—and may drive a market for much greater storage. (p. 90)

The field of wearable computing has also created capture technologies. Key work has been done by Steve Mann, who started developing wearable computing devices in the late 1970s. From 1994 to 1996 Mann continuously broadcast full motion video footage of his everyday life to the Internet through his head-mounted wearcomp system (Mann & Niedzviecki, 2001). Recent iterations fit in a pair of eyeglasses, which Mann suggested could be used for "continuous lifelong video capture to record exactly what our eyes see over an entire lifetime" (Mann, Fung, Aimone, Shgal, & Chen, 2005, p. 2204).

Recently receiving a surge of attention is SenseCam—a wearable camera with on-board sensors, which automatically captures images based on the passage of time and change in environmental parameters such as motion, temperature, and light. It is fitted with a low-resolution wide-angle lens and worn around the user's neck, and therefore can theoretically capture everything in the user's line of sight (Hodges et al., 2006).

These technical developments have opened the possibility for users to passively capture and store comprehensive representations of their personal experiences. Sellen and Whittaker (2010) described two classes of lifelogging systems: "total capture," which aims to continuously collect as much multimodal data as possible at all times, and "situation specific capture," which aims to automatically record multimodal data as completely as possible for specific activities or places where activities happen. The total capture class is still viewed as an extreme practice and has been attempted only by a handful of researchers, including Gordon Bell, Steve Mann, and Cathal Gurrin,

who has been wearing SenseCam nearly everyday since 2006. There have been almost no systematic evaluations of the effects of these systems on pervasive lifeloggers (for one exception, see Doherty, Pauly-Takacs, Gurrin, Moulin, & Smeaton, 2009), leaving much to be learned about the implications of the total capture model. The concept has also raised a number of concerns and criticisms around important issues such as privacy and security (Cheng, Golubchik, & Kay, 2004; O'Hara, Tuffield, & Shadbolt, 2008) and the value of forgetting (Bannon, 2006).

In their critique of lifelogging, Sellen and Whittaker (2010) contended that the focus should not be total capture, and a "human-centred research agenda" should be explored that moves from technical challenges and toward understanding how lifelogging systems can be in synergy with human memory systems. This point has been corroborated in our research, an interdisciplinary effort that starts from the requirements and challenges faced by our participants, and draws from psychology, neuroscience, and social work to inform evaluations of personal memory technologies. The personal memory technology research community is also moving away from just exploring narrow technical issues to considering psychological and societal implications from multidisciplinary perspectives. Technical research on lifelogging systems is shifting from problems of capture and storage and toward the challenge of managing, filtering, retrieving, and visualizing information from large multimodal datasets (Doherty et al., 2007).

SenseCam has been particularly important for these efforts, as researchers from many disciplines became interested in it following studies that show its potential as an autobiographical memory aid for patients with cognitive impairments. In their seminal study on a patient with limbic encephalitis, Berry et al. (2007) demonstrated that systematically reviewing SenseCam images of personal experiences can improve autobiographical memory for specific events over a period of a year compared to use of a written diary and no intervention. A follow-up fMRI study on that patient found that relative to the written diary rehearsal condition, successful recognition of SenseCam images of personal events was associated with activation of frontal and posterior cortical regions, which suggests that review of SenseCam images may provide powerful triggers for the recall and consolidation of stored but inaccessible memories (Berry et al., 2009).

Psychological evaluations with SenseCam continue to grow and diversify in focus, as evidenced by the range of topics being probed by recent SenseCam research, including examination of gender differences in autobiographical memory (St Jacques, Conway, & Cabeza, 2010), intervention with a child with anterograde amnesia (Pauly-Takacs, Moulin, & Estlin, 2010), and assessment of memory impacts in healthy younger adult populations (Sellen et al., 2007). SenseCam was not explicitly designed with these psychological effects or evaluations in mind, but rather as an engineering exercise to make a "black box for the human body" (Twist, 2004). This research is still in early days, but the collaborations that have formed among psychologists, computer scientists, and other researchers show how the development of future personal memory technologies can be more strongly influenced by human-centered interdisciplinary approaches.

2.2. Supporting Cognitively Impaired Persons Through Life Stories

Life review has been proposed as a class of techniques to improve quality of life for cognitively impaired patients (Lewis & Butler, 1974). One prominent form of life review is reminiscence therapy, "the discussion of past activities, events and experiences with another person or groups of people, usually with the aid of tangible prompts such as photographs, household and other familiar items from the past, music and archive sound recordings" (Woods, Spector, Jones, Orrell, & Davies, 2008, p. 2). Other life review interventions can be more structured activities that focus on an individual's entire life as a means of evaluating and reframing life events (Haight et al., 2003). Studies show that such interventions can carry benefits for AD patients such as stimulating reminiscence, increasing the quality and quantity of communication, enhancing feelings of well-being, and providing a shared family legacy (Allen, 2009; Bourgeois, Dijkstra, Burgio, & Allen-Burge, 2001; Moos & Björn, 2006).

Previous work has shown the potential for technology to support reminiscence in cognitively impaired and healthy older adult populations, including evaluations of Internet protocol videophones for networked reminiscence sessions performed across geospatial distance (Kuwahara, Abe, Yasuda, & Kuwabara, 2006), a scrapbook-like interface for reminiscing (West, Quigley, & Kay, 2007), and tabletop interfaces for sharing digital photos (Apted, Kay, & Quigley, 2006). These studies suggest the possible role of technology in supporting reminiscence but have studied primarily usability and technical measures rather than wider contextual effects. In contrast, the Computer Interactive Reminiscence and Conversation Aid (CIRCA) project investigated the psychosocial impact of technology for reminiscing. CIRCA, consisting of a database of archival multimedia content that users access via a touch-screen interface, was used in group reminiscence therapy sessions and found to stimulate engagement among participants who normally had limited reactions to traditional reminiscence therapy (Gowans et al., 2004).

Work has also been done on storytelling with lifelogging technologies. Many studies focus on the technical challenges of constructing narratives from very large datasets (Byrne & Jones, 2008). Other studies have taken a sociological approach. For example, Harper, Randall, et al. (2008) demonstrated the unique qualities of narratives made with lifelogging technologies through an exploratory study that found the device enabled users to create artistic and evocative stories about mundane events that would not normally merit narrative accounts. Lindley, Randall, Glancy, Smyth, and Harper (2009) showed that the social dynamics of families is an important factor in understanding how users reconstruct narratives from lifelog data.

Yet research that combines storytelling and lifelogging technologies to support cognitively impaired persons has been limited. A notable exception is efforts by Lee and Dey (2008), who developed a system for providing memory cues to individuals with AD that leveraged SenseCam images annotated with audio narration and graphical cues. The motivation behind this research is to develop an appliance that provides memory cues to support the episodic memory of cognitively impaired individuals in a

manner similar to practices utilized by caregivers, but that does not require caregiver intervention.

Our Digital Life Histories project is an example of an interdisciplinary effort to understand the implications of personal memory technologies for cognitively impaired persons. We have experimented somewhat with the design of these technologies but have been primarily concerned with evaluating their impact and assessing how users may interact with them in their everyday lives. Our work did not start with technology as the focus, but rather with the concept of the life story and how technology for conveying these narratives may benefit cognitively impaired persons and their families.

Cognitive impairments such as AD affect more than the memory of patients. Studies suggest that autobiographical memory impairment is linked to loss of identity (Addis & Tippet, 2004) and communication abilities (Burgio, Allen-Burge, Stevens, Davis, & Marson, 2000). In confronting these challenges our group has been inspired by theories of person-centered care and personhood that contend that the sense of self and identity of dementia patients persist throughout the duration of the disease and are strengthened through interpersonal contexts (Kitwood, 1997). Our approach was also influenced by classic work on identity such as Erikson (1950), who argued that we face different goals and social roles, and our identity must therefore be able to adapt to them, and Butler's (1963) theory of life review that sees it as a process that engages elderly individuals in an active reflection of their experiences that can help them acknowledge and accept their life and sense of self. The objectives of the Digital Life Histories initiative have thus been to support reminiscence, identity, communication, and well-being through technologies that help cognitively impaired persons and their loved ones produce, review, and share representations of their life stories. Given this background, we now describe our three studies.

3. DIGITALLY RECONSTRUCTING LIFE STORIES

In our first study we produced MBs with 12 persons with AD or MCI and their families and evaluated the psychosocial effects of repeated viewings (Damianakis et al., 2009; Smith et al., 2009).

AD is the most common cause of dementia and includes deficits in memory and at least one other cognitive domain that are severe enough to impact functional abilities. Mild cognitive impairment (Petersen, 2003) is a term used to describe older individuals with acquired cognitive impairment but not to the degree that it impacts functional abilities significantly; MCI is often viewed as a "transitional state between normal aging and dementia" (Bell, 2010). Individuals diagnosed with MCI that includes impairment in memory have been reported to progress to dementia at a rate of 10 to 15% per year, although one in four do not convert to AD (Bell, 2010).

Inspired by participatory design practices (Greenbaum & Kyng, 1991), we worked closely with family members of AD participants and directly with individuals with MCI to produce the MBs. MBs were collections of personal assets including photos,

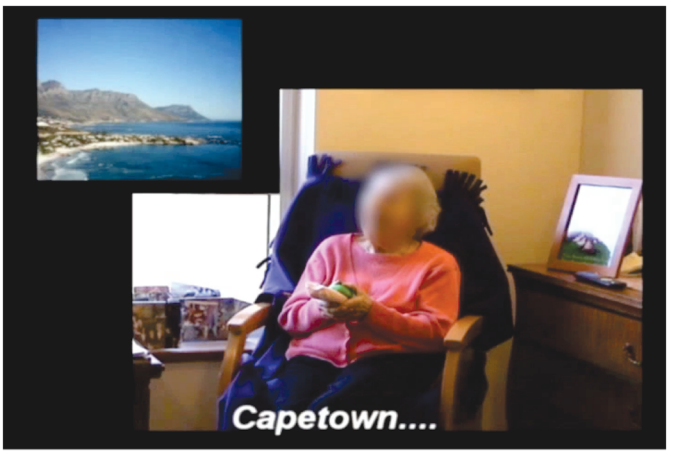
home movies, documents, music, and narration compiled into a digital video that represented a person's life story. Family members and participants provided the media assets and directed the script and storyboards. We helped them plan the stories, gather and digitize media, and shoot new footage. We used DVD editing suites such as Final Cut Pro to author the MBs, which were typically 35 to 40 min in duration (the shortest MB was 15 min, and the longest was 60 min). We structured MBs as a series of "acts" that represented major life stages arranged chronologically or in terms of themes such as adolescence, marriage, hobbies, or "my life in politics." Each act contained several "scenes." Scenes comprised still photos, video clips, music, and usually narration from family members (see Figure 1). We typically produced two DVDs: one a linear "movie" and one with "branching points" where the viewer can choose to see more scenes or proceed to the next act (for a detailed account of the production process, see Smith et al., 2009).

We then filmed the participant's response to an initial viewing. Family members and caregivers were asked to show the MB to the participant once or twice a week and record his or her reactions. We returned after 3 months, filmed the participant viewing their MB, and conducted semistructured interviews with the family to elicit responses to the MB. This process was repeated again 3 months later. The interview and video data were transcribed and analyzed line by line through open coding methodologies (Berg, 1995; Creswell, 1998). Both verbal and nonverbal responses captured in video and interview data were coded. Finally, categories and subcategories were extracted and compared across the two primary data sets (interview and video), time, and sample populations (AD and MCI).

Overall, our findings show that the MBs helped participants reminisce about their past with feelings and emotion (see Figures 2 and 3).

FIGURE 1. A MB storyboard and a workspace for gathering and organizing media. (Color figure available online.)

FIGURE 2. Ms. F viewing her MB and remembering an important place: "*Capetown . . .*" (Color figure available online.)



MBs evoked a range of emotions from the both participants and family members (e.g., joy, sadness, frustration, loss, boredom, hope), but overwhelmingly, the data indicated that participants enjoyed the experience of creating and watching the MBs. Participants and family members who watched the MBs together often engaged in conversations around life stories (see Figures 4 and 5).

Family members and participants perceived the MBs as a means for preserving the personhood of their loved one and presenting their story to future generations. Third-party caregivers such as nurses at long-term care facilities also viewed the MBs. Family members believed that viewing the MBs helped third-party caregivers learn

FIGURE 3. Ms. F reflecting on a feeling: "*It was very good to live there . . .*" (Color figure available online.)

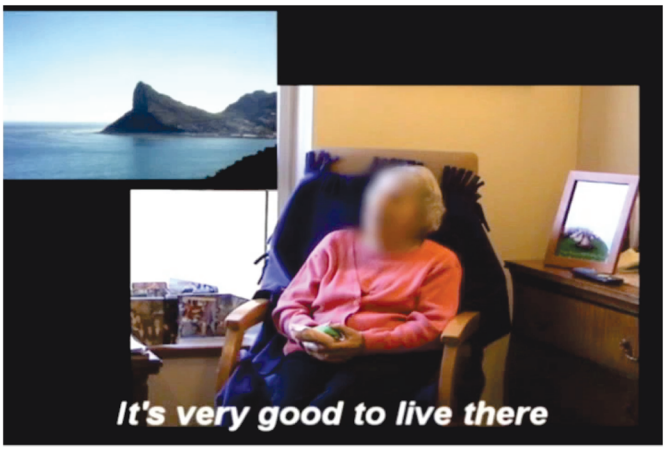


FIGURE 4. Ms. Z and her daughter connecting in a moment of praise and reflection with the daughter remarking: "*Katharine Hepburn you looked like . . .*" (Color figure available online.)

about their loved one's history and enabled them to better empathize with them and care for them.

Participants chose various media to include in their MBs and were told to include anything they wanted to share with their family. Content was mostly personal collections of photos, home movies, letters, favorite music, and voice narratives from family members recounting shared stories and experiences. Personal photographs and personalized music selections often elicited the strongest and most positive emotional responses from participants and provided opportunities for family members to engage their loved ones in conversations about the past. These findings show the importance of personalized media for engaging cognitively impaired persons in past experiences,

FIGURE 5. Ms. Z and her daughter connecting with an important song from the past: "*My father used to sing it to us . . .*" (Color figure available online.)

which extend upon previous studies that explored generic media for supporting reminiscence in cognitively impaired populations (Gowans et al., 2004).

The MBs also demonstrate that personal memory technologies can have different effects for multiple stakeholders that we cannot always anticipate. During production we realized that telling a life story is always an act of reconstruction. Family members sometimes disagreed over the events of the past and how to present them; some families and patients selectively chose to highlight some episodes over others. We learned that telling stories of the past is not about documenting clear objective series of facts. Instead, each user of personal memory technologies may perceive the past in different ways and want their interpretations reflected in the media.

The experience for most MCI participants was much different from the AD participants, as they essentially created autobiographies with less input from family members. Being in control of the authorship process led some participants to feel introspective and critical but also provided some with feelings of self-growth, as by the end of production they had accomplished something about which they were at first unsure. MCI participants also reported different viewing experiences. For example, after repeated viewings Ms. K began to worry about how she could have made her MB differently. She became so consumed by her critical analysis of the MB that watching it became an upsetting experience. Nonetheless, she noted that this introspection had a positive influence on her sense of self and expressed that she had told her social worker that "I felt better about myself after having looked at the video, because I saw a lot of good things in it good things that I had enjoyed that I had allowed to be and to do."

Sharing and screening preferences was also a variation across participants. For example, the son of one participant expressed interest in putting the MB on the Internet to share it with distant family. Yet one MCI participant preferred to watch her MB alone and did not want to "impose" it on her family. Privacy is an important element for personal memory technologies; users must be able to choose how much data they want to share with others.

The take-away lesson is not only that the MB should be editable but also that we cannot predict what the response to materials in the MB will be due to changing life circumstances and attitudes. In contrast to the discrete memory of a computer system, human memory is revisionist. Intimate technologies for constructing personal identity and experiences must allow editing of the "past" to match one's current viewpoint.

MBs were constructed from commonly used media assets (photos, home movies, etc.) and presented through familiar technologies (DVD players, TVs, etc.). We purposefully chose these familiar technologies to enable easy adoption and integration of the MBs into the domestic environment of our participants. Although the familiarity of the technology was convenient, our participants also reported shortcomings. Producing MBs can be a time-consuming process for which families struggling with the daily challenges of caregiving may not have the time. Our project participants benefited from the technical and story design support our research assistants provided. Yet we believe that family members caring for cognitively impaired persons could produce MBs by themselves and that the production process in itself can be a beneficial collaborative experience for families. To encourage and guide the

production of MBs we have authored a guide for families that may be interested in making their own MB (Technologies for Aging Gracefully [TAG lab], 2011). Yet more efficient search and media selection tools for handling personal memory media could make the production process faster and more approachable for typical users. We also learned the importance of making the MBs accessible to seniors without caregiver intervention. Although DVDs are inexpensive and available, playback devices proved to be complicated for some participants to use alone, and seniors required assistance from family members and caregivers.

Based on this first study we moved to extend this research and explore new capture and display technologies for supporting life stories and measures for evaluating their impact in cognitively impaired populations.

4. THE IMPACT OF DIGITAL NARRATIVES ON IDENTITY

In our second study, we sought to combine MBs—an edited, multimedia digital format consisting of distant memories—with images of the recent past captured by a SenseCam (Massimi et al., 2008). The resulting digital life history, consisting of both past artifacts and SenseCam images, was also subjected to a more rigorous single-subject case study evaluation in an effort to understand the psychosocial impact of both the authoring and viewing processes. Finally, to allow independent viewing, an ambient display format was chosen. The ambient display presenting the digital life history was then situated on the kitchen table in the participant's home (see Figure 6).

In the case study format employed, a 74-year-old man with moderate AD (Mr. H) was given a set of three psychological tests at approximately 1 month apart,

FIGURE 6. The ambient display within the domestic space. (Color figure available online.)

which we term baseline, interim, and final. Psychological tests included measures for anxiety, depression, apathy, self-image, autobiographical memory, and general cognitive functioning. Informant measures of these constructs, along with caregiver strain, were collected from his daughters and part-time caregiver. At baseline, Mr. H had no exposure to the process of creating a digital life history, nor viewing one. For 4 weeks, we worked with the subject to create a MB in the same style as in the first study. Following this authorship process, we conducted the interim evaluation. We then presented Mr. H with the completed digital life history in the ambient display format for 2 weeks before completing the final evaluation.

The results from the standardized tests were analyzed, and results showed improvements in apathy and positive self-image both at the time of the interim and final evaluations. No improvement was noted in measures of autobiographical memory, anxiety, depression, or general cognition. Thus, the results suggested that the subject's sense of identity was strengthened by the authorship and viewing processes, and without an accompanying improvement in memory abilities. This perspective was supported by interviews with Mr. H's caregivers.

> [His memory] is much the same . . . Has it improved? Probably not . . . but he is remembering a lot about . . . [pause] . . . I guess I'm contradicting myself . . . He's talking a lot about what's on it. . . . It's obviously made him more interested I think in the past. It's stimulated his interest in his memories, if you like. — Daughter

This observation challenges prevalent theories that suggest memory is a necessary condition for creating a positive identity; instead, SenseCam and other multimedia allow the participant, family, and caregivers to participate more actively in identity-supporting activities such as group reminiscence and conversation. In other words, the digital life history performed not as a "replacement" memory but as a gateway to engaging in the activities that memory often makes possible, such as reminiscing or sharing stories.

> He's enjoyed the attention he is getting from everybody. . . . I think he's enjoying the process knowing that . . . we're discussing his past more. — Daughter

It is important to note that this was achieved through both the process of authoring the content, and actually viewing the content. Although we may often think of lifelog data as an overwhelming collection to sort through, this same sorting process created an opportunity to review the past and connect to family members. The authoring of digital personal memories, then, is not in all cases a burdensome process that demands automation. Rather, authoring tools should be considered alongside tools for capture.

> The fact that he's enjoyed seeing his past and remembered it, and he feels quite proud of what he's done. I think he feels he's got a sense of pride in the past, which he had forgotten before. He's reminded himself, in a way, of what he's achieved, I think. — Daughter

Creating lifelogs or other forms of digital memories may be, in some cases, as useful for psychosocial outcomes as reviewing the final product.

5. COMPARING RAW LIFELOGS TO NARRATIVE ACCOUNTS

In our most recent and previously unreported study, we conducted a systematic evaluation of the cognitive and psychosocial impact of reviewing raw SenseCam data compared to narrative accounts constructed from SenseCam images depicting special outings shared by cognitively impaired persons and their partners. We term these conditions SenseCam *reexperience* and SenseCam *remix*. SenseCam *reexperience* presents unprocessed SenseCam images replayed at two frames per second in chronological order. SenseCam *remix* is composed of a selection of 24 SenseCam images edited and narrated by the cognitively impaired persons' partner resulting in a multimedia representation of the day's events that merges participant and partner perspectives (see Figure 7).

To enable semiautomated *remix* media production, we developed software that simplifies the task of selecting 24 SenseCam images (the number of images in a traditional roll of film) from among the hundreds of captured images. Our software combines image-processing algorithms (Doherty et al., 2007) to automatically group SenseCam images into event-based sequences with a simple user interface that simplifies the image selection and organization process (see Figure 8). A click-and-speak recording tool enables the addition of commentary as an audio file paired with each image file in the resulting narrative. Images are presented to the cognitively impaired participant with a basic video player.

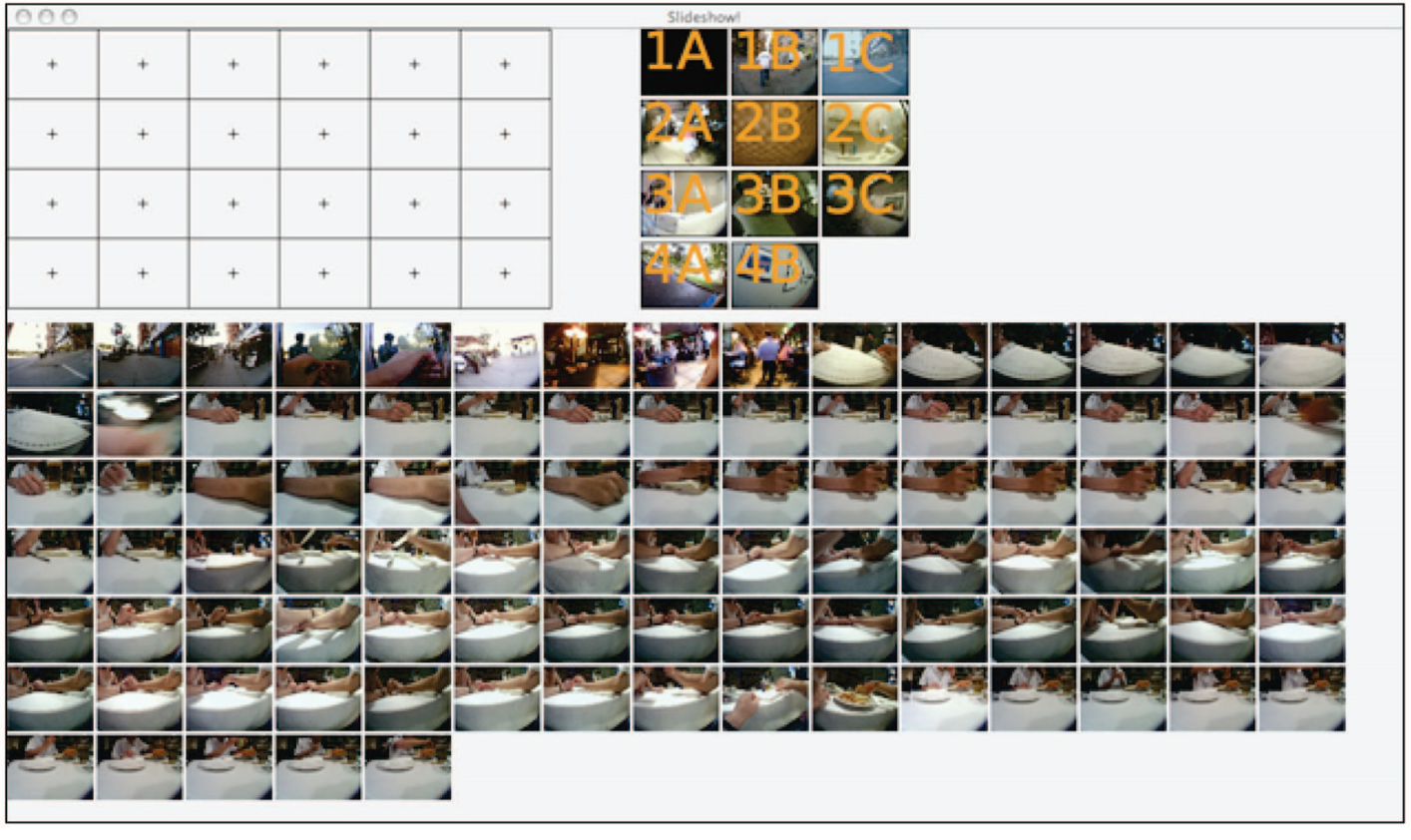
Similar to our previous studies our evaluation of this technology focused on memory, psychosocial outcomes, and interactions with family. To determine the impact of viewing SenseCam media formats on autobiographical memory, we used a customized version of the Autobiographical Interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002).

Autobiographical memory is commonly understood as memory of events and other knowledge about oneself across a lifetime (Radvansky, 2006). It is the type of memory typically associated with personal memory technologies even if designers do

FIGURE 7. Comparison of the two SenseCam media formats

SenseCam Reexperience	SenseCam Remix
Automated passive capture	Automated passive capture
First-person perspective	First-person perspective
Unfiltered image stream	Selection of 24 images chosen by partner
Raw experience	Elements of storytelling
No audio	Audio narration (partner's voice)

FIGURE 8. Interface for selecting SenseCam images. (Color figure available online.)



not explicitly state it as such. There are two forms of autobiographical memory: episodic and semantic. Tulving (1985) explained that episodic memory refers to remembering specific past events along with their contextual details, whereas semantic memory includes facts about the world and one's self.

The AI is a standardized instrument that provides an interview method for eliciting autobiographical memory details and scoring system for assessing the quantity and quality of details recalled. The AI technique for scoring responses from the interview sessions consists of content analysis that segments memories into informational details that are defined as a "unique occurrence, observation, or thought typically expressed as a grammatical clause" (Levine et al., 2002, p. 679). Details are further segmented into two broad categories: internal and external. Internal details relate specifically to the event under question and are thought to represent episodic reexperiencing. External details include semantic information and details about events outside of the one in question. A unique feature of the AI that differentiates it from other autobiographical memory questionnaires is that it is able to distinguish between recollections of personal experiences from general semantic knowledge.

Previous SenseCam studies have scored free recall based on the number of events reported as remembered, known, or guessed (Sellen et al., 2007), or the number of general event details recalled (Berry et al., 2007; Kalnikaite, Sellen, Whittaker, & Kirk, 2010). These methods produce interesting results but do not separate episodic from semantic details. With the AI we are able to isolate details related to episodic memory, which represent the form of "mental time travelling" that many personal memory technologies are seeking to support.

5.1. Study Design

Five participants with early AD or MCI wore SenseCam during three personal outings accompanied by a study partner (typically a spouse). The participants were instructed to go on events lasting 2 to 4 hr that were outside of their usual routines and represented special locales they had not visited in the previous 6 months. Typical events included visits to cultural attractions (e.g., museums, zoos), and outdoor venues (e.g., the beach, family picnics). Directly after each outing the participants were engaged in a $2\frac{1}{2}$-week evaluation period in which they were interviewed five times using a modified version of the AI. Each event was separated by a 1- to 2-week break resulting in three events and 15 AI sessions over a 3- to 4-month period.

In our modified version of the AI protocol we use five stages of questioning during the interview sessions. The first stage is a free recall session in which the participant is asked to recount everything that he or she can remember about a particular event. The second stage is a general probe intended to ensure that the participant has related all the details that come to mind. The third stage is probed recall in which the participant is asked a series of specific questions regarding the event. These rounds of questions are followed by review of one of the SenseCam media conditions or the control of no media. After viewing the media the participant is asked if any further

details come to mind. In the case of the control condition the participant is shown no media and simply asked if he or she has anything to add to the description of the event. The ordering of conditions was randomized to account for any ordering effects.

Three months after each event, a long-term follow-up AI session was conducted. A family screening was then held in which the participant and partner were encouraged to invite family members who had previously not participated in the study to view the various media formats together typically in their family home. These family screenings were video recorded. In-depth interviews were conducted directly after the screenings with the participant and family members.

We evaluated the impact of the two formats on the autobiographical memory of our participants about two outings as rated by the AI results. The third outing was an active control in which no SenseCam media were viewed. Psychosocial effects and participant interpretations were revealed through the in-depth interviews and participant observations. Data collection also included general neuropsychological evaluations, well-being questionnaires, and cognitive tasks. This article focuses on summarizing AI data and qualitative results. A more detailed neuropsychological account and findings from other measures are reported in Baecker et al. (2012).

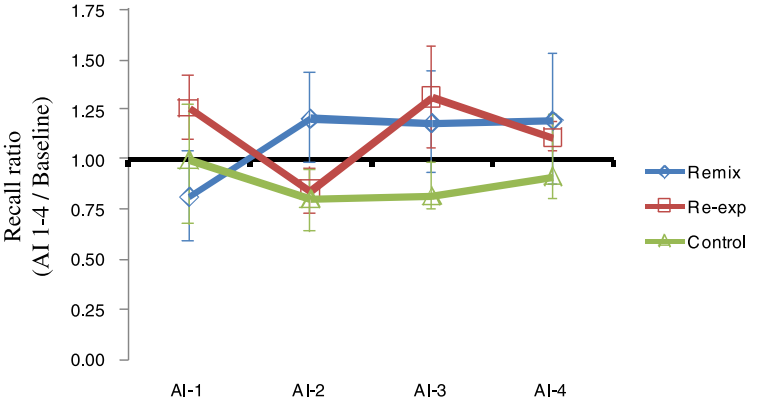
5.2. Impact on Autobiographical Memory

Statistical assessment of the AI results was conducted using analysis of variance methods with condition and AI assessment (1–4) as within-subject, repeated measures. Four subjects (Ms. A, Ms. C, Ms. S, Ms. H) completed all three conditions and AI assessments with a trained interviewer. The final participant (Mr. R) also completed all three conditions, but a different research assistant conducted the AI interviews. The AI instrument is sensitive to administration, and there was evidence of low effort during AI assessments for Conditions 2 and 3 (*remix* and *reexperience*) for this participant. As a quantitative outlier assessment would not be valid for this sample size, we report groupwise analyses first with all five participants and then again with Mr. R's data excluded.

When all five participants were included in the analysis (see Figure 9), there was no main effect of condition or AI assessment, nor was there an interaction between these two factors (all ps $> .05$). Qualitative review of each subject's data revealed that Mr. R demonstrated a pattern of results that was in direct contrast to the other participants, with recall performance declining for both SenseCam conditions and improving for the unrehearsed control condition. This finding is consistent with the interviewer's report of declining effort in these latter assessments.

As a result we reanalyzed the data excluding Mr. R. In this analysis there was again no significant main effect of AI assessment ($p > .05$), consistent with the previous results and indicating that overall episodic recollection was not associated with the time of assessment (i.e., AI-1 to AI-4; see Figure 10). In contrast, the main effect of recall condition was now significant, $F = 3.6320$, $p = .037$. This finding suggests

FIGURE 9. Average episodic event detail recalled at each assessment period ($N = 5$). (Color figure available online.)



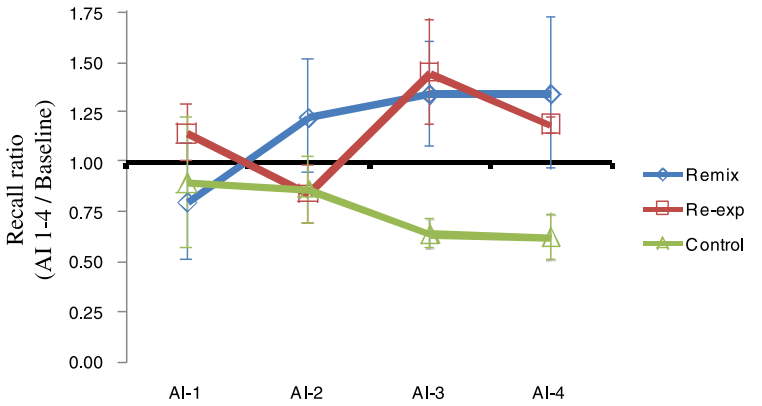
that irrespective of the assessment period, episodic recollection was significantly impacted by the rehearsal conditions. Again, as with the previous analysis, there was no significant interaction between AI assessment period and condition ($p > .05$), suggesting that the impact of condition on episodic recall was not dependent upon the time of assessment.

These results suggest that reviewing SenseCam images of personal events can support episodic recollection of the experiences over time.

5.3. Qualitative Results

Interview transcripts and video recordings of family viewings were analyzed using the same methodology utilized in our MB study (Daminiakis et al., 2009).

FIGURE 10. Average episodic event detail recalled at each assessment period ($N = 4$). (Color figure available online.)



Through line-by-line open coding of the interview transcripts and review of the video recordings we segmented responses in the dataset into themes including perceptions of the two media conditions, different interpretations of the story, psychosocial and behavioral effects, and reactions to the technology. We describe each of these themes in turn.

Perceptions of the Two Media Conditions

During interviews and family screening sessions participants expressed preferences for one or the other of the two media conditions. Three participants (Ms. S, Ms. C, and Ms. A) and some caregivers reported that they felt SenseCam *reexperience* was more effective at cueing memories because of the greater number of images included:

> If you are looking at the full range of all those images you are seeing that many more images of . . . that particular subject matter. . . . I think each image would help with the recollection. — Husband of Ms. S

Participants also noted that the speed at which the images were played (2 fps) was beneficial:

> If they had been still photographs I don't think I would've been that interested. The fact that they were moving and moving quickly. . . . I got the sensation of being there again. — Ms. A

Most participants also found SenseCam *remix* a helpful source of memory cues but not to the same extent of SenseCam *reexperience*. Ms. S expressed that SenseCam *remix* "remind[s] me of the event, but the details would be less [than SenseCam re-experience]." In contrast, the husband of Ms. S thought the narration may have added an additional layer of cues that could be beneficial to his partner, "I think it may have [helped the memory of Ms. S], because I was commenting on some the stuff that was there and without the narration it is possible that a detail wouldn't have come back to [Ms. S] quite so quickly." Similarly, Mr. R felt that SenseCam remix had the greatest effect on his memory, as the format "completed [the story] more."

Although the majority of participants reported that SenseCam *reexperience* had qualities that made it a more effective cue for recall, they also expressed that SenseCam *remix* was more enjoyable to watch and share with others. Some participants noted comfort in the addition of their partner's voice to the slideshow of 24 images. Family members who were not part of the project until the family screening also commented that the narration provided context to the images they were watching. For example a family member of Ms. C noted during the screening that the SenseCam *remix* gave her "more of a flavor for what's going on" and another family member stated, "I prefer . . . the narrated one, because it makes it more interesting obviously."

These show that different personal memory media can be interpreted by users as better suited for different purposes and settings. Participants appreciated SenseCam

reexperience's generous collection of cues due to the volume of images and speed of playback. Yet the raw data were harder for loved ones who had not experienced the event to contextualize, and *remix's* audio narration provided a useful voice and structure.

Different Interpretations of Shared Experiences

The SenseCam *remix* condition combines participant and partner interpretations, as the images from the first-person perspective of the cognitively impaired are paired with the selection preferences and audio narration of the caregiver. The cognitively impaired participants were not involved in the production of the SenseCam *remix* in order to control their exposure to the media condition stimuli for the purposes of the experiment. Some caregivers expressed that their solitary role in authoring the SenseCam *remix* meant that they may not be selecting images that properly reflect their loved ones experience:

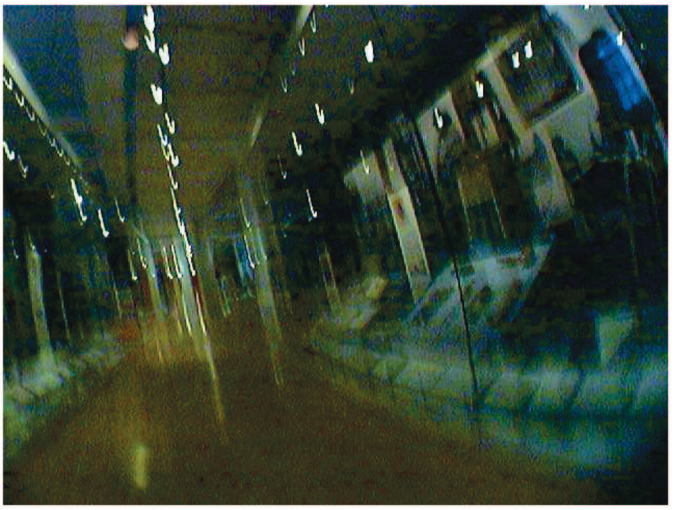
> Because I am the one choosing the images and [Ms. S] is experiencing the whole event, not the same as me. She is not here when I am doing the choosing . . . there may have been images that were scanned, that [Ms. S] would have selected that had more meaning for her, for this event, that I didn't realize because I was looking at something else maybe. — Husband of Ms. S

The importance of different points of view was also noted by Ms. A: "I would like someone to edit [the images] I think, but then you can't edit, because you don't know what's important to me". The husband of Ms. A is an artist, and during the production of a SenseCam *remix* depicting a trip to the art gallery with his wife he made an interesting selection of images including favorite sections of the gallery and blurry shots of "abstract views" that reminded him of the textures of watercolors (see Figure 11).

Upon reflecting on these selections during our in-depth interviews, Ms. A expressed that she and her husband "look at things from two totally different perspectives" and explained "We are different people and what he would find interesting. . . . We both find the same things interesting we just look at them totally different." Although she found the addition of her husband's voice to the depiction of their trip to the gallery enjoyable, it also led her to reflect on their differing interpretations of the experience:

> [Husband's name] is a not detail-oriented person . . . like we'd gone to the art gallery and we were both standing in front of the same picture and we would both have a totally different feeling about the picture. I would want to know the history of the picture and what was behind it and I would want to know the story involved in the picture whereas [husband's name] would look at it he would think about how the paint was used and how the colours were mixed and so it's a different thing . . . so to have him [select the images] didn't mean anything to me. — Ms. A

FIGURE 11. SenseCam image selected for its abstract artistic qualities. (Color figure available online.)



Ms. A expressed that his selection of images made her feel "a little annoyed because you picked things that meant something to him not things that meant something to me."

These results echo our previous two studies that authorship, selection, and sequencing of shared personal experiences reflect multiple interpretations of these experiences.

Psychosocial and Behavioral Effects

Participants expressed a number of perceived psychosocial effects from viewing the two SenseCam media conditions. Some reported changes in behavior and new insights into their condition that were both positive and negative. Ms. A repeatedly noted the benefits of reviewing SenseCam images: "When I watched the pictures I actually feel as though I am doing it again I remember a lot about it." These perceived effects led Ms. A to express that without the images, "I probably would have just had this empty feeling about each place we went to."

Some participants also noted that reviewing the images and the interview sessions gave them new insights into their impairment:

> It gave me . . . some insight I guess . . . about taking things in better, about focusing in better on what you are seeing. I think . . . I do a lot of not focusing, but then I don't remember, or very poorly. — Ms. S

Similarly Ms. A expressed that using the SenseCam could help her communicate to others about how she "felt it was going because my Alzheimer's will be progressing

at the same time." She further explained that the SenseCam might help her feel more comfortable in social situations. She recalled a recent family event in which she felt upset and left early, as she did not feel comfortable communicating:

> If I had had the camera I would have treated it as more a day like my cousins said it was a time for us to spend together and if I had had the camera I would have stayed and treated it more as an event rather than concentrating on my own inability to communicate properly that day.

Of interest, the experience of wearing SenseCam made a lasting impression on the behavior of Ms. A. Prior to the study she explained that she rarely took photographs and when "we get our photographs developed we don't keep them on the computer and . . . I would think I throw away 85 percent of the photographs we take because they don't mean anything to me." Following the experience of viewing SenseCam images of recent events, she began having her husband take photos of family events.

For other participants, confronting their impairment through the personal memory technology and our testing regiment was a difficult experience. Ms. S enjoyed the outings and reviewing the media but found the testing difficult. She felt she took "it too seriously" and was upset to the point of tears during some of the study measures. Similarly Ms. H revealed a lot about her fears and upsetting feelings about living with AD that, to her, were "verified when you all came in here." However, Ms. H also reported that the project helped her confront feelings about her condition and shared her reflections with us: "Number one you don't want to talk about it [AD], to anybody. Not to your friends, not to anybody. And you feel as if you are a leper."

Personal memory technologies can have a wide range of psychosocial impacts. For some, it led to positive reflections and feelings of autonomy. For others, it was a difficult experience, as it forced them to confront the extent of their cognitive impairments.

Reactions to Personal Memory Technologies

The majority of participants and caregivers found the SenseCam relatively easy to use. For example, the husband of Ms. S reported, "The camera was very simple to operate; you just had to be smart enough to turn it on. After I figured that out it was quite straightforward." However, a few participants noted that the buttons were too small and there was not enough feedback from the device to understand if it was working properly. The low resolution of the images was also a commonly reported downside.

Some remarked that integrating it into their lives would be relatively seamless.

> Oh yeah, because it's unobtrusive and I think people would just have to become accustomed to the fact that I'm wearing this thing around my neck. — Ms. A

Others reflected on the unique qualities of passive capture:

> If you are going on vacation, the ideal would be to have your own photographer along on the trip; so you can enjoy the trip and he can take the photographs or the images . . . if you are actually into the event you are not going to be taking photos. So things that you are really the most into, you will probably have the fewest photos of. That is the beauty of this SenseCam, it is taking images all the time. — Husband of Ms. S

Participants varied in their comparisons of SenseCam images to traditional still photographs. Ms. C noted that she enjoyed photo albums better than SenseCam. In contrast, Ms. A felt that SenseCam images have unique qualities over still photos. Although she began to take photographs of personal events following her experiences in the study, she found that these images did not have the same effect as SenseCam:

> Christmas was a real eye-opener for me because . . . we made sure we took a camera. I took some photographs and [husband's name] took some photographs and I didn't have the emotional connection to them at all. It was totally different when you show me the [SenseCam images]. I can feel like at the beach I can feel the breeze I can feel the temperature and hear the seagulls . . . with the photographs that I took it's like they're just photographs. — Ms. A

Although some participants noted difficulties operating the SenseCam, the majority had positive reactions that indicated they felt lifelogging technologies could be integrated into their everyday lives with relative ease. Although some participants preferred still photographs, others expressed that lifelogging technologies can have unique properties that trigger sensations that traditional technologies for personal memories do not.

6. DISCUSSION

Our three Digital Life Histories studies moved from familiar media such as photos and home movies to new capture and viewing devices and methods. The work demonstrates evaluation of constructs including memory, identity, family dynamics, and emotional well-being. Our research reveals recurring themes—the dynamic and reconstructive nature of life story narratives, the psychosocial impacts beyond support of recall, differing technology preferences and usability, and the importance of multiple stakeholders—which we discuss in turn.

Narratives of the past captured by these technologies are not just collection of facts for users to record, store, and remember, but also reconstructions of experiences that are subject to dynamic interpretations. The importance of multiple perspectives is also reflected in Harper et al. (2008a), who contended that lifelogging devices should not be considered as good or bad recorders of human memory but rather as devices that record the "past in particular ways." This view of personal memory technologies is

important in working with cognitively impaired persons and their families. Rather than perceiving these systems as replacements for the impaired memory of this population, we view them as supports for allowing cognitively impaired persons and their families to engage in stories of the past and select and author narratives as they desire.

In our first study we showed the potential for familiar technologies to support reminiscence, reflection, family dynamics, and communication. Our second study shows that novel personal memory technologies can also support constructs like identity without an accompanying improvement in memory abilities. Finally, our third study showed that personal memory technologies can support autobiographical memory but also revealed that the properties of the media and the authorship of the narrative can affect interpretations of past experiences.

We also learned that the design of current personal memory technologies could introduce usability difficulties. We made efforts to provide simple user interfaces and devices to our participants but found that even familiar technologies such as DVDs and TVs proved difficult for some users. Use of an ambient display in the second study removed many barriers to viewing the content but at the same time may be a repetitive or disruptive presence in the home. Novel personal memory technologies like SenseCam could also be improved to make operation and interaction more intuitive. Our first study revealed that producing personal memory media can be a time-consuming process, and some participants were more interested in sharing their MBs than others. Clearly, greater automation, more intuitive interfaces, and user controlled privacy settings should be considered in future designs and studies.

Our studies showed that personal memory technologies can have profound outcomes for more than the person whose life is depicted. The loved ones of our cognitively impaired participants were key members of each study. We learned equally from their experiences as we did from our participants. We were also surprised by the range of stakeholders these technologies affected, such as the unexpected use of MBs by third-party caregivers in our first study, and how Mr. H invited the mailman into his kitchen to "show off" his MB in the ambient display in the second study. We have come to see personal memory technologies as supports for both cognitively impaired persons and their broader social network of care.

7. DESIGN IMPLICATIONS

Based on lessons learned from our research and related work from other groups, we present design implications and ideas for future work on personal memory technologies. Implications respond to four questions:

- For whom are we designing?
- What capabilities should we support?
- Why do we choose these capabilities and not others?
- How do we build systems that can be maximally effective?

7.1. For Whom Are We Designing?

Designs for personal memory technologies should consider stakeholders beyond the individual (typically thought of as the primary end user) whose personal memory is being supported with a digital representation. As our work has shown, the data collected and conveyed through personal memory technologies can have impacts on a range of stakeholders including spouses or partners; children; other family members; and, in some cases, third-party caregivers. Stakeholders may also encompass individuals beyond the immediate domestic environment and include geographically distributed families. In these cases, considerations should be made for sharing personal memory media over distances. Our work and other studies on lifelogging within the context of family have shown collective reminiscence is an important activity that goes beyond recalling events to interpreting shared identities and sharing feelings of legacy (Lindley et al., 2009).

Another important consideration is how users in different stages of the life course will approach personal memory technologies. Whereas many lifelogging projects are designing systems intended to be used over the human lifetime (Gemmell, Bell, & Lueder, 2006; Mann et al., 2005), very little work has been done to explore how developmental changes may affect the practice of lifelogging. Our research has been inspired in part by Erikson's (1950) theory of developmental stages, which proposes that as we age, we encounter different goals and social roles that affect our conceptions of self. As personal memory technologies increase our ability to capture and store representations of our past, we must understand the changing ways we interact with these records as we progress along the life course. The end of the life course is also important. Once a person passes away, their personal memory technologies and data may be perceived and used differently by those who inherit them (Massimi & Baecker, 2010).

7.2. What Are We Designing?

Personal memory technologies should not be seen as devices for recording the "facts" of a life but as systems for supporting storytelling and narrative, thereby enabling meaning making. This conceptualization requires an individual to have the capabilities to select, highlight, rearrange, emphasize, and delete data in the personal memory technology. Various stakeholders may thereby create their own versions of "history," but so has it always been with other recording techniques. Digital personal memories must allow the repurposing of accounts of one's life for different stakeholders, different audiences, and different situations.

Providing users with ways to assert greater control over their personal digital information is becoming increasingly important, as we accumulate vast digital footprints that are highly distributed and often under the domain of third parties (Harper, Rodden, Rogers, & Sellen, 2008). As O'Hara, Tuffield, and Shadbolt (2008) argued, lifelogs may be an important means to reaffirm our digital identities. Designs for new personal memory technologies must be considered within this constant deluge

of information with sensitivities to how new methods and modalities of data capture and storage may affect the ways we convey and negotiate personal identities.

7.3. Why Are We Designing It?

The design of personal memory technologies must go beyond supporting single outcomes such as supporting the ability to recall experiences and to consider the wider range of constructs, such as memory, identity, personhood, family conversation, engagement, and intimacy. Framing these technologies as a means for portraying life experiences helps to illustrate the need for holistic design frameworks that take into account the multiple dimensions our life stories support.

Systems should also be designed with evaluation in mind, including opportunities for long-term evaluation in ecologically valid settings. This requirement implies the embedding of sufficient instrumentation to reconstruct precisely how it has been used. Evaluations should integrate multidisciplinary perspectives and methodologies to allow better understanding of the psychosocial impacts and societal implications of new personal memory technologies.

7.4. How Should We Be Designing It?

Technological developments provide opportunities for new modalities of personal memory technologies to capture information and convey it to users. Besides familiar media such as images, video, and audio, we now have new kinds such as geo-location, environmental data, and physiological indicators. Different methods of capture have also been explored, from active to passive techniques. These modalities and techniques can have profound effects on how we record and perceive personal experiences and may differ significantly from how we have previously viewed the past.

We have shown the potential benefits of mixing automated capture with narrative accounts and how multiple data streams can create greater opportunities for individuals to reflect on their experiences. We encourage further research on new capture techniques and modalities, and novel form factors and hardware for both capture and viewing devices. Devices like SenseCam have shown the effect novel hardware can have on user experience (Hodges & Villar, 2010). New devices will further change users' experience of the past, but small adjustments to existing technologies may also have significant effects. For example, how would users' experiences be changed if SenseCam technologies were embedded in glasses or otherwise benefit from eye gaze in order to obtain a better sense of the focus of a frame?

How users interact with representations of the past should also be considered. As computing moves from desktop and mobile models to being ubiquitously embedded in the environment, we should consider displaying and accessing representations of the past via wall displays, shrines, photo frames, jewelry, and clothing.

Decisions on how to proceed should be informed by our design principles of who, what, and why to consider possible impacts that different forms of data

collection and review may have on how we view the past. As these technological developments continue for personal memory technologies, interdisciplinary design frameworks that are sensitive to psychosocial, societal, and ethical considerations are critically important for assessing the full implications.

8. CONCLUSION

In the studies we have just outlined, we have had the opportunity to observe and report on emerging phenomena concerning personal memories and how they might be best represented in new forms of technology. Our work has focused on older adults with cognitive impairments. However, we believe that the lessons learned and design considerations we have outlined may also apply to healthy populations at various stages of the life course. Future work is needed to explore how different user populations may respond to our approach.

Our experiences corroborate arguments that technologists must consider the psychological impact of this new form of technology (Sellen & Whittaker, 2010). Indeed, reflection on our work suggests to us that a strict consideration of only the individual and his or her cognitive capabilities is to underestimate the potential power of digital personal memories. When we say personal memory technologies are not just personal, we mean to say that these technologies have profound interpersonal applications. When we suggest that personal memory technologies are not just for memory, we point to the potential for these systems to be used as representations of self, as legacies of a life lived, and as tools for communication and storytelling. In the design considerations presented here, we suggest the power of these technologies for personal memories rests not just in their ability to recall the past but to engage present happenings to create new meaning from a lifetime of experiences.

NOTES

Acknowledgments. We are grateful to Steve Hodges, Emma Berry, Georgina Browne, Gavin Smyth, Yaakov Stern, Peter Watson, and Ken Wood for guidance and encouragement; to Fady Akladios, Aha Blume, Sarah Chatland, Kante Easley, Anoop Ganda, Isabel Lam, Natalie Langlois, Simona Mindy, Kristin Ramdeem, Karen Louise Smith, Brandon Vasquez, Mark Watson, and Martin Yeung for research assistance; and to Alan Smeaton and Aiden Doherty for use of their image-processing package. We recognize the work of Elsa Marziali (co-primary investigator on the Multimedia Biographies project) and Renee Climans, who initially explored the development of multimedia histories of persons with AD, and Thecla Daminakis for her work on the Multimedia Biography project. We thank the anonymous reviewers of *Human–Computer Interaction* for their comments. Most important, we thank all the project participants and their families.

Support. The Multimedia Biographies project was financially supported by the Alzheimer's Association and Intel Corporation. We are grateful for financial support from Microsoft Research for the third project.

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HCI Editorial Record. First manuscript received December 13, 2010. Revision received June 20, 2011. Accepted by Elise van den Hoven. Final manuscript received December 15, 2011. — *Editor*

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