From Human Memory Aids to HCI

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Introduction

Throughout history, people have used memory aids and strategies to help them remember long strings of words or features that aren't inherently memorable. For example, some believe orators of epic poems used music and singing to help them remember the events of the story. People also use their environment to help remember. Writing is a way to store concepts in one's surroundings in order to recall them later. With the advent of human-centric technology and design, memory aids are moving from the simple strategies we all know, such as mnemonics and visual associations, to both workstations and wearable computer systems that actively augment the user's memory. In this paper, I give a brief overview of traditional memory aids, then discuss how the virtual reality, augmented reality, and human-computer interaction (HCI) communities have worked towards creating memory-enhancement devices.

Traditional Memory Aids and Strategies

To frame this discussion, let us define a few terms. The word memory can refer to either short-term store or long-term store or both, depending on the situation. Performance is considered high if memory tests have a higher rate of effectiveness, and performance is low if a memory test shows a lower rate of memory effectiveness. A memory aid is any strategy or tool consciously used that increases memory performance.

Memory aids can be split into two categories: internal and external. Internal memory aids act purely on the brain and its internal operations and structures, and do not involve any changes to the environment. These include such things as repetition and building associations between words. It's well-known in both psychological literature and common society that repetition improves one's ability to remember a given item or set of items. Another way to improve memory performance without external help is by building associations. For example, to more easily remember “Cole”, the name of a person with an obvious mole, one would build a phonetic or graphemic association between the words “mole” and “Cole”. In the process of remembering that person's name, one would then recall the person's face, remember the mole, then remember the link between “mole” and “Cole”.

External memory aids involve modifying one's environment in order to remember something. These include taking notes, writing reminders, setting clocks, and putting objects in a specific configuration or location. Some external aids are actually internal aids as well. For example, the act of taking notes causes memory of the information written down to be recalled more easily, even if the notes are not available during the test. Other external aids, such as setting clocks, schedule a specific sensory input intended to cause recollection at a future time. Memory aids based on technology are almost always external, because they depend on a certain environment or prosthetic device.

Technology as Memory Aid

The Early Stages

E-mail

E-mail, created to facilitate rapid, long-distance communication, introduces the concept of an accessible, fast, flexible message queue: the inbox. Over time, as people have grown to use e-mail more and more in their daily lives, it has evolved into a memory aid on top of its intended use. [Jovocic 2000] The inbox can be used as a todo list by leaving unhandled messages in it. For example, organizations use e-mail as a way to send announcements of meetings or events at specified times to members of that organization. If a member of the organization plans to attend, they leave the message there as a reminder to attend that meeting. Otherwise, they can just delete it so it never has to be dealt with again. The inbox can also be used as a post-it note system, if the user sends a reminder note to herself. Since the user will probably check their inbox multiple times per day, the message serves as a reminder to address the contents of that message. Conceptually, using the e-mail inbox as a memory aid is assumed to improve memory performance in two ways: repetition by seeing the message every time the inbox is checked; and a sensory reminder, just like a reminder note.

However, as e-mail is used more and more, it shows a large disadvantage as a memory aid: the sheer volume of messages that can pile up makes it nearly impossible for a human to efficiently locate and retrieve previous messages. This brings us to the next topic...

Indexing

A fundamental aspect of several memory-assisting technologies is the concept of "indexing". Indexing takes a large corpus of media, usually text, but sometimes video and audio segments, and searches through it, building associations that facilitate classification and rapid queries on content and relationships.

The field of text indexing is somewhat advanced, enabling rapid and generally correct queries of extremely large databases, such as the World Wide Web. The search engine Google, out of Stanford, is highly effective and efficient, searching taking only a fraction of a second. [Brin, Page] Text has also been successfully filtered for semantic content. [Foltz 1990]

One problem with text indexing is that most indexes use the graphemic aspects of a word or phrase to search rather than the semantic meaning. A modified spreading activation network as proposed in [Collins, Loftus 1975] can be used to search in a database for all words semantically similar to the search terms. [Ruge 1995]

Computer science has not quite gotten to the point where video and audio can be indexed in a very useful way. This could be because it's much harder to pull useful semantic information from video and audio. Multiple techniques and algorithms will have to be combined in order to successfully retrieve information from large multimedia databases. [Gabbe, Ginsberg, Robinson 1994]

As indexing technology gets better, technological memory aids will show direct benefits.

Prosthetics

Over time, computing hardware gets smaller, more power-efficient, and faster. In 1992, the Rank Xerox Research Center (RXRC) in Cambridge started work on a system to use a wearable computer as an aid to human memory by passively and unobtrusively capturing information about the environment that can later be used to recall specific details of which the user may have forgotten. In the workplace, it is thought that the easiest and yet costliest forgetting is that of names. [Brown and Bovey 1995] Also, as a person gets older, episodic memory performance goes down, while semantic memory stays relatively the same, [Erngrund, Mantyla, and Nilsson 1996] so memory-augmenting devices are expected to be more and more beneficial, A memory prosthesis is increasingly feasible, as the combination of small computer systems and growing storage densities allow several compressed streams of audio and many periodic snapshots from a camera to be stored on personal digital media. In fact, as of 2003, a single 2 GB portable drive can hold about five days worth of compressed audio and images. [Hoisko 2003]

Early Experiences of Visual Memory Prosthesis for Supporting Episodic Memory

[Hoisko 2003] describes early observations of a wearable computing system supporting human memory. His system is split into three conceptual components: the database engine, data collection, and the user interface. Since PDAs and wearable computers are not yet powerful enough to perform all tasks necessary for augmenting memory, the data is minimally processed on the portable computer and processed more deeply and effectively on a larger computer. The data collection engine involves one or more cameras, set to take digital snapshots every thirty seconds. Full motion video is still too large for current portable systems, but this is expected to change. Binaural microphones mounted on glasses continuously record the user's audio environment. (Binaural audio recordings are claimed to be much more effective at cuing recall than monaural ones.) Optional projection glasses were included in the system for viewing thumbnails of previous events.

I am not aware of any intensive, formal studies using a memory prosthetic such as Hoisko's. However, a limited set of people have tried similar systems for periods of time. One interesting observation is that while taking notes is much more effective than examining the visual recordings in a recall setting, examining visuals takes only a couple minutes. This makes the benefit-cost ratio for visual recordings high. Both notes and visual recordings can be used together for even better detail recall. Larger user studies using these observations can be prepared.

Hoisko mentions that a memory prosthetic is applicable to a wide temporal range of memory tasks. Short-range tasks include asking “Where did I park my car?” or “What did I have for lunch?” Long-term tasks can range up to several months. For example, “What did we discuss at the conference?” Autobiographical tasks range over several years. “What were the first words of our baby?”

Forget-me-not

RXRC's system is called “Forget-me-not” and is primarily led by Mik Lamming and Mike Flynn. [Lamming, Flynn 1994] As Hoisko's pre-review above addresses most of the issues involved in the design and implementation of a portable memory aid, I will only discuss elements of Forget-me-not's that we haven't yet touched.

An important contribution of portable computing is the additional context that can be stored along with any data. GPS locators can store your location throughout the day, which can be indexed for better queries. The question “Where was I last Tuesday?” becomes trivial to answer given storage of physical location versus time. Environmental status, such as weather pulled from the Internet, can be stored as well. Context data turns out to be an important part of all memory prostheses.

Wearable Digital Library of Personal Conversations

[Lin, Hauptmann 2002] briefly describes a system that Carnegie Mellon University has developed to unobtrusively record conversations and use face recognition algorithms to index the conversation with the name of the person so that it can be retrieved later. It uses a laptop computer in a backpack, a miniature camera for the face recognition, and two microphones: one for the speaker and one for the dialog partner. The system uses software for face recognition, voice identification, and speech recognition in order to store a transcript along with the data. The paper primarily focuses on the implementation details and the algorithms than actual usage data, but this research clearly fits into the umbrella of memory prosthetics.

Enhanced Environments

Stepping away from the paradigm of wearable computing as a constant aid to memory, some researchers have tried to enhance the workplace with additional communication and storage mechanisms and/or sensory input channels. These allow for higher memory performance, in turn leading to better long-term job performance.

The Infocockpit

Carnegie Mellon University and the University of Virginia teamed up to create the Infocockpit [Tan 2001]: an immersive workstation in which the user's workspace is augmented by sensory inputs, such as environmental visuals and sounds, as well as body-relative locational information. Their approach to HCI is that a good interface should make information easy to remember as well as easy to deal with. An interface designed to be usable *and* improve memory of the information within could improve task completion times over the long term, as opposed to improving performance in one isolated task.

The Infocockpit has two primary enabling components. The first is a set of multiple monitors arranged in a semicircle around the user. This forces the user to turn their body towards the information, which causes the mind to encode locational and orientational information along with the information on the display. The other part of the Infocockpit is a virtual environment around the workstation and displays. The user is surrounded by three projection displays and a six-channel audio system, used to show panoramic scenes and ambient sounds to give a sense of “place”.

In an initial user study, subjects were given a customized cued-recall memory test where there were three lists of ten cued target words. In the control condition, words were learned at a normal desktop computer. In the Infocockpit condition, words from a given list were learned on a specific LCD display with environmental input matching the name of that list. For example, in the list named “Museum”, the environmental display would look and sound like the inside of a museum. Once the subject had every word remembered, they were sent away to come back the next day, at which a standard cued-recall test was performed in a separate room. Users that studied the lists in the Infocockpit showed 56% better cued recall performance.

The Infocockpit experiment shows that controlled consistency and differentiability of contextual information can significantly improve memory performance in at least one situation.

MessyDesk/MessyBoard

Another couple systems at Carnegie Mellon designed to improve memory by giving a consistent context in which to work are the MessyDesk and MessyBoard. [Fass 2002] One problem with the Infocockpit above is that users are not willing to spend the time to create new contexts in which to work. The MessyDesk and MessyBoard allow the user to create context by decorating their virtual workspace in a persistent and collaborative way. MessyDesk is a replacement desktop environment that allows free-form decoration. MessyBoard is a large, projected, collaborative bulletin board that encourages shared information management and decoration. As in the Infocockpit, these systems are designed to encourage better memory of information dealt with when working by associating additional context with the work. MessyDesk and MessyBoard use three design criteria: 1) Contexts must be distinct, 2) The context should be meaningfully related to the work at hand, and 3) The user should put some effort into creating the context.

MessyDesk operates by allowing the user to drag content such as pictures and text onto the windows desktop and decorate it. This creates a context for the user, customized for the type of work and programs from which the decorations come. In informal user testing, it turns out that MessyDesk, while perhaps having context-related benefits, turns out to be more of a hassle than it's perceived worth. MessyBoard is an adaptation of MessyDesk that adds a new incentive to the existing decoration aspect: communication.

MessyBoard is a shared, digital bulletin board run from the users' desktop computers. Each team or project would maintain a single MessyBoard as a context in which to work. Through using it to organize information and pictures, a work-related context is created as a side effect.

The MessyDesk and MessyBoard systems have not yet been formally tested as to their memory effectiveness. Along with Infocockpit, however, they show that research in including contextual information as part of the work flow is being done. This may indicate that more emphasis in the human computer interaction community will be placed on systems that improve long-term performance by taking characteristics of human memory into account.

Spatial Audio in Conferences

Jessica Baldis at the University of Washington has done research into using spatialized audio in teleconference settings to see if it improves memory or comprehension of the discussion. [Baldis 2001] She bases her hypothesis on Baddeley and Hitch 1974, which splits working memory into two distinct slave systems: the phonological loop and the visuo-spatial sketch pad (VSSP). Because they're independent, they can be efficiently used in parallel. Thus, two tasks using the same subsystem will take longer than two tasks that can be partitioned onto both subsystems. Applying this theory to teleconferencing, it is hypothesized that using spatial audio will improve both memory and comprehension of the conference.

In a traditional teleconference, audio for all nonpresent persons comes from one source in the room. This requires the user to use the phonological loop for both determining who is speaking and comprehension. By incorporating spatial audio and having sound for each person come from a different part of the room, the VSSP can be utilized to determine who is speaking, leaving the phonological loop to focus on comprehension. To test this, Baldis executed an experiment.

The experiment brings up both memory and focal assurance, but I am only going to talk about the memory aspect. One at a time, each subject was placed in a closed off, sound-proof room with a single 21" CRT monitor. The monitor had four faces shown on it, each representing a voice in the teleconference. There were three conditions: non-spatial, co-located spacial, and scaled spatial. In the non-spatial case, all sounds came from one speaker. In the co-located spatial, the voice corresponding to a face on the monitor came from a speaker located directly above the face. The scaled spatial case was similar to the co-located spatial one, except that the speakers were placed farther apart. The results of the experiment show that the scaled spatial condition resulted in greater performance than the co-located spatial one, and both were significantly better than the non-spatial condition. Not only did the subjects remember which person had a given viewpoint and said certain lines better, they comprehended the discussion better.

To summarize, using spatial audio in a conference setting results in much higher comprehension and memory of the event. It is believed this is because spatial audio increased intelligibility, provided an additional cue for recall, and allowed for more efficient use of working memory.

Conclusions

We have discussed several memory aids, ranging from internal ones that don't depend on any external tools, external ones that require very basic technology, and the cutting edge of human computer interaction, virtual reality, and augmented reality. I make the claim that new research in HCI will have to take human memory models into account for even semi-accurate predictions of human behavior and memory. Strangely enough, in 1986, a “memory extender personal filing system” was developed long before wearable computers. It uses something similar to a spreading activation network to index relations between several documents and more closely match how humans perceive their documents. [Jones 1986] Surprisingly, memory models from the cognitive psychology literature are not totally pervasive in contemporary HCI, but I predict this will change as the technology becomes more reliable and available. The focus then will shift back to how to best apply the technology to the person.

References

[Baldis 2001] Baldis, Jessica J. (2001) Effects of Spatial Audio on Memory, Comprehension, and Preference during Desktop Conferences. *Proceedings of the SIGCHI conference on Human factors in computing systems.*

[Brin, Page] Brin, Sergey and Page, Lawrence. The Anatomy of a Large-Scale Hypertextual Web Search Engine. *http://www7.scu.edu.au/programme/fullpapers/1921/com1921.htm*

[Brown and Bovey 1995] Brown, P. J. and Bovey, J. D. (1995) Wearable Computers as an Aid to Human Memory. *Developments in Personal Systems, IEE Colloquium on, 23 Jun 1995*

[Collins, Loftus 1975] Collins, Allan M. and Loftus, Elizabeth F. (1975) A spreading-activation theory of semantic processing. *Psychological Review. Vol 82(6), Nov 1975, pp. 407-428*

[Erngrund, Mantyla, and Nilsson 1996] Erngrund, Karin; Maentylae, Timo; Nilsson, Lars-Goeran. (1996) Adult age differences in source recall: A population-based study. *Journals of Gerontology: Series B: Psychological Sciences & Social Sciences. Vol 51B(6), Nov 1996, pp. P335-P345*

[Fass 2002] Fass, Adam; Forlizzi, Jodi; Pausch, Randy. (2002) MessyDesk and MessyBoard: two designs inspired by the goal of improving human memory. *Proceedings of the conference on Designing interactive systems: processes, practices, methods, and techniques*

[Foltz 1990] Foltz, Peter W. (1990) Using Latent Semantic Indexing for Information Filtering. *ACM SIGOIS Bulletin, Proceedings of the conference on Office Information Systems, Volume 11 Issue 2-3*

[Gabbe, Ginsberg, Robinson 1994] Gabbe, John D. and Ginsberg, Allen, and Robinson, Bethany S. (1994) Towards Intelligent Recognition of Multimedia in Real-Time Applications. *Proceedings of the second ACM international conference on Multimedia.*

[Hoisko 2003] Hoisko, Jyrki. (2003) Early Experiences of Visual Memory Prosthesis for Supporting Episodic Memory. *International Journal of Human Computer Interaction* ***15(2)****: 209-230*

[Jones 1986] Jones, William P. (1986) The Memory Extender Personal Filing System. *CHI '86 Proceedings*.

[Jovovic 2000] Jovovic, Sasha. (2000) Role of Memory in Email Management. *CHI '00 extended abstracts on Human factors in computing systems.*

[Lamming, Flynn 1994] Lamming, Mik and Flynn, Mike. (1994) "Forget-me-not" Intimate Computing in Support of Human Memory. *Proceedings of FRIEND21, '94 International Symposium on Next Generation Human Interface.*

[Lin, Hauptmann 2002] Lin, Wei-hao and Hauptmann, Alexander G. (2002) A Wearable Digital Library of Personal Conversations. *Proceedings of the second ACM/IEEE-CS joint conference on Digital libraries.*

[Ruge 1995] Ruge, Gerda. (1995) Human Memory Models and Term Association. *Proceedings of the 18th annual international ACM SIGIR conference on Research and development in information retrieval.*

[Tan 2001] Tan, Desney S.; Stefanucci, Jeanine K.; Proffitt, Dennis R.; Pausch, Randy. (2001) The Infocockpit: Providing Location and Place to Aid Human Memory *Proceedings of the 2001 workshop on Percetive user interface.*