The Infocockpit: Providing Location and Place to Aid Human Memory

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ABSTRACT
Our work focuses on building and evaluating computer system interfaces that make information memorable. Psychology research tells us people remember spatially distributed information based on its location relative to their body, as well as the environment in which the information was learned. We apply these principles in the implementation of a multimodal prototype system, the Infocockpit (for "Information Cockpit"). The Infocockpit not only uses multiple monitors surrounding the user to engage human memory for location, but also provides ambient visual and auditory displays to engage human memory for place. We report a user study demonstrating a 56% increase in memory for information presented with our Infocockpit system as compared to a standard desktop system.

Keywords
Multimodal systems, spatially distributed information, human memory, human-computer interaction.

1. INTRODUCTION
We believe systems should be designed not only for usability, but also to make information more memorable. Current interface design has been tailored to usability, that is, making tasks immediately easy for users to perform [2]. The success of an interface has often been judged based on immediate usability measures such as task completion time and error rate. In order to optimize for these evaluation measures, interface design has focused largely on consistency, both in operation and appearance [1]. Consistency decreases demands on users' attention, so that the interface does not distract users from the information. However, much less emphasis has been placed on long-term effects, such as users' cognitive representations and information retention rates. As a result, although interfaces are easier to use, they make little effort to help users remember the information that they are meant to deliver.

We access our memories through cues acquired at the time we learn, or encode, the information. Memory retrieval works best when we have multiple cues for recalling information [16]. When we acquire information in the real world, we are inevitably located in a context. This context is incidentally encoded with the learned information and serves as a cue during memory retrieval [15]. Psychologists researching spatial memory have found that two important components of this context are *location* and *place*. Location refers to the positions of objects in the space around us. Place refers to the environment we inhabit at the time of encoding. Although they have not directly utilized location and place to provide memory cues, computer scientists have explored these concepts in the design of media spaces [6].

Figure 1. Infocockpit – Multiple monitors to create location; ambient visuals and audio to create place.

In our work, we aim to apply the above principles of human memory to designing user interfaces, and thus provide a better learning environment. As a demonstration of principle, we have built a prototype system, the *Infocockpit* (for "Information Cockpit"), which provides users with distinctive cues for both location and place to improve their recollection of material presented (see Figure 1). We conducted a user study that shows that Infocockpit users recalled 56% more information than traditional desktop users in a word pair recall task. In this task, we trained users on pairs of words, each containing a cue word and a target word. We tested users on how well they were able to later recall the target word when presented with the cue word.

2. CREATING LOCATION WITH MULTIPLE MONITORS
One of the memory cues that we hope to provide is location. As we interact with the world, we cannot help but notice the location of objects in space. With little effort, we almost automatically encode location along with the information we remember [9]. People trying to remember a particular passage of text will often

recall its position on the page [12]. However, they rarely recall which page it was on since the pages were stacked and occupied essentially the same position in space.

Current desktop systems present all information on a single monitor. Since windows are stacked, there are few spatial cues encoded with the information and no way of easily retrieving information by remembering where it was seen. Users manage multiple windows on the monitor in order to bring information to themselves. Chance et al. have shown that people have better memory of locations in 3D space if they turn their bodies rather than turning the world about them [3]. The presence of vestibular, proprioceptive, and somesthetic cues strongly affects spatial memory. Several interfaces, such as the Rooms metaphor [7] and Data Mountain [11], provide spatial cues by presenting a 3D space behind the single 2D display surface. However, these interfaces have had limited success because they do not provide the user-centered cues that help in remembering locations.

In contrast to current systems, we provide user-centered cues by surrounding users with multiple monitors. Distributing information around users forces them to orient themselves to the information. In doing so, they will inadvertently notice and encode the location of information. Thus, users are more likely to remember what they have seen by associating it with the location of the monitor on which it was presented.

3. CREATING PLACE WITH AMBIENT VISUALS AND AUDIO

The other memory cue we hope to provide is place. The incidental encoding of place, or environmental context, has been researched in psychology for the past few decades. Smith found that associations are made between information and the place in which it is learned [14]. These associations are incidental but provide useful retrieval cues when attempting to recall information.

In computer science, many researchers have recognized the importance of knowing the environmental context in which users work. For example, Lamming et al., in their Forget-me-not system, implement a portable ‘memory prosthesis’ that collects and organizes information about users’ context to form a biography [8]. Users may later inspect this biography to aid in the recollection of past events. Salber et al., in their Context Toolkit, attempt to define and standardize the notion of integrating environmental context with software components [13]. This toolkit supports development of context sensitive interactive systems. Others are working on perceptive user interfaces, giving human-like perceptual capabilities to computers so they may recognize and adapt to the context of the working environment [17].

In our work, we think about context differently. Rather than sensing the environmental context, we create it. By immersing the user in distinctive contexts, we synthetically provide useful places for creating memory associations. We believe that users must feel a sense of presence in our synthetic environments for such environments to serve as memory aids. Since we would prefer not to distract our users by drawing attention away from the focal information, we provide ambient sounds along with peripheral visual context. Davis et al. have already shown that environmental sounds facilitate recall even when they are not reinstated at time of retrieval [4].

4. IMPLEMENTATION: INFOCOCKPIT

We have constructed a system, the Infocockpit, which uses both location and place as memory aids and serves as proof of concept for our hypotheses. The Infocockpit is a configurable large screen multiple display system with two Appian Jeronimo Pro 4-port graphics cards, allowing one computer to drive 8 displays simultaneously. The current configuration consists of three focal LCD monitors surrounded by three ambient projection displays (see Figure 1). Both sets of displays are arrayed three across, with the LCD monitors directly below the projection surfaces. We picked this particular configuration to leverage people’s natural ability to locate objects egocentrically with respect to the cardinal directions – left, right, up, down, front, back [5]. The LCD monitors serve as the main working area on which users interact with information. The projection displays provide a horizontal viewing angle of approximately 145 degrees and are used primarily to immerse the user in a particular place. Our efforts so far have involved displaying panoramic images across the three projection displays.

We created and played back audio contexts using a Digidesign Pro Tools Mix24 [10] digital audio workstation running on a Macintosh G4. Each context contained 6 channels of sound that surrounded the user. Speakers were placed directly in front of the user at ear level and 4 feet above ear level, +/- 30 degrees at ear level, and +/- 120 degrees at 4 feet above ear level. The speakers at ear level were 5 feet away from the user; those above the user were 8 feet away. We are currently investigating less expensive playback systems.

5. USER STUDY

We have conducted an initial study to examine the effectiveness of the Infocockpit in helping users remember information. In this study, we tested users on their memory for pairs of words. We chose this task because the paired-associate paradigm is well understood in memory research. In this task, we first trained users on 3 lists, each with 10 word pairs. Each word pair consisted of a cue word and a target word. Users returned a day later to be tested for how many of the target words they could recall when given the appropriate cue words.

Words were chosen for their frequency in vernacular English. All three lists used the same 10 cue words. Doing so made it harder for users to remember the respective target words, which were unique across the three lists. As an example, valid pairs for the 3 lists were ‘plate – passenger’, ‘plate – string’, and ‘plate – scientist’. We named the lists *Lawn*, *Museum*, and *History* to help users parse the lists in memory.

The study had two conditions (*desktop* or *Infocockpit*), defined by the system on which users learned the word lists. One group learned the word lists on a desktop computer with a single monitor; the other learned on the Infocockpit. In the Infocockpit condition, users learned each list on a different monitor. For each list, they were also presented with a different panoramic image and ambient sound. For example, while users learned the Museum list on the center LCD monitor, they saw a panoramic photograph of the interior of a museum and heard ambient museum sounds.

We conducted the study in two phases: the learning phase and the recall phase. In the learning phase, the system presented the users with word pairs from the first list, each for 5 seconds. After exposing users to the words once, we trained them to ensure that all users had learned the lists completely. In this training, the system randomly presented the user with a cue word and asked for the associated target word. The system provided feedback either by confirming their answer as correct or by providing the right target word. This process continued until the user provided the target words for all the cue words in the given list. Users then repeated this process to learn the next list.

In order to allow users time for memory consolidation, we had each user return a day later for the recall phase. We tested the users on a laptop computer in a different room from the room in which they had learned the word lists on the previous day. To improve performance, users were shown each of the cue words for 5 seconds and asked to think about the associated target words. Then, we tested users on their ability to remember associated target words for each list separately (recall that each list had the same set of cue words). As with training, users were presented with the cue words and asked to type in the target words. In this phase, they were given no feedback on their responses.

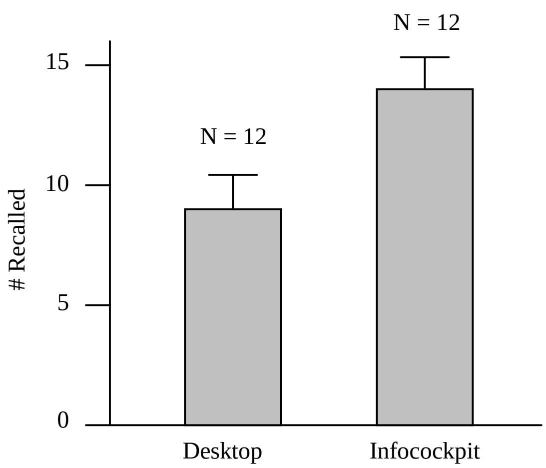

Figure 2. Infocockpit users recalled significantly more word pairs than desktop users.

Twenty-four (12M, 12F) undergraduate college students were paid for their participation. An equal number of males and females were randomly assigned to each condition. We found no significant difference between conditions in the time or number of iterations required to learn the lists to 100% criterion. There was a significant difference in number of pairs remembered between the two groups, $p = 0.04$, $F(1,23) = 4.72$. On average, participants in the single monitor condition remembered 9 word pairs out of the possible 30. Participants in the Infocockpit condition performed better, remembering 14 word pairs out of 30 (see Figure 2). This represents a 56% improvement in memory performance.

In addition, we also assessed how well Infocockpit users remembered where they learned each of the word pairs. In this test, users viewed a complete pair of words on the laptop and were asked to report the monitor on which they first learned the words. They did this for all of the thirty word pairs presented in random order. On average, users remembered the location of 20 out of 30 word pairs. In addition, the recall of location highly correlates with the number of target words they remembered correctly in the recall test, $r(10) = 0.880$, $p < 0.01$.

6. DISCUSSION AND FUTURE WORK

We have shown that users are better able to remember semantic information presented on our Infocockpit than on a standard desktop system. We believe this is because the memory cues that we are providing – location and place – are proving helpful in encoding and retrieving information. Without active effort, Infocockpit users showed increased recollection of information. The effect is statistically reliable and shows that memory may indeed be a means of evaluating the effectiveness of computer systems. It is important to note that there was no difference between the conditions in the time or number of trials required to learn the pairs. The Infocockpit did not influence the time or efficiency of learning the material. Its effect was solely on later recall.

We would like to identify the individual contributions of location and place to this significant effect. With respect to location, we plan to present information on three LCD monitors without synthetic place cues. Preliminary results confirm users' abilities to encode location of information presented on the three LCD monitors. We would like to verify this result and to understand how this extends to different numbers of locations.

We would also like to examine how well place aids memory by having users work without location cues on a single LCD monitor. We further hope to examine the effects that visual and auditory components individually have on the users' sense of place. Other members of our group are working on methods of automatically generating context and associating it to the information presented. These synthetic place cues will be compared to the place cues that users get from the real world, such as the room in which they perform the tasks.

Because we tested all users in a different context on a single monitor laptop in the user study, we did not explicitly provide any retrieval cues to users. We believe that memory could be improved further if we test users with the same system on which they learned the word pairs. We would like to explore the use of different devices in reinstating cues for location and place when users are away from the Infocockpit.

7. CONCLUSIONS

We have described the memory advantages associated with providing users with location and place cues at the time of information acquisition. With little effort, users encode these cues with the information they learn, making the information easier to later retrieve. We have described the Infocockpit as one possible implementation of computer system that utilizes these principles. In this system, we use multiple monitors surrounding the user to provide location cues as well as ambient multimodal displays to immerse the user in a synthetic place. We have also presented a user study showing that memory is indeed improved on the Infocockpit system as compared to a standard desktop system.

8. ACKNOWLEDGEMENTS

For their collaboration on this project, we would like to thank Adam Fass and Andrew Faulring of the Stage 3 Research Lab at Carnegie Mellon University; Tom Banton, Traci Downs, Steve Jacquot, Johnny Lee, Shawn O'Hargan, Evan Rapoport, Cedar Riener, Jessica Witt of the Proffitt Perception Lab at the University of Virginia; Chris Kyriakakis at the University of Southern California.

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