Title
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Abstract

Previous research in our lab (Tan, Stefanucci, Proffitt & Pausch, 2001) demonstrated that a multimodal prototype computer system, the InfoCockpit, could increase users' memory of information compared to a standard desktop computer. Displaying information on multiple monitors with ambient visual and auditory dispays engages context-dependent memory and memory for location, thus facilitating recall. We replicate this finding and isolate the memory cues to find whether the combination of contextual information and spatial location is necessary to obtain this memory advantage. Our findings show that contextual information alone provides users with the best strategy for later recall.

Introduction

In the past years, computer interfaces have been designed with the goal of promoting usability. These interfaces have a consistent "look and feel" that fosters usability but does not help the user remember information learned on the system. Our research examines a newly built interface, termed the InfoCockpit, which supports and aids human memory and performance while preserving usability.

The design of the InfoCockpit is based on psychological research that has uncovered many ways of improving memory through the use of spatial and environmental memory cues. These cues are incorporated into the InfoCockpit so that users can more easily recall information that they learn on the computer. This system provides users with "locations" and "places" to hook their memories onto without compromising usability.

Creating Place

Memories are tied to the environmental context in which they take place (Smith, Glenberg, & Bjork, 1978). For example, one might try to help a friend remember a conversation by referencing the context of that conversation (e.g. "don't you remember we talked about this at the coffee shop downtown?"). Having recalled the place of the conversation, the friend can more easily remember what was said. This strategy recruits an important cue for human memory; the context or "place" is a reference to start a search for the information discussed. Being in places, or referencing them, evokes memories and increases the chances of remembering information.

Psychologists have researched the use of environmental context as a cue for memory for the past few decades (Godden & Baddeley, 1975; Smith, Glenberg & Bjork, 1978). Smith (1979) found that people associate information and the environmental context in which it is learned. Although these associations are often incidental, they can be useful retrieval cues when recalling information. Smith (1982) also had participants encode information in multiple learning environments or different "places". He showed that the amount of information recalled increases when learning takes place in different contexts. In further studies, however, Smith (1984) found that recall performance in multiple learning contexts was not significantly improved when participants returned to the place that they were in at the time of encoding. Diverse learning environments provide a memory advantage over a single learning environment but this advantage is not contingent upon reinstatement of the context at retrieval.

In addition to the number of learning environments, contexts that are distinctive can also increase memory performance. Places that draw attention are the most effective in producing a memory advantage (Smith, Vela, & Williamson, 1988). Learning information through different sensory modalities can create a distinctive context. In addition to visual cues, ambient three-dimensional sounds can serve as distinctive cues for memory. It has been shown that ambient sounds enhance memory for visual information presented in their context (Davis, Scott, Pair, Hodges, & Oliverio, J., 1999).

Providing Location

Memories are also tied to a location in space (Gordon, 1903). Whereas we use "place" to denote an ambient environmental context, "location" refers to the position of information within that "place". We cannot help but notice, for example, the position of an object in a room. The location of that object in space is processed preattentively and remembered almost automatically (Logan, 1998). Similarly, most people comment that they can remember where on a page they read something without remembering the information they read. Several studies confirmed this anecdote by showing the reliability of spatial location as an important memory cue (Rothkopf, 1971; Zechmeister & McKillip, 1972). Given the evidence above, it follows that spatially distributed information is easier to remember than information presented in a single location (Gordon, 1903).

Combining Location and Place: The InfoCockpit

The InfoCockpit (see Figure 1) uses multiple projectors to display a panoramic image of a "place" onto large screens. It provides a context for users to reference when they are retrieving information from memory. Ambient three-dimensional surround sound is added to immerse the user in the place. For example, panoramas of a woodland scene are projected with consistent 3D sounds like leaves rustling, birds chirping, and insects. The InfoCockpit provides spatial cues by presenting information to users on multiple monitors. When learning the information, users inadvertently notice on which monitor information is presented. We hypothesized that users would be more likely to remember the information if they could recall on which monitor it was presented.

Figure 1. – The InfoCockpit uses multiple monitors to provide "location" cues and ambient visuals with three-dimensional sounds to create "place" cues.

This system stands in stark contrast to current desktop systems, which present all information to the user on a single monitor, and do not display a place cue. Desktop users do not have to orient themselves to information; windows simply bring information to them. There are no spatial cues encoded with the information and no way of easily retrieving information by remembering the context in which it was seen.

Previous research has not attempted to construct environments that present "location" and "place" cues to systematically examine whether a large effect can be obtained. In our lab, we combined these cues (location and place) to see if they produced a greater memory advantage than when presented independently (Tan, Stefanucci, Proffitt, Pausch, 2001). Tan et al. found that users of the InfoCockpit had a 56% improvement in memory performance when compared to users of a standard desktop computer.

The current paper addressed whether users of the InfoCockpit systematically relied on one cue over the other or if the combination of "location" and "place" was the best way to promote later recall. Each of the cues was examined in isolation to assess its solitary contribution to the larger effect. Based on our previous findings, we assumed that participants using the InfoCockpit would be able to remember more than participants using a standard desktop computer. And indeed, this was true. In addition, we hypothesized that "more is better"; participants in the InfoCockpit condition would remember significantly more word pairs than participants who received "location" or "place" cues in isolation. Contrary to our hypothesis, our experiment revealed that participants receiving only "place" cues performed significantly better than participants in all other conditions.

Method

Participants

Eighty University of Virginia students (40M, 40F) participated in the experiment. Participants were paid $20 for their participation. They were naïve to the purposes of the experiment and had not participated in a previous memory experiment like this one.

Apparatus

The apparatus used to display materials, the InfoCockpit, is a large multiple screen display system (see Figure 1). The displays are run from a Dell Precision Workstation with 620 Pentium III Xeon dual processors. Installed in the Dell are two Appian Jeronimo Pro 4-port graphics cards that allow the computer to drive the six display screens. Two sets of displays are arrayed three across, with NEC 18" LCD monitors directly below the projection surfaces. 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 to immerse the user in a particular place. Three Sharp Notevision 6 projectors (2200 lumens) display the context images on the projection screens.

We created and played back audio contexts on a Macintosh G4 using a Digidesign Pro Tools Mix24 digital audio workstation. The contextual environments were comprised of 6 channels of sound. Speakers were placed surrounding the user at ear level and at 4 feet above ear level, +/- 30 degrees at ear level, and +/- 120 degrees at 4 feet above ear level. The ear level speakers were 5 feet away from the user while the speakers above were 8 feet away.

Procedure

The experimental design consisted of two phases: a training phase and a testing phase.

Training Phase Participants learned three lists of words, each list containing ten pairs of words (all common, high frequency nouns). All participants learned the lists one at a time. Each list consisted of 10 cue words and 10 target words. The 10 cue words were the same for the 3 lists, but the target words varied from list to list (i.e. 'plate-passenger', 'plate-string', and 'plate-scientist'). We named the lists Lawn, Museum, and History to help the participants parse the lists in memory. For the participants in the InfoCockpit or Context conditions, these names referred to projected places.

The training phase consisted of both a study period and a learning period. During the study period participants were presented with each pair of words once (for 5 seconds each). After study was completed, the learning task began. One of the cue words from a pair was randomly presented to the participants. Participants then typed the target word that went with the cue. Feedback was given to the participants. If they were incorrect, the correct word was presented. Another cue word would then appear and they would have to type its target. This went on iteratively until participants had recalled all of the pairs correctly in one iteration (meeting 100% criteria). This ensured that all participants' knowledge of the material was equivalent before testing. Participants had unlimited time to finish the learning portion. The procedure for learning the word lists was explained to participants before training began.

Participants were assigned to one of four conditions (Desktop, InfoCockpit, Spatial, or Context) defined by the display configuration on which they learned pairs of words. An equal number of males and females were randomly assigned to each condition. Participants in the InfoCockpit group studied and learned the word lists, each on a different monitor and associated with different contextual images and sounds. For example, participants would see images and hear sounds from a museum while they were learning the word pairs for the "Museum" list on the middle monitor.

The Desktop group performed the task on a standard desktop computer with a single monitor. They learned the same three lists (Lawn, Museum, and History) on one screen, with no projected context images or three-dimensional sounds.

For the Spatial condition, participants learned the three word lists on different monitors. However, they did not learn the lists in different projected contexts. They also had no sounds. This condition was designed to assess the individual contribution of spatial cues in the InfoCockpit.

Participants in the Context condition learned the three lists on one monitor. Each list was presented with its corresponding context. Participants learned the lists with the projected context images and sounds, all on the same monitor. This condition tested the importance of contextual place cues on learning in the InfoCockpit.

Testing Phase The testing phase of the experiment took place a day later. All participants returned to the lab and were tested on how many word pairs they remembered from the training phase. Retrieval was done on a laptop in a different room than the training phase. Participants were given cue words from each of three lists, one list at a time, and were asked to type in as many of the targets as they could remember. They received no feedback on their performance.

Results

Out of 30 possible items, the mean recall scores were 8.80 for the Desktop group, 11.65 for the InfoCockpit group, 9.60 for the Spatial group, and 15.05 for the Context group. A one-way analysis of variance (ANOVA) comparing the four conditions revealed significant differences between the groups, $F(3, 76) = 9.065$, $p < 0.000$ (see Figure 2). Post hoc comparisons using the Fisher LSD test showed that participants in the Context condition recalled significantly more word pairs than the Spatial, Desktop and InfoCockpit conditions. In addition, the InfoCockpit condition remembered significantly more word pairs than the Desktop condition. A one-way analysis of variance (ANOVA) comparing number of iterations to learn the word pairs to criteria did not show a significant difference among the conditions, $p = 0.762$.

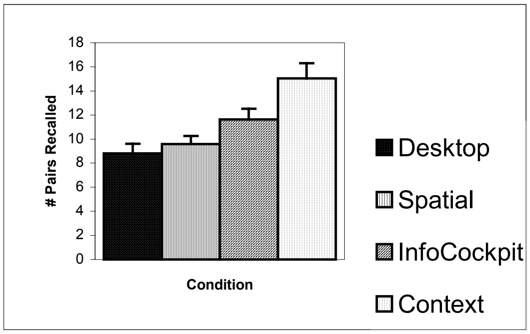

Figure 2. Number of word pairs recalled by each condition.

Discussion

InfoCockpit participants remembered significantly more word pairs than participants using a standard desktop computer. Adding "location" and "place" cues to a computer enhanced participants' memory for information learned on that system. This conclusion replicates previous research from our lab (Tan, Stefanucci, Proffitt, Pausch, 2001).

We assumed the individual components of the InfoCockpit would improve memory with relation to the standard desktop computer, but we did not believe they would be as effective as the ensemble of cues. Our hypothesis that "more is better" was incorrect for this task. Participants receiving only "place" cues at encoding recalled more words than participants in all other conditions.

This finding may be a consequence of the strategy the InfoCockpit participants used when retrieving the word pairs. We believe these participants had two strategies available at recall for remembering the information. One of the strategies involved the location of the list on one of the monitors. Participants could retrieve the appropriate target by recalling the location of the monitor on which it was learned. Likewise, InfoCockpit participants could access environmental place cues to recall the pairs. To remember the target word they could imagine the contextual images and sounds displayed when learning the pair. It is possible that these two recall strategies interfered with each other, compromising the best recall strategy (simply recalling the "place" cue) by the evoking the less effective location recall strategy. In the task we describe, the contextual place information was a more reliable cue for later recall and those participants in the Context condition were able to exploit it to the fullest.

While participants in the InfoCockpit condition performed better than participants in the standard desktop computer, they were not as successful as participants in the Context condition. Providing users with a single cue in isolation (place) was more effective than providing them with two sets of cues. This finding is not surprising given previous research. For instance, Jones (1976) and Smith (1984) found that isolated cues could help their participants retrieve an entire memory, even when combinations of cues were present at encoding. More recently, Parker and Gellatly (1997) showed that an increase in the amount of cues at encoding did not produce a reliable increase in recall. They gave their participants both music and odors while encoding information. At retrieval, either both or only one of the cues was reinstated. In either condition, participants recalled the same amount of information. In contrast, our findings suggest that participants receiving only one of the cues (place) at encoding had an advantage over the other conditions. The type of cue we used may account for the difference. Perhaps the place cue was more distinctive than the location cue and people were more successful in associating it with the words. The "more is better" approach to the design of computer interfaces should be examined closely because there may be situations in which a "less is more" attitude can augment performance to a higher degree.

Conclusions

The InfoCockpit increased memory compared to a standard desktop computer. It utilized both "place" and "location" cues to facilitate memory retrieval. When presented with "place" cues in isolation, participants' memory performance increased significantly in comparison to performance on the InfoCockpit. Providing multiple memory cues at encoding increases recall. However, interference between contextual and spatial cues may have a negative effect on performance. Evaluation of the interactions between cues, as well as the cues themselves, is necessary to ensure a complete understanding of the role that these cues play in memory.

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