Is a Picture Worth a Thousand Words?
An Evaluation of Information Awareness Displays

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Abstract

What makes a peripheral or ambient display more effective at presenting awareness information than another? Presently, little is known in this regard and techniques for evaluating these types of displays are just beginning to be developed. In this article, we focus on one aspect of a peripheral display's effectiveness—its ability to communicate information at a glance. We conducted an evaluation of the InfoCanvas, a peripheral display that conveys awareness information graphically as a form of information art, by assessing how well people recall information when it is presented for a brief period of time. We compare performance of the InfoCanvas to two other electronic information displays, a Web portal style and a text-based display, when each display was viewed for a short period of time. We found that participants noted and recalled significantly more information when presented by the InfoCanvas than by either of the other displays despite having to learn the additional graphical representations employed by the InfoCanvas.

Key words: Peripheral display, ambient display, information visualization, awareness information, empirical evaluation

1 Introduction

Peripheral awareness displays are systems that reside in a user's environment within the periphery of the user's attention. As such, the purpose of these displays is not for monitoring vital tasks. Rather, peripheral displays best serve as communication media that people can opportunistically examine to maintain information awareness [11, 17].

The term *ambient display* [22] has been used to describe systems like this as well, but to avoid confusion, throughout this document we use this term to describe peripheral awareness systems that generally convey only one piece of information. We use the term *peripheral display* to describe peripheral awareness systems that may present multiple information items. Both peripheral and ambient displays are designed not to distract people from their tasks at hand, but to be subtle, calm reminders that can be occasionally noticed. In addition to presenting information, the displays also frequently contribute to the aesthetics of the locale in which they are deployed [1].

Dozens of peripheral/ambient displays have been created in many shapes and form factors. Some displays, such as the dangling string [21], tangible displays including water lamps and pinwheels [4], and the Information Percolator [7] have utilized physical (and often everyday) objects. Other displays, such as Informative Artwork [8] and the Digital Family Portrait [16] use electronic displays to represent information in a graphical manner. All these systems primarily communicate one item of information.

Other peripheral/ambient displays exist that are capable of conveying more than one information item simultaneously. The Digital Family Portrait, although primarily intended to allow geographically separated family members maintain awareness of each other, allows for the optional displaying of additional information such as weather [16]. Audio cues, instead of visual displays, have also been utilized in peripheral displays to convey multiple nuggets of information in the Audio Aura system [15]. The Kandinsky system [5] attempts to create artistic collages of various pieces of information, and the Scope system is an abstract visualization displaying notification information from multiple sources [19]. SideShow [3] provides a display sidebar containing multiple awareness icons such as traffic and weather indicators.

The InfoCanvas [14], the focus of this article, differs from the initial set of systems above by explicitly promoting the conveyance of multiple pieces of information concurrently. It differs from the latter set of

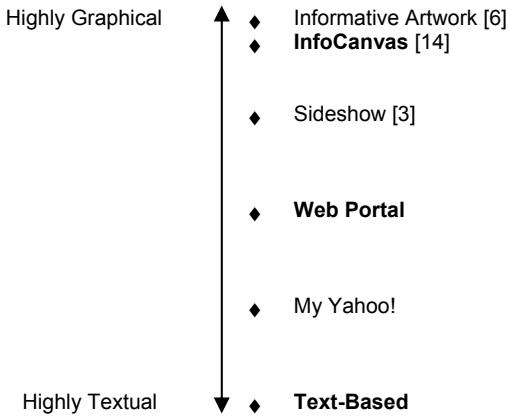

Figure 1: A spectrum of awareness displays ranging from textual to graphical presentations of information.

systems in promoting greater flexibility of information monitored and its subsequent visual representation, as well as allowing for greater user control in specifying those mappings.

Although many types of displays exist and new ones are being developed, little is known about what makes a particular peripheral/ambient display more successful at presenting information than another [10]. Furthermore, such displays are inherently difficult to evaluate formally since they are designed not to distract the user. As a result, evaluation techniques have been limited, as Mankoff *et al.* note [10], to formative ethnographies [16] and within-lab studies where displays are developed and subsequently refined over time by their designers [6]. However, there has been recent work on developing new evaluation techniques for ambient displays, most notably Mankoff *et al.*'s set of discount formative techniques [10] and McCrickard *et al.*'s notification system categorization framework [13].

The goal of this study is *not* to evaluate peripheral displays in general. Rather, we focus on one particular component of a peripheral display's effectiveness, its ability to communicate information. More specifically, we examine how the abstract data mappings of electronic information artwork affect people's interpretation and memory of the data.

Both the InfoCanvas [14] and the Informative Artwork [8] projects make use of dynamic pieces of electronic artwork to represent information in an eye-appealing manner. Such displays are placed within a person's work environment or are publicly displayed, enabling at-a-glance information awareness. How well the systems convey information is not known, however.

Note that the success of a peripheral/ambient display involves more than simple information acquisition. Because these displays are positioned in people's environments, aesthetics and attractiveness influence adoption as well. The research reported here, though, focuses solely on such displays' ability to convey information. In a companion study, the issues of aesthetics and longer-term use of the InfoCanvas system are currently being explored.

2 Experimental Design

This study examines if an electronic picture "is worth a thousand words." That is, how well are users able to learn mappings and subsequently comprehend and recall information when it is presented in the form of electronic artwork in comparison to more traditional methods. We accomplish this by designing an InfoCanvas display as well as two more conventional information displays and evaluating participants' memories of them when they only see the displays for short periods of time.

Study participants viewed three examples of each display with each example encoding different data values (described in detail in the next section). After viewing a display for eight seconds, participants recalled the information presented using a multiple-choice questionnaire.

2.1 Materials

Ten items of information were selected to be monitored: time of day, a weather forecast, a temperature forecast, traffic conditions, a news headline, the Dow Jones stock index value, an airfare price, updates to a Web site, a count of new emails, and a baseball score. These items are examples of information people typically seek to maintain awareness of [14].

Three information screens were designed including an InfoCanvas beach scene, a minimalist text-based display, and a Web portal-like display. These three displays were chosen to represent interesting points in a spectrum of possibilities, as depicted in Figure 1, for representing awareness information on electronic ambient displays. Styles range from pure textual presentations to highly abstract, graphical imagery. The InfoCanvas and the Text-based display inhabit positions near the endpoints of that spectrum. The Web Portal display was designed to incorporate a hybrid of textural and graphical representations, and resemble the types of Web "start pages" that people frequently use to maintain information awareness today [14].

Other interesting points in the spectrum include more direct graphical (typically iconic) representations of information as embodied by systems such as Sideshow [3], and could be the subject of future experiments. For this study, we compare the InfoCanvas to two widely deployed types, Web portals (e.g. MyYahoo!) and text-heavy news summaries or Web pages.

All three displays in the study were designed seeking a balance of experimental control and representation of ecologically valid real-world use. Extensive pilot testing and redesign was used to refine their appearance. We designed the three displays to encode the ten pieces of information in an appropriate manner for that display style. In all three, we added a small amount of extra information beyond the ten queried information values, much as similar real world displays would undoubtedly do.

All displays were presented full-screen on a Viewsonic 15" LCD display running at a resolution of 1024 x 768. The InfoCanvas used the entire screen area, and the other two displays used slightly less of the entire display as will be explained below. In the following subsections, we describe each of the displays in more detail.

InfoCanvas Display

The InfoCanvas system supports a variety of artistic scenes or themes. We chose to use a beach scene as shown in Figure 2 for the experiment due to its popularity with trial users. Individual objects in the scene represented the ten data values as follows:

- **Airfare price**: Represented by the vertical height of the kite in the sky from $0 (near the water level) to $400 (top of the screen).
- **News headline**: Shown on the banner behind the plane.
- **Time of day**: Denoted by the sailboat moving from the left side (12:01 AM) to the right side (11:59 PM).
- **Web site update**: Represented by the color of the leaves on the palm tree, green indicates a recent update and brown indicates no recent changes.
- **Weather forecast**: Illustrated through the actual weather shown in the sky (e.g., clouds represents a forecast of cloudy weather).
- **Temperature forecast**: Represented by the height of the large seagull in the sky, ranging from 50 degrees at water level to 90 degrees at the top of the screen.
- **Dow Jones stock market change**: Displayed by the arrangement of seashells on the shoreline. Shells form an arrow to indicate whether stocks are up or down and the quantity of shells indicates the value (three shells indicate a change of 0 – 50 points, five shells indicate a change of more than 50 points).
- **New email messages**: Depicted by the height of liquid in the glass ranging from 0 new emails (empty glass) to 20 new emails (a full glass).
- **Current traffic speed on a local roadway**: Symbolized by the color of the woman's bathing suit with red indicating speed less than 25 MPH, yellow indicating a speed between 25 and 50 MPH, and green indicating a speed greater than 50 MPH.
- **Baseball score**: Shown by the size of two beach balls: A larger ball indicates a winning team and identical ball sizes indicate a tied score. Color is used to distinguish the two teams.

These mappings were chosen to reflect a variety of objects moving or changing size or color. In addition, some mappings were chosen for being more intuitive and direct, such as using weather icons to represent weather or the metaphor of a kite flying in the sky to reflect airfare price. Other mappings, such as representing updates to a Website by tree leaf color, were intended to be more abstract and indirect. A pilot study of four InfoCanvas users revealed a wide variety of mapping styles, both natural and abstract. As a result, we wanted the scene used in this study to reflect this. Furthermore, as also done in actual use, we placed additional items in the scene such as the chair, umbrella, and crab simply for aesthetic purposes.

Several items within this display present information as a precise point along a continuous scale, including the time-of-day, airfare, and forecasted temperature, by displaying objects that move along a line. Other items, including the traffic speed, stock update, and baseball score, are represented using categorical encodings. For example, the different shell arrangements representing the Dow Jones stock update indicate four different ranges of values. The implications of this difference will be explored more fully later when describing the questionnaire formats.

Text-Based Display

The Text-based display (shown in Figure 2) predominantly uses text to display information. Web pages such as MyYahoo were the inspiration for the Text-based display, but the use of images, different colors, and graphics were removed. Thus, the display represents a position near the endpoint of the graphics-text spectrum presented earlier.

As a result, we restricted formatting on this display to changes in point size and the use of bold text with the exception of using a fixed-width font to indicate stock change values. (The fixed-width font helps to align numerical stock values, providing a clean and orderly appearance similar to the style used by existing services.) Extra information beyond the ten data values on this display included a few lines from a news article related to the current headline, the current date, and additional stock information for the Standard & Poor's 500 and

News

Iraq's Armed Forces Dissolved, U.S. Says

BAGHDAD, Iraq – The military that failed to protect Saddam Hussein's regime took its final fall Friday, as the American occupation force ordered the dismantling of the Iraqi army and the

Personal Finance

Dow Jones	8117.23	+64.0	+.99%
S & P 500	777.2	-3.30	-.15%
NASDAQ	1210.11	+1.23	+.28%

Today's Forecast

Temperature: 53
Conditions: Cloudy

Traffic Conditions

Average Speed: 62 MPH

Travel

Airfare from ATL to LAX
Lowest Price: $220

Communication

Photo Website: Unchanged
New Email Messages: 4

Sports

Atlanta Braves: 2
Pittsburgh Pirates: 1

Date & Time

Tuesday, September 8
3:34 AM

Date & Time

Monday, August 1
6:56 AM

Traffic
Current Conditions

Peachtree Hwy
Average Speed: 15

Communication
Email

New Email Messages: 16

Website Monitor

Family Photo Website
Recently Updated

News
Front Page News from MSNBC

Bali bombing suspect admits role

AKARTA, Indonesia -- A key suspect in last year's Bali attacks has admitted in court he was involved in the bombings.

Ali Ghufron, known by his alias Mukhlas, was testifying at the trial of Abu Bakar Ba'asyir, a Muslim cleric and the alleged spiritual head of Jemaah Islamiah (JI), the regional militant group agitating for a South East Asian Islamic state.

Personal Finance
Stock Quotes

Name	Last	Change	%Change
Dow	8257.67 ▼	-35.00	-1.91%
S&P 500	900.1 ▼	-2.90	-2.12%
NASDAQ	1183.29 ▼	-1.39	-0.75%

Weather
Forecasts

Rain
Temp: 88

Sports
Coverage from ESPN

Atlanta: 0
Pittsburgh: 0

Travel
Airline Fare (ATL to LAX)

Delta $62

Figure 2: Examples of the InfoCanvas beach scene (top), text-based (middle), and Web Portal displays (bottom) used in the study.

NASDAQ indices—items likely to appear on such a display.

The Text-based display consisted of a region 970 pixels wide to 330 pixels high on the screen. Pilot testing found this size optimal in allowing the use of columns, section headers, and white space to make an effective and visually pleasing display. Furthermore, pilot testing indicated that information recall suffered as the display's size increased, perhaps due to increased eye movement, even though the data elements remained located in the same position.

Web Portal Display

The Web Portal display (shown in Figure 2) also mimicked the look and feel of popular no-cost "start" Web pages such as My Yahoo. However, we added additional formatting and iconic graphics/images as found in awareness displays such as Sideshow [3] to differentiate this display from the Text-based display. Web portals, in actuality, tend to make relatively limited use of images and graphics. Our introduction of graphics and images served two main purposes—making the display more of a hybrid between the highly artistic InfoCanvas and a display utilizing only text, and also to increase the effectiveness of the design by using graphics to position items or convey information.

Graphics that encode values—those that change to reflect information—in the Web Portal display include the weather icon indicating the weather forecast, the speedometer icon with a meter indicating the current speed of vehicles, and an icon indicating the presence of new email messages. In addition, an image related to the news headline was displayed. Iconic images that did not change and were used solely as positional anchors included a picture frame icon for the Web site update item, baseball team logos, and an airline logo. In addition, colors and arrows were used to indicate stock trends and the baseball team currently winning was displayed in bold text.

The Web Portal display's extra information (e.g. not encoding the ten queried values) included a few lines of a news story related to the headline and the current date, and the two other stock indices as done in the Text-based display.

The Web Portal display used an area of 968 pixels wide by 386 pixels high on the display. Again, iterative development and pilot testing helped determine this size was best to create a balanced and ordered layout and be an effective presenter of information. As in the Text-based display, each element on the Web Portal display remained in the same relative position.

Design Considerations

As noted above, wherever we faced a design choice in creating the Web Portal and Text-based displays, we attempted to optimize the display to promote comprehension. For example, both the Web Portal and Text-based displays represent substantial improvements over real-life examples. The Web Portal design contained more graphics and images than what typically appears on these Web pages. Pilot subjects found these graphics and images to be beneficial in remembering information. Furthermore, individual items were modified during pilot testing to assist recall. For example, we made the size of the weather forecast image substantially larger than what is typically found on Web portals.

Likewise, we designed the Text-based display to be a substantial improvement over existing text-based information displays, such as tickers or small desktop window applications, by introducing columns, section headers, and white space.

Initial full-screen presentations used for the Web Portal and Text-based display tended to look unwieldy and resulted in lower recall of information during pilot testing. We attributed this to the larger screen area that participants had to visually parse. Hence, we reduced the screen area occupied by those displays to promote comprehension. Following that logic, InfoCanvas' larger size should have served to negatively impact its performance, if anything.

2.2 Participants

Forty-nine (11 female) individuals with normal or corrected-to-normal eyesight participated in this study. Participants ranged from 18 to 61 years of age (mean 24.2). 27 were graduate students, 17 were undergraduates, and 5 were non-students. Participants were compensated $10 for their time.

2.3 Procedure

Testing occurred in individual sessions lasting approximately 45 minutes. Participants sat two feet in front of the LCD monitor. The keyboard and mouse were removed from the area, leaving empty desk space between the participant and the display. The experimenter informed participants that they were participating in a study to determine how much they could remember from different information screens when they could only see the screen for a brief amount of time.

A within-subjects experimental design was used and the ordering of the display conditions was counterbalanced. Participants were randomly assigned to an ordering sequence. For each of the three displays, an in-

troductory tour, preparation task, and practice task were given prior to performing three actual trials.

The introductory session included an explanation of the display and the information found on it. For the InfoCanvas and Web Portal displays, the behaviors of the elements on the displays were also explained. Due to the display's more complex and dynamic nature, the introductory tour took longer to perform with the InfoCanvas, approximately 3.5 minutes in duration, than with the Web Portal and Text-based display, both approximately 1.5 minutes in duration.

Initially, especially with InfoCanvas, we had concerns that the introductory tour might not be sufficient to allow participants to learn each display. Pilot testing, however, revealed that participants were able to quickly learn the information mappings. To further ensure that we would be testing information comprehension and recall but not mapping recall with respect to the InfoCanvas, participants were asked to point out the different objects on a sample display and say aloud what information each object represented. We also provided participants with a reference sheet labeling the mappings between information and objects on the InfoCanvas. In practice, we found that participants seldom looked at the sheet and some actually turned it over.

During the preparation task, participants were shown an example display and instructed to complete a sample recall questionnaire (explained in more detail later in this section), much as they would in the actual trials. In this phase, however, no time limit was enforced for viewing the display. This task then allowed the participant to better familiarize him or herself with the display, the questionnaire style, and to ask additional questions regarding the display, all while it was visible.

Next, in the practice task, participants were exposed to what the actual trials would be like. A recall questionnaire was placed text side down in front of the participant and then an information display was shown for eight seconds. Pilot testing determined that this was a suitable amount of exposure time to avoid ceiling or floor effects, with recall averaging about five or six items. Furthermore, participants during pilot testing felt that this amount of time was indicative of the duration of a glance of a person seeking multiple information updates. Upon completion of the exposure, the computer prompted the individual to turn over and complete the recall sheet. Participants were instructed to not guess on the recall questionnaire; if the participant did not remember an item at all, he or she left that item blank on the questionnaire.

The actual trials followed the practice task and consisted of three exposure and recall activities involving different data sets and hence data displays. Again, specific emphasis was made to discourage the participant from guessing on the recall. The same data values were used for each position of the nine total experiment trials independent of the display ordering, ensuring a balance across the experiment.

"Exact Value"	**"Categorical"**
What is the status of the Dow Jones?	What is the status of the Dow Jones?
☐ + 89 points	☐ Up over 50 points
☐ + 42 points	☐ Up 0 – 50 points
☐ - 2 points	☐ Down 0 – 50 points
☐ - 75 points	☐ Down over 50 points

Figure 3: Example of exact value and categorical recall questions.

Upon completion of the three different display conditions, participants were given several concluding surveys that captured subjective feedback from the participants regarding perceived performance and display preferences.

Recall Task

Ten questions, one per each information item, were presented to participants after exposure to an information display. We varied the question topic order across trials to discourage participants from becoming accustomed to a particular topic being the subject of the first few questions and then seeking out information from the displays on those topics. While participants were not explicitly informed of this, the varied order came as no surprise when they performed actual trials since they had already encountered the recall sheet in the preparation and practice tasks.

To minimize cognitive load, the questions were designed to elicit the comprehension and recall of information in the same manner that it had been encoded. For all questions about the Text and Web Portal displays, and for the majority of questions about the InfoCanvas display, the question style was multiple-choice, typically including four exact-value answers spread relatively evenly across the range of possible answers. For instance, the potential answers for the time of day might have been 3:42am, 8:36am, 5:09pm, and 10:11pm. The newspaper headline question used four possible answers containing some similarity (usually using the same key words such as "Iraq" or "President Bush") to ensure the recall of the headline by context, not by recognition of a key word. The Web site update question simply asked whether the site had been updated, with yes and no as the possible answers. Finally, the baseball score question asked which team was currently winning and offered the choices of the Braves, Pirates, or tied game. The data values used to generate displays for the nine trials also were chosen to range across the possible set of values.

	1st Trial	2nd Trial	3rd Trial
Text-Based	5.14 (1.59)	5.12 (1.33)	5.02 (1.57)
Web Portal	5.67 (1.61)	5.65 (1.54)	5.29 (1.89)
InfoCanvas	6.27 (1.80)	6.22 (1.79)	6.31 (1.76)

Table 1: Means and standard deviations of correct responses for three trials of each display.

	1st Trial	2nd Trial	3rd Trial
Text-Based	11.47 (4.92)	11.78 (4.81)	10.57 (5.02)
Web Portal	12.88 (5.09)	12.35 (5.84)	11.27 (6.40)
InfoCanvas	13.88 (5.96)	14.02 (5.89)	13.82 (6.63)

Table 2. Means and standard deviations of correct responses for weighted scores for three trials of each display

For topics that the InfoCanvas presented categories or ranges of values (e.g., traffic conditions, baseball score, and stock updates), answer choices to the recall questions were also presented in the form of ranges. Figure 3 shows an example of how these differed using stocks as an example. Note how the exact-value answers lie within the intervals used; the questions and answers were designed to be as similar as possible. Furthermore, we felt that the more general issue of participants needing to translate pictures into exact, usually numeric, values would counter any benefit received by the InfoCanvas in using ranges for a few questions.

Adjacent to each multiple-choice question on the recall questionnaire was a confidence level scale with choices for high, medium, or low confidence. Participants were instructed to indicate their relative confidence for each item. We did this to further lessen the "guessing factor" and identify whether confidence would play a measure.

Following the nine cumulative trials for all three displays, participants completed a Likert scale survey rating all the displays for facilitating the recall of information, being an effective presenter of information, and visual appeal. In addition, participants rank-ordered each display for facilitating recall and visual appeal. Lastly, participants responded to open-ended questions regarding which display they would employ at their workstation or on a wall if a dedicated display would be available.

3 Results

Table 1 presents the means and standard deviations across all conditions of the raw number of correct responses for each of the three trials under each display. A repeated measures ANOVA identified an overall effect of the display for accurately recalled items, $F(2,96) = 22.21$, $MSE = 2.31$, $p < .0001$, and there was no effect for order. Additionally, pair-wise comparisons between display types found an advantage of the InfoCanvas display over the Web Portal, $F(1,48) = 14.65$, $MSE = 2.66$, $p < .0005$), the Web Portal over the Text-based display, $F(1,48) = 8.17$, $MSE = 1.76$, $p < .007$), and the InfoCanvas over the Text-based display, $F(1,48) = 40.01$, $MSE = 2.51$, $p < .0001$).

To take into account participants' confidence of their answers, a second method to evaluate performance was developed. Weights of value 3, 2, and 1 were assigned for the high, medium, and low confidence levels, respectively (e.g. a correct answer with medium confidence yielded +2 points, while an incorrect answer also with a medium confidence yielded –2 points). Questions not answered on the recall task were assigned a weighted score value of 0.

Participants forgot to assign a confidence on 13 of the 4410 responses collected in the study. Since this number of accidental omissions was quite low, items with omitted confidence ratings were assigned a medium level, the median of the obtainable point values. Of the 13 questions with omitted confidence, 3 were answered incorrectly.

In examining the weighted scores shown in Table 2, an overall effect was found on the display, $F(2,96) = 10.40$, $MSE = 25.35$, $p < .001$, and again there was no effect of order. Furthermore, pair-wise comparisons between the displays again found an advantage of the InfoCanvas display over the Web Portal, $F(1,48) = 7.29$, $MSE = 30.56$, $p = .0095$, and of the InfoCanvas display over the Text-based display, $F(1,48) = 22.21$, $MSE = 22.93$, $p < .0001$. However, the weighted scores gave no advantage of the Web Portal over the Text-based display, $F(1,48) = 2.59$, $MSE = 2.51$, $p = 0.11$.

Figure 3 presents an item-by-item breakdown of the percentage of correctly answered questions for each display. The InfoCanvas had the highest average on

Ease of Info. Recall	1	2	3	4	5	Mean
Text-Based	7	18	14	10	0	**2.6 (1.0)**
Web Portal	1	8	18	17	5	**3.3 (0.9)**
InfoCanvas	2	4	13	20	10	**3.7 (1.0)**
Effective Data Pres.	**1**	**2**	**3**	**4**	**5**	**Mean**
Text-Based	6	18	16	7	2	**2.6 (1.0)**
Web Portal	2	3	14	24	6	**3.6 (0.9)**
InfoCanvas	5	9	13	18	4	**3.1 (1.1)**
Visual Appeal	**1**	**2**	**3**	**4**	**5**	**Mean**
Text-Based	20	19	8	2	0	**1.8 (0.9)**
Web Portal	1	2	12	22	12	**3.9 (0.9)**
InfoCanvas	1	1	10	17	20	**4.1 (0.9)**

Table 3: Likert scale responses for display characteristics, with 1 = low rating and 5 = high rating.

seven of the ten items. The Web Portal score was higher on the time and baseball items, and the Text display was best for the airfare price.

Table 3 contains a breakdown of participants' Likert ratings captured during the post-experiment surveys. These results mirror the performance data with the InfoCanvas generally being rated higher with the exception that participants generally ranked the Web Portal higher as being a more effective presenter of data.

Participants' order rankings of the three displays for facilitation of recall and personal preference are shown in Table 4. Here, the Text-based display fared poorly along both dimensions. More participants preferred the Web Portal but rated the InfoCanvas as best for recall.

4 Discussion

Participants in the study recalled information best using the InfoCanvas display despite having the greater cognitive load of remembering mappings and representations used in the art paradigm. This cognitive load also includes translating pictorial InfoCanvas objects to the values used in the recall questions, while the two other displays presented data values more closely to the format of the questions. Even with these disadvantages, the InfoCanvas conveyed information better and was more vividly recalled.

Another possible interpretation is that the InfoCanvas system actually reduces the cognitive load of the individuals. In this scenario, it follows that it is easier and cognitively more efficient to remember and recall the InfoCanvas images, and then translate later to the values desired.

Regardless of their cognitive interpretation, the study's results should not be too surprising. People are able to process images rapidly by leveraging the sophisticated, parallel, and high-bandwidth nature of the perceptual system [20]. Umanath and Scamell showed that graphics are conducive towards recall tasks involving simple fact retrieval in a series of studies investigating the role of recall in real-time decision-making [18]. Furthermore, "ecological" layouts with objects in natural positions have been shown to facilitate faster browsing [2]. This study, however, confirms our intuition that the InfoCanvas, and displays like it, has potential to be an effective peripheral display where people seek to obtain information at a glance.

Several interesting observations emerged from the results of this study. We noted that participants generally expressed preference for the Web Portal display over the InfoCanvas display even though they felt that the InfoCanvas display had best facilitated the recall of information. When asked about this preference, one participant remarked that the Web Portal design was "more professional looking" and "more common than the other two." Other participants praised the Web Portal for its ability to display information in a more "logical and precise" manner and providing "accurate information that is not influenced by my interpretation." These comments seem to imply a conservative attitude about adopting a new and unconventional technology such as an ambient display

Other participants appeared to capture the essence of peripheral/ambient displays and their abilities to be subtle communication channels, not distracting a user. One participant remarked that, "I think I could choose to ignore it [InfoCanvas] while I was working. I think once I got used to what all the icons meant and what the scales were, I could easily look at it to see the information I was interested in." Others also echoed this sentiment: "[InfoCanvas] is the quickest and easiest to see at a glance the information you want" and "[InfoCanvas] is informative but also relaxing." Finally, one participant summarized the benefits of the InfoCanvas as being "able to keep working and not get distracted by details; [InfoCanvas is] faster to see and interpret from a distance."

In the context of this study, the InfoCanvas was evaluated on its abilities as an information purveyor. The mappings between information and graphical elements used in this study were designed by the authors, and as such, did not always feel instinctive to participants. Some participants indicated they had difficulty in learning the mappings; one participant remarked that "I struggled with the visual mappings" and another felt that InfoCanvas was "counterintuitive." As was mentioned earlier, this was a concern in the design of the

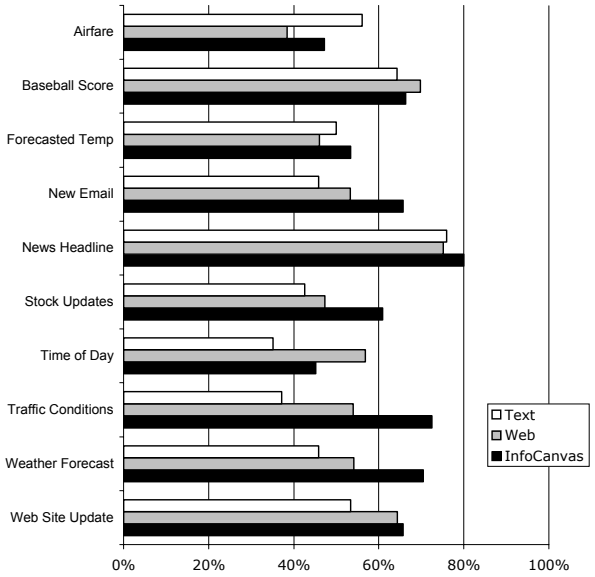

Figure 3. Mean percentage for correctly recalled items for each display type

	Text-based	Web Portal	InfoCanvas
Best Recall Facilitator	2 (4%)	16 (33%)	31 (63%)
Worst Recall Facilitator	41 (84%)	5 (10%)	3 (6%)
Most Preferred	2 (4%)	35 (71%)	12 (25%)
Least Preferred	35 (71%)	2 (4%)	12 (25%)

Table 4: Rankings of displays for facilitating recall and personal preference.

study—would individuals even be able to learn these mappings in such a short period of time? Pilot studies and the final study data both indicated that despite not being able to define their own mappings for the information, participants were able to recall more information when presented on the InfoCanvas.

A crucial implication lies in this; the InfoCanvas is designed to be a highly personalized peripheral display where users specify their own mappings and layouts. Since participants were able to recall information quite well when they did not specify the mappings, it seems logical to conclude that comprehension and recall would benefit even more when people design their own display and it is constantly present in their environment.

Several interesting discussion points arise from the breakdown of correctly recalled items shown in Figure 3. First, note that on the whole, the InfoCanvas yielded the largest percentage of correctly recalled items per category, with the exception of the airfare, time of day, and baseball score items. However, performance of the three displays on the baseball score item was comparable, averaging a recall rate of 64-70%. In regards to the airfare and time of day items, the InfoCanvas produced the second best percentage of correctly recalled items and was outperformed by the Text and Web Portal displays, respectively. Slightly lower performance was somewhat expected with these two items, since their representations moved along a straight line to indicate a point on a scale. Pilot participants often remarked that these representations were more difficult to keep track of since they could be found in different areas. Interestingly, even with these representations, the InfoCanvas performed better than the Web Portal (for the airfare item) and the Text display (for the time item), indicating that despite their moving nature, graphical representations still worked relatively well. The temperature element, also represented by a moving object, illustrates this point as well, generating a higher recall than the other displays.

Interestingly, the InfoCanvas appeared to have the largest advantage over the other two displays with the traffic conditions item. While some may argue that this is due to the use of intervals to represent conditions, as opposed to the exact-value representations on the Web Portal and Text displays, note that the use of intervals for the baseball score did not yield such an effect. This difference implies that the representation used to indicate traffic conditions—the color of the woman's bathing suit—provided an excellent mapping. Therefore, we speculate that if individuals create their own mappings, leveraging their personal experiences, recall with InfoCanvas will benefit even more.

This study examined the information conveyance abilities of three specific examples of displays involving a sample population consisting mainly of academic-related, relatively young individuals. Generalizing its findings too much would be unwise. Nevertheless, we speculate that the results would extend to other similar types of displays and people of different demographics.

The lessons learned from this study could be applied to the design of new information systems. For example, in designing a system using a docked PDA as an information display, a graphical representation of information, such as using a miniature InfoCanvas, might convey information more effectively than a traditional text-based manner.

5 Conclusion and Future Work

In this paper, we present a formal evaluation of information recall from three different electronic information displays, the InfoCanvas, a Web Portal-like, and a Text-based display. We present results indicating that participants comprehended and recalled more awareness information when it was represented in graphical manners; participants recalled more information from the InfoCanvas display than the Web Portal and Text-based displays. Likewise, participants recalled more information from the Web Portal display than the Text-based display. Our results suggest that there are benefits for comprehension, when a person may only glance at a display for a short period of time, by displaying information in a highly graphical or stylized nature.

A number of potential directions for follow-on work exist. It would be interesting to compare a more abstract graphical presentation of information as embodied by the InfoCanvas with a purely graphical, but more direct iconic encoding, such as in Sideshow [3].

In this study, we positioned the information displays directly in front of participants. Another possible experiment could position the display further away, perhaps on a neighboring wall, from the person's main computer display. Yet another possibility is to introduce an explicit primary task thus making information comprehension more truly peripheral. For instance, participants could perform a primary task such as document editing while information is presented for comprehension and recall on a display in another location as done in several other studies [9,12].

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