Evaluating Animation in the Periphery as a Mechanism for Maintaining Awareness

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Abstract: Small animated displays such as tickers and faders are increasingly being used to convey information on computer screens. Relatively little is understood, however, about their use as peripheral displays, that is, tools for communicating lower-priority awareness information to people. This article describes two experiments that examine the tradeoff of communication capability versus distraction in peripheral displays. We found that the presence of animated textual peripheral displays did not distract people from a central information browsing task, and we identified particular animation and display characteristics that facilitate different information-centric tasks.

Keywords: peripheral displays, awareness, monitoring, animation, empirical evaluation, dual-task evaluation

1 Introduction

People naturally wish to stay continually informed of ongoing events of interest. For instance, an office worker may want to stay appraised of the weather outside, the traffic situation for the ride home, how certain stocks are performing, or how well a favorite team is playing. While people may want to maintain awareness of such information, or perhaps even monitor it intermittently, such awareness ideally should not distract them from their primary work or task.

A variety of information communication devices have been developed to help people maintain a sense of casual awareness of interesting information. The classic examples of these types of devices are email alerts, load monitors, and stock tickers. More recently, similar displays use visual and audio presentation methods to show news, weather, sports, personal data, and other information in a small portion of the desktop (Greenberg, 1996; McCrickard, 1999; Zhao & Stasko, 2000). Also becoming prevalent are off-the-desktop interfaces that use objects in the environment and changes in lighting or background noise to communicate anything from network traffic to traffic in the hallways (Ishii & Ulmer, 1997; Heiner et al., 1999).

Our focus in this article is a set of peripheral communication techniques used on computer displays that we call *peripheral displays*. Typically, peripheral displays use very little screen real estate, but they still attempt to convey a fairly large amount of information. Often, this translates into some use of animation to cycle through items of interest via scrolling or fading techniques.

While animation has been shown to be a strong perceptive attention draw that consequently may distract people from their primary task (Ware et al., 1992), it has also proven to be an effective way to show large amounts of information in a small space (Robertson et al., 1993). Researchers have speculated that smooth animations would not be overly distracting (Fitzpatrick et al., 2001), and organizations like Yahoo, ESPN, and AOL provide tickering and fading desktop displays that show continuously updated news headlines, stock quotes, sports scores, weather reports, and the computer activity of friends. There are even toolkits that help enable programmers to include these and similar techniques into their interfaces (Fitzpatrick et al., 1998; McCrickard & Zhao, 2000).

While numerous studies have examined people's willingness to use peripheral displays in maintaining awareness (for example (Parsowith et al., 1998; McCrickard et al., 1999)), relatively little research has been conducted to understand better the information communication versus distraction tradeoff for different techniques of peripheral communication. Our goal is to explore the balance between distraction, reaction, and comprehension for different animated peripheral displays via empirical evaluations of realistic but controlled situations. This paper describes several such evaluations that asked participants to search hypertext spaces for answers to a series of questions while completing activities and answering questions based on information in peripheral displays.

2 Related work

Some of the earliest evaluations of constantly changing displays examined the perceptibility and readability of rapid serial visual presentations (RSVPs) of letters, strings, and words. Foster found that participants could correctly identify about four out of six words in a sentence when rapidly presented a word at a time in a single visual location (Foster, 1970). Juola also found that comprehension of information was comparable when presented as RSVPs and in multi-line paragraph format (Juola et al., 1982). In some of the first studies of smoother animated effects, Duchnicky and Kolers performed a series of experiments examining the readability of text scrolled on visual display terminals as a function of window size (Duchnicky & Kolers, 1983). They found that larger displays typically led to faster performance on reading tasks. A study led by Granaas found that in scrolled displays, larger jumps (four to ten characters) led to better comprehension than smaller jumps (one to two characters) (Granaas et al., 1984). Kang and Muter, in comparing a tickering effect to a non-animated RSVP effect, found no difference in comprehension for a reading task (Kang & Muter, 1989). These experiments addressed many important factors that we explore further in our research, including different informational tasks (recognition and comprehension), different sized displays, and different ways to change the display.

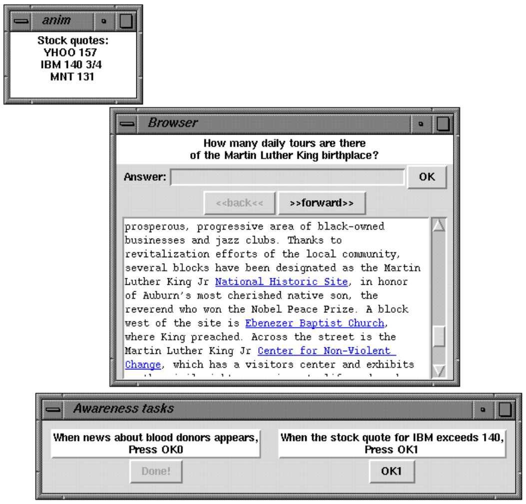
All the previously mentioned evaluations considered the reading of small animated displays as the sole task of the participant. However, in the case of peripheral displays, participants would be performing some main task with attention to a small animated display part of a secondary task. One experiment with this type of dual-task scenario was conducted with OwnTime, a peripheral timespace management system that alerts people when visitors are waiting to meet with them (Rodenstein et al., 1999). The study found that OwnTime visitor interactions were less intrusive than direct engagement for participants performing recall and comprehension tasks. The research of Bartram et al considered the effectiveness of using motion cues to draw attention (Bartram et al., 2001). They found that motion cues outperform static representations and that certain types of motions are more distracting and irritating than others.

In other work, Maglio and Campbell performed a series of dual-task experiments in which participants performed document editing tasks while a peripheral display showed news headlines later used to answer questions (Maglio & Campbell, 2000). The peripheral displays included a continually scrolling display that jumped five pixels per step, a start-and-stop scrolling display that briefly paused when each headline appeared on the screen, and a fading display that increased the brightness of the text to make it visible. They found no difference in the communication abilities of different peripheral displays (as measured by how well information is remembered). Also, all of the animated peripheral displays were found to be distracting to the main task of document editing, though the start-and-stop display was the least distracting.

Research on the effects of Instant Messaging (IM) notifications on desktop computer tasks found that IM typically was disruptive to primary tasks, particularly so for fast, stimulus-driven search tasks similar to the ones in the Maglio experiments (Cutrell et al., 2001). However, IM does not use smooth animation in its updates, which may have excaberated the distraction. Our study examined whether a slower, semantic-based search task is affected by various smooth peripheral displays, and whether the peripheral displays can effectively communicate information to users.

3 Experiments

To examine whether animated displays impact information acquisition when maintaining awareness, two empirical evaluations were conducted. Participants were asked to complete a series of browsing tasks while simultaneously keeping abreast of a peripheral display showing constantly changing news, weather, stock, and sports information. We utilized three peripheral displays in these experiments: a tickering display that horizontally moves information across the screen, a fading display that gradually fades between pieces of information, and a RSVP-style "blast" that switches between items in the display without smooth animation. For the tickering effect, we employed a smooth animation that repeatedly moves the text a pixel at a time in an attempt to minimize distraction. The early previously-described studies typically tickered a display by several characters at a time (Duchnicky & Kolers, 1983; Granaas et al., 1984; Kang & Muter, 1989), and even Maglio and Campbell's 5-pixel jump when scrolling creates a jerky effect that may have resulted in unnecessary distraction (Maglio & Campbell, 2000). Prior work has noted that people tend to perform better on certain decision-making tasks with smoother animations (Gonzalez, 1996). We suspect that smooth animations may prove to be less distracting than the ones used in prior work.



Stock quotes:
YHOO 157
IBM 140 3/4
MNT 131

How many daily tours are there
of the Martin Luther King birthplace?

Answer:

prosperous, progressive area of black-owned businesses and jazz clubs. Thanks to revitalization efforts of the local community, several blocks have been designated as the Martin Luther King Jr National Historic Site, in honor of Auburn's most cherished native son, the reverend who won the Nobel Peace Prize. A block west of the site is Ebenezer Baptist Church, where King preached. Across the street is the Martin Luther King Jr Center for Non-Violent Change, which has a visitors center and exhibits

When news about blood donors appears,
Press OK0

When the stock quote for IBM exceeds 140,
Press OK1

Figure 1: Layout of the experimental environment experienced by participants. At the center is the browser used by the participants in the experiment. At the top of the screen is the fade peripheral display that cyclically showed the state of several types of information. At the bottom is the area used for monitoring activities. After each round, the screen cleared except for a question area where the awareness questions were presented.

Participants used the information presented in the peripheral display to complete short-term monitoring-style awareness activities (monitoring activities) and to answer longer-term knowledge-gain questions (awareness questions). The experiments consisted of several rounds (six in the first experiment, eight in the second), each consisting of four browsing tasks, two monitoring activities, and up to five awareness questions. The layout of the information on the computer screen is in Figure 1. Motivations for our experimental choices follow.

3.1 Browsing tasks

In performing the browsing tasks, participants used a simple browser and hypertext pages. The browser consisted of a textual information area containing a number of condensed pages from World Wide Web sites. The text-only information area contained highlighted, underlined links that pulled up other pages when clicked with the mouse. The participants navigated the information space by clicking on the links and by using the forward and back buttons. The browsing tasks were non-trivial: the participants had to read and navigate through a hypertext space to find certain information in the pages, enter it into a box connected with the browser, and press a button to continue.

To minimize the typing required, all solutions to browsing task questions were numerical (for example, “In what year was Mount Rushmore carved?”) If an incorrect answer was entered, the interface beeped and the participant had to continue working on the problem until the correct answer was entered. When the correct answer was entered, the participant could proceed to the next browsing task. The order in which browsing tasks were presented was held constant for all participants.

3.2 Monitoring activities

While performing the browsing tasks, the participants used information in the peripheral display to complete a set of monitoring activities and to answer a series of awareness questions. The peripheral display cyclically showed instances of different types of information, such as a sports score, a stock quote, and a weather report. Each instance was updated frequently but irregularly as it often is in real life. Participants were asked to press a button when the information in the peripheral display matched some criteria (for example, “When the temperature drops below 35, press OK1.”) The information that was selected for display was interesting but rarely vital, and the informational occurrences that were selected were chosen because they might spur a user to perform some real-life activity, such as bringing in a plant that is outdoors or selling a stock that is performing poorly.

Each round included two such monitoring activities. The order in which monitoring activities were presented was held constant for all participants. If the button was pressed at the correct time (that is, after the needed information was presented), it was greyed out to alert the participant that the task had been completed successfully. If the button was pressed too soon, the interface beeped and the button remained active.

3.3 Awareness questions

At the end of each round, the participants were given awareness questions that asked them to recall information that was shown in the peripheral display. The questions were multiple-answer multiple-choice questions that addressed both content and temporal issues. Each question had four possible answers, all initially unselected, and there was always at least one correct answer.

The first question in each set listed four types of information and asked the participant to choose the ones that had been displayed. If they correctly recalled seeing information, later questions asked about details of it, such as which news stories appeared, which stock quotes constantly increased, or which sports team scored the most points. For example, if a participant correctly noted that news headlines had been displayed, later questions would present a list of headlines and ask the participant to select the ones that had appeared. All of the information was fictional but realistic, and no attempt was made to intentionally deceive the participants with slightly different information (for example, a stock quote that almost always increased).

3.4 Data collection and evaluation

To compare performance among groups, the dependent variables were the times for all browsing tasks and monitoring activities and the answers to the post-round awareness questions. The results were analyzed to determine whether differences in certain measures occurred for participants in different conditions (participants using different types of peripheral displays in the first experiment, and participants using different sizes and speeds in the second).

The *browsing time* is the time from which the browsing task and browser information appeared on the screen to the time when the participant typed in the correct answer and pressed the OK button. The *monitoring time* is the time from when the information was first entered into the cyclic display until the information was acknowledged as matching the current criterion via a button press.

For the awareness questions, the participants’ responses to each of the four answers were collected. We considered each question as being worth four points: correctly or incorrectly assessing each possible response to a question.

A number of different methods can be used to determine a participant’s ability to recall information. The most obvious measure is to compare the percent of correct responses for the awareness questions in different situations. The percent of correct responses is referred to as the *correctness rate*.

The correctness rate measure potentially can misrepresent a participant’s awareness of information, however. Note that a participant who did not remember seeing anything in the peripheral display and left all responses unchecked could have a correctness rate as high or higher than a participant who remembered seeing several items but was mistaken about what was seen and checked the wrong box(es).

An alternate measure for determining responsiveness is the *hit rate*, a term from signal detection theory defined as the ratio of correctly identified stimuli to the total number of times the stimulus was presented. The hit rate is typically accompanied by the *false alarm rate*, the ratio of incorrect stimuli responses to the total number of times when the stimulus was not present. Since a typical goal when using a peripheral display is to proactively recall seeing information, it may be better for a participant to be mistaken about seeing information that was not displayed than to be mistaken about not seeing information that in fact was displayed. Perhaps a person wants to remember that a story occurred, or that a tornado watch is under way, or that a traffic bulletin appeared. The hit rate would reflect the awareness potential of an animated display.

In analyzing the results, analyses of variance (ANOVAs) were performed to check for statistical significance among different conditions of the experiments. If the ANOVA revealed a significant difference, pairwise t-tests were performed to determine which conditions differed.

3.5 Experiment 1

The first experiment compared relative performance when using fading, tickering, and blasting displays as well as when no peripheral display was present.

3.5.1 Method

This experiment focused on three factors: the possibility for degradation in performance on a browsing task when a peripheral display was present, the speed in identifying and reacting to changes in peripheral displays, and the ability to remember information that appeared in a peripheral display.

Seventy undergraduate students participated in this experiment for class credit. The experiment was conducted on identical workstations, each connected to a 15-inch monitor with an optical mouse. Participants were run in small groups, one participant per computer. The experiment was explained to each group verbally and again on the computer with examples.

The participants performed six rounds of browsing tasks, monitoring activities, and awareness questions. In each round, participants completed four browsing tasks while performing two monitoring activities using either a fade, ticker, or a blast animation. The speed with which the information was displayed corresponded to the mean speeds for each device selected by the participants in a previous study (McCrickard, 2000). While this resulted in different rates of information display for the animations, we felt it was a more realistic and ecologically valid measure of how people would use them. The ticker continually shifted one pixel every 50 milliseconds, while the fade and blast updated their entire contents every 2 seconds. The fade required 500 milliseconds to fade between items, while the blast updated instantaneously.

At the end of each round, participants answered awareness questions about the information that appeared in the animated display. The first question asked which types of information appeared in the display. For each correctly-identified instance of information appearing, two questions about the information were asked up to a total of five questions.

As a base case, one group of participants ($n = 15$) did not have any animations present at any time and as such performed only the browsing tasks. For the other groups, all participants experienced all animations, with orders based on a latin square design (blast - fade - ticker ($n = 17$), fade - ticker - blast ($n = 17$), or ticker - blast - fade ($n = 21$)). A different animation was used for each of the first three rounds with the order repeated on the last three.

3.5.2 Results

For the time required to carry out the browsing tasks, there was not a significant impact due to the presence of a peripheral animated display ($F(3,58) = 0.60$, $MSE = 46277.71$, $p = .62$). Furthermore, the type of animation did not affect the browsing times ($F(2,46) = 0.62$, $MSE = 25411.63$, $p = .54$), (see Figure 2).

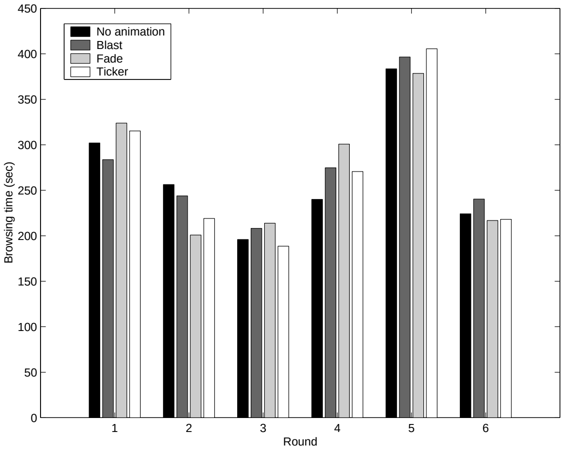


Figure 2: Average completion times for browsing tasks for each round based on the type of animation that was present. Participants performed about the same on the browsing tasks regardless of the type or even the presence of animation. By showing the rounds individually, one can see that there is not even a trend to suggest that participants performed better in certain cases.

In the monitoring activities, participants pressed a button when they noticed specified information in a peripheral display. Since a round ended when the browsing tasks were completed, it was possible that not all of the monitoring activities were completed, meaning it was possible that some types of peripheral displays led to more activities completed than others. However, the number of activities completed (out of 4 possible, blast = 3.83, fade = 3.80, ticker = 3.71) does not depend on the type of animation, $F(2,96) = 0.77$, $MSE = 0.25$, $p = .46$. That is, it does not appear that a participant is more likely to identify (or miss) a piece of information when using one type of animated display than another.

While the identification rate when monitoring information was not affected by device type, the time to react to it was. The times to complete the monitoring activities differed significantly depending on the type of animations used, with blast requiring an average of 88.85 seconds in each round for the two activities, fade 117.41 seconds, and ticker 192.93 seconds ($F(2,52) = 17.24$, $MSE = 4528.75$, $p < .001$). Pairwise comparisons revealed that the blast and fade animations resulted in significantly faster monitoring times than the ticker ($p < .001$ and $p = .01$, respectively) and there was a trend toward faster blast times than fade ($p < .09$).

For the awareness questions, Figure 3 summarizes the results using the three metrics described earlier for measuring performance on the awareness questions: correctness rate, hit rate, and false alarm rate.

While the correctness rate for ticker was slightly higher than that for fade or blast, suggesting that the ticker may be better, the difference was only marginally significant, $F(2,96) = 2.62$, $MSE = 0.02$, $p = .08$. In turning to the hit rate, there was a significant difference among hit rates. The hit rate for ticker was higher than that for fade and blast, $F(2,96) = 3.87$, $MSE = 0.03$, $p < .03$.

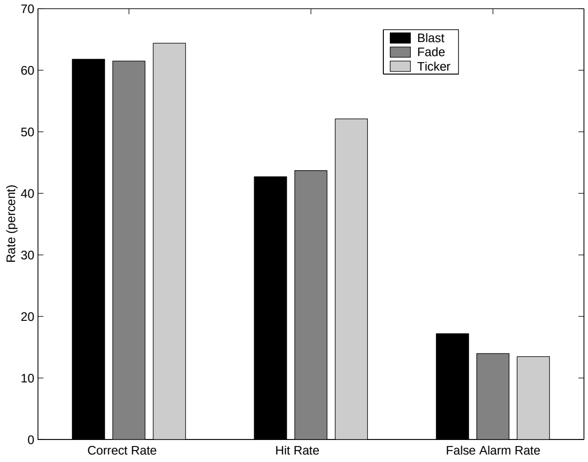


Figure 3: Cumulative correctness rate, hit rate, and false alarm rate for the awareness questions. The participants had a significantly higher hit rate when using the ticker.

One drawback of many techniques that achieve high hit rates is that they often result in high false alarm rates as well. However, this was not true in this situation as there was not a significant difference among false alarm rates for blast, fade, and ticker, $F(2,96) = 0.55$, $MSE = 0.03$, $p = .58$.

3.5.3 Discussion

One might suspect that participants who are not faced with an animation and not burdened with the additional monitoring activities and awareness questions would perform significantly faster on the browsing tasks, but the results suggest that this is not the case. In fact, the results did not even indicate a trend toward lower times in the cases when an animated display is not present (see Figure 2). While this seems to contradict the results found in prior studies (Maglio & Campbell, 2000), recall that the primary task in those studies were editing tasks that required participants to perform in-depth readings and make corrections. The browsing tasks of this experiment were less demanding, but based on previous studies (Fitzpatrick et al., 1998; McCrickard, 2000) they also may better match the type of primary tasks that a user would be doing while using peripheral displays.

The times to complete the monitoring activities differed significantly depending on the type of animations used. The blast and fade animations resulted in significantly faster monitoring times than the ticker. This result seems to follow from previous results that indicate that moving text is read more slowly than non-moving text (Sekey & Tietz, 1982; Granaas et al., 1984). As the tickering display relies on motion to cycle between items while the fade and blast do not, it seems reasonable that the ticker would result in slower performance, particularly if the participants were reading the displays to identify information that they were monitoring.

In analyzing the responses to the awareness questions, the correctness and hit rates for the three animation types suggested that the ticker may be better. This does not contradict the results noted previously indicating that moving text was more difficult to read than non-moving text. The nature of the monitoring activities and the awareness questions are quite different. In fact, other studies have shown that comprehensibility, unlike reading speed, is not affected by motion (Kang & Muter, 1989), so it is reasonable to expect the results to differ. The implication of these results on the development and use of animated displays is clear: if the goal is to identify items quickly, an in-place display like a fade or blast should be used, while if the goal is to increase comprehension and memorability, a motion-based display like a ticker should be used.

3.6 Experiment 2

The previous experiment suggested that there are differences in performance when using the fade and ticker displays. In a follow-up experiment, we wanted to explore whether certain factors, namely display size and animation speed, impacted performance in any way. Perhaps making the display area larger would result in faster recognition times and allow the awareness questions to be answered with greater accuracy, or perhaps a slower speed would be less distracting, resulting in lower times on the browsing tasks.

3.6.1 Method

Ninety-one undergraduate students participated in this experiment for class credit. The materials and procedure were similar to the ones used in the previous experiment with the differences described here.

A between-subjects size and speed condition was added. The participants were presented with a display having one of three characteristics: normal display size and animation speed, normal size but slow speed, or small size but normal speed.

The *normal* displays were used as the comparison point for the small and slow displays. Normal displays used large display areas and fast speeds, though both well within the ranges of sizes and speeds selected by participants in a previous study (McCrickard, 2000). Both the fade and ticker had a width of 1180 pixels (about 160 characters) with a height of one line. This size was chosen because it fits nicely along the top or bottom of the screen and because it is large enough to hold long streams of information (such as news headlines and weather bulletins) in their entirety. The ticker speed was at the upper range of the possible speeds for the platform, one pixel per 20 milliseconds. The fade cycle step had a 100 millisecond delay between each of five steps with a three-second delay before the next fade.

The *small* display used a smaller area but the same speed as the normal display. The fade and ticker width was more than halved to 840 pixels (about 70 characters), small enough to fit above a single terminal window. This reduction in size meant that most streams of information could not be shown in their entirety.

The *slow* display was the same size as the normal display, but slower. The speed was chosen to be at the slow end of the range selected by participants in the previous study. The ticker updated at a rate of one pixel every 140 milliseconds. The fade updated one shade every 150 milliseconds with a delay of 9 seconds before the next fade. The size for the widgets was the same as in the normal display.

We focused on results from pairs of displays that differed in either size or speed but not both. That is, we did not examine the differences between the slow and the small displays because they differed in both speed and size. Instead we focused on the normal-small versus normal-slow pairings so that any differences in performance could be attributed more confidently to one factor.

The awareness questions also differed from the first experiment. In the first experiment, the first question asked participants to select the types of information that were displayed, then for each case where the participant stated correctly that a type of information was displayed, two additional questions were asked about that information, the first relating to content and the second relating to order. In this experiment, each participant answered all five of the questions. This change seemed reasonable since a cue such as a word or phrase in a question can aid retrieval from memory.

The number of rounds was increased from six to eight. It was determined that participants would still be able to complete the experiment within the requested hour even with the additional rounds. Also, the type and order of the animations was changed. Since the blast display resulted in performance similar to the fade display and was consistently rated as the least favorite display by participants in the first experiment, it was not used in the second experiment. Participants alternated between using fade and ticker in each round, with one group starting with fade, then twice using ticker then fade again and repeating (fade, ticker, ticker, fade), and the other group swapping the order starting with ticker.

In summary, there were six groups of participants differentiated by animation classification (normal, slow, or small) and starting animation (fade or ticker). Each group had 15 participants except the slow fade-first group with 16 participants.

3.6.2 Results

For the cumulative time required to complete the browsing tasks, changes to the size and speed of the animated display did not lead to differences for either the fade or the ticker, (for fade: normal = 2999.03, slow = 2890.87, small = 3131.10 with $F(2,88) = 0.58$, $MSE = 765992.08$, $p = .56$; for ticker: normal = 3036.83, slow = 3036.93, small = 3079.45 with $F(2,88) = 0.01$, $MSE = 997900.50$, $p = .99$).

For monitoring activities, the results showed that changes to the nature of the peripheral display affected performance when using the ticker ($F(2,29) = 5.23$, $MSE = 40792.90$, $p = .01$) but not the fade ($F(2,66) = 1.62$, $MSE = 12712.58$, $p = .21$). We considered pairwise t-tests to determine where the significance lay. Did the *size* of the display affect performance on monitoring activities? Figure 4 suggests that it does. When using the ticker, the time to complete the monitoring activities was significantly different based on the size of the animated display, $p = .02$.

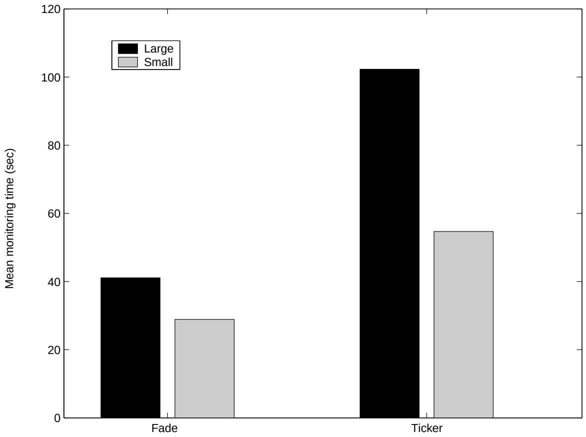


Figure 4: Mean completion times for each monitoring activity when using large (normal) and small displays. For the ticker, smaller displays resulted in significantly lower times than larger.

Did the *speed* of the display also affect performance on monitoring activities when using ticker? For each display type the monitoring times appear to have been similar regardless of speed (fade 41.1 and 45.7 seconds, ticker 102.3 and 100.7 seconds for the fast and slow displays, respectively). The analysis verifies that there was no significant difference: for the ticker, the t-test resulted in $p = .79$, for the fade, $p = .87$.

For the awareness questions, the cumulative hit rate when using the fade was virtually identical regardless of display size or speed (with normal 67.4%, slow 66.8%, small 68.3% and $F(2,88) = 0.09$, $MSE = 0.02$, $p = .92$). However, when using the ticker, the hit rates did differ significantly (with normal 68.2%, slow 61.3%, small 68.3% and $F(2,88) = 3.26$, $MSE = 0.02$, $p = .04$). A t-test revealed that the difference between the normal and slow displays was significant ($p = .03$), while the difference between the normal and small displays was not ($p = .98$). As in the previous experiment, the false alarm rate did not differ regardless of display size or speed for either the fade (normal 18.4%, slow 16.8%, small 20.8%; $F(2,88) = 2.24$, $MSE = 0.01$, $p = .17$) or the ticker (normal 19.3%, slow 18.8%, small 19.7%; $F(2,88) = 0.10$, $MSE = 0.01$, $p = .91$).

3.6.3 Discussion

As was noted in the previous experiment, for the type or presence of an animated display, neither the display size nor the animation speed seemed to negatively impact the time required to complete browsing tasks.

Users did not complete monitoring tasks more quickly with a fast animation than a slow one. One possible explanation for this result is that even though the increase in speed gives participants more opportunities to see the information, each opportunity is shorter because the information disappears more quickly. These two factors could balance out to result in similar monitoring times.

Although changes in the speed of the display do not seem to affect monitoring times, changes in the size do. A smaller display results in significantly faster monitoring times when using the ticker, and there is a trend toward faster times when using the fade (see Figure 4). While this result is not immediately intuitive, it does seem to correspond to the model that most people use during peripheral monitoring activities: they are focused on a primary task while occasionally glancing at the peripheral display. As noted by Rayner (Rayner, 1978), only a limited number of characters (up to 20) can be processed in a quick glance at a display. The greater number of characters in a larger display may make it more difficult for a person to find the desired information with a quick glance.

While the size of the display seemed to impact performance on the monitoring activities, it does not seem to impact performance on the awareness questions. The participants performed equally well on the questions whether using the larger or smaller display. One reason the display size may make a difference in answering the questions but not in performing the monitoring activities lies in the nature of the two tasks. Whereas the monitoring activities require only a quick glance, the ability to answer questions requires a more careful reading of the entire information entry. In fact, it is somewhat surprising that the larger display did not show better results on the awareness questions than the smaller one, though this may be because the smaller display was still large enough to contain most or all of the information for many of the information entries.

The speed of the tickering display seemed to impact performance on awareness questions. A slower animation resulted in poorer performance on the questions than a faster one, perhaps because the participants too often glanced up to see the same information. This result is consistent with the Granaas work that showed faster tickers (with larger jumps in the scrolling) resulted in better comprehension than slower tickers with smaller jumps (Granaas et al., 1984).

In comparing performance on the awareness questions between experiments, the result from the previous experiment was not replicated: the ticker did not result in improved performance over the fade. This may be related to the amount of information on the screen. The tickers in this experiment were as large or larger than the ones in the first experiment, resulting in far more information on the screen at any given time for the ticker, especially compared to the fade. The shape of the display may also be a factor. The fade display in the first experiment was a three-line display, while in the second it was a one-line display identical in size and shape to the ticker. It is possible that multi-line displays are more difficult to process and comprehend in a glance than single-line displays. Future work is necessary to test that hypothesis.

4 General discussion

The goal of the empirical evaluations was to explore the balance between distraction, reaction, comprehension, and memorability when using peripheral animated displays. The first experiment showed that fading, tickering, and blasting peripheral displays did not significantly distract users from a primary task yet could effectively communicate information. The type of animation impacted performance on monitoring activities and awareness questions. The second experiment showed that changes in size and speed also could impact performance on monitoring activities and awareness questions.

The following recommendations can be derived from the results of these experiments:

- **Animated displays can be used in the periphery with minimal negative impact on certain primary tasks.** While other work (Maglio & Campbell, 2000) seems to suggest otherwise, both experiments supported this claim. The difference may result from a primary task that is less cognitively demanding and smoother, slower animations.

- **In-place displays such as fade and blast are better than motion-based displays like ticker for rapid identification of items.** Participants were able to complete monitoring activities more quickly when using the fade and blast than when using the ticker. This seems to extend prior results that indicated that moving text is more difficult to read than static text (Sekey & Tietz, 1982; Granaas et al., 1984).

- **Motion-based displays such as ticker are better than in-place animations for comprehension and memorability.** While in-place displays aid rapid identification, on the awareness questions participants who used the ticker obtained a better hit rate and a marginally better correctness rate than those who used the blast and the fade. At the very least, this suggests that if it is essential to remember information at the risk of mis-remembering it, a motion-based display should be used.

- **Small displays result in faster identification of changing information.** This may be related to the amount of information that a viewer can read in a glance. Larger displays may make it difficult to obtain desired information.

- **Fast displays are better than slow for establishing comprehension and memorability.** This was noted in the second experiment for the tickering animation and may be related to the amount of new information that is available in a glance. Slower displays may discourage people from looking at them often.

5 Conclusions and future work

The results of the experiments and the growing popularity of peripheral displays suggest that people can use them to help maintain awareness. Besides providing immediate information, smoothly animated changes to the display can be small, subtle, and predictable, allowing the user to adapt to the changing display to the point where it is less distracting. It is necessary to understand the trade-off between the importance of the information being communicated and the resources necessary to display and process it.

This research has developed an understanding of the nature of the awareness problem and of how users' wants and needs differ in maintaining awareness. It is reasonable to conclude that the use of animation can assist in maintaining awareness without causing undue distraction in particular situations. As with most tools, peripheral animations can be and have been misused, but when used properly, this research has shown they have the potential to be beneficial.

The population of participants in the study was undergraduates at a technical school with significant exposure to computers and interfaces. Further studies are necessary to determine the effectiveness of peripheral displays for other segments of the population, such as people with more limited skills and people with little computer experience. Other ongoing work is examining what types of information are best suited for display in the periphery and other primary tasks that are not negatively impacted by the presence of peripheral displays. As was noted previously, the particular focus of this work on controlled situations allows us to understand and compare performance for certain scenarios, but it is also important to apply the lessons learned in this work to real-world applications.

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