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Moving Icons, Detection and Distraction

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Abstract: Simple motion has great potential for visually encoding information but there are as yet few experimentally validated guidelines for its use. Two studies were carried out to look at how efficiently simple motion cues were detected and how distracting they were in different task contexts. The results show that motion outperforms static representations and identify certain types of motions which are more distracting and irritating than others.

Keywords: information visualization, visual attention, perceptual interfaces

1 Introduction

Graphical user interfaces rely heavily on visual *codes* such as symbol colour, shape, size and position. These coding devices can be very effective in supporting rapid access to information as they are *mentally economical*: processed pre-attentively requiring minimal cognitive effort [Woods 1995]. However, only a small amount of information can be encoded in each visual dimension. For example, a typical recommendation is that no more than eight colours be used to define information categories [Gilmore et al. 1989]. For this reason there is a shortage of perceptually efficient codes that can be used in information-rich user interfaces.

One promising way of visually coding information is to use simple motion. Motion has a unique ability to attract attention over a large visual field and offers a rich graphical vocabulary. Its use has only recently become feasible due to the advent of fast graphics processors and supporting software technologies. However, compared with the use of colour coding, which is supported by a large literature of design guidelines based on decades of experimental studies, there has been little research relating to the effective design of motion codes. Such work is urgently needed because available technologies such as Javascript and image animation have led to a riot of moving and jiggling icons that compete for our attention. In this paper we discuss some of the relevant results from the human perception literature and report two experiments we have conducted to investigate the value and effectiveness of moving icons in attracting the attention of a computer user. Our results show that motion outperforms colour and shape codes especially in the periphery, and that certain types of motions are inherently much more distracting and irritating than others.

2 Perceptual and Cognitive Theory

Research into human perception tells us a great deal that is relevant to the use of icon motion as a coding mechanism. Of special interest is the fact that motion triggers a kind of orienting response, attracting a user's attention, even when it appears in the periphery of the visual field [Faraday and Sutcliffe 1997].

Motion compares very favourably to colour and shape if we are concerned with designing icons to attract a user's attention at the edge of a computer screen. The human visual system is very non-uniform with respect to our ability to resolve detailed information. For example, we can only resolve about one tenth of the detail about ten degrees of visual angle to the side of the point of fixation [Smith and Atchison 1997]. Thus icons that rely on detailed shape to convey their meaning are only effective if directly fixated. Our ability to discriminate colour information is also very non-uniform across the visual field. In fact in the periphery we are almost colour-blind [Wyszecki and Stiles 1982]. One of the great potential advantages of motion as an attention-getting device is that our ability to perceive motion falls off much less towards the periphery of the visual field. Peterson and Dugas [Peterson and Dugas 1972] confirmed this in an applied setting that showed static targets to be virtually invisible in the far field whereas moving targets were easily detected.

Our ability to see things at the edge of a computer screen may vary with our level of attention to the task we are performing. A "searchlight metaphor" has been used to model how attention falls off in the visual periphery as a function of the cognitive load or the stress level of an operator [Wickens 1992]. A phenomena known as tunnel vision occurs under conditions of very high stress, but even under relatively low stress conditions the focus of attention narrows considerably [Williams 1985]. Focusing attention in a visually "noisy" field requires the user to both maintain control of where she is attending and awareness of potentially interesting areas as conditions change. Woods defines several criteria for signals he terms *cognitive tools* to support control and direction of attention [Woods 1995]: *accessibility* (i.e., the user should be capable of picking them up without losing track of current activities); *partial information* (the signal should carry enough partial information for the user to pick up whether to shift attention to the signalled area); and *mental economy* (the representation should be processed without cognitive effort).

Because other information can remain on the screen while a user attends to a moving signal, it may provide the required accessibility. Because motion can be registered in the periphery it may be ideal for conveying partial information, and because motion is pre-attentive it may have the required characteristic of mental economy. However, all of these qualities require experimental verification in task-related studies.

The human visual system is very good not only at perceiving but also at tracking and predicting movement. We can track up to five moving objects in parallel [Pylyshyn et al. 1993] without effortful context-switching. Hillstrom and Yantis [Hillstrom and Yantis 1994] suggest that it may not be motion *per se* that attracts attention, but rather the appearance of a new object in the visual field. These findings suggest that introducing extensive motion into user interfaces may be problematic. When a new object gains the attention of the tracking system, another object will typically be lost. This can lead to problems occurring with distracting irrelevant items. In particular the moving banner animations that grace many web pages may be particularly effective in attracting this perceptual resource.

2.1 Previous studies with moving icons

Blinking can be considered to be an elementary form of motion and much use has been made of blinking in user interfaces to attract and direct visual attention. In many systems it is the primary visual cue for alarm conditions. However, anecdotal evidence indicates that people find blinking excessively annoying and visually ineffective when too many items are flashing (who has not cursed the WWW HTML blink function?) In large-scale systems where alarms tend to propagate rapidly, over-flashing not only reduces effective alarm information but also renders the displays visually disturbing, distracting users from effectively perceiving the needed information from other representations [Gilmore et al. 1989] [Sarter and Woods 1995] [Woods 1995]. Ware et. al. investigated the use of a simple moving icon as a "human interrupt" signal in the interests of seeing if this would evoke the same direct pull of attention as blinking or flashing without causing the associated irritation [Ware and Limoges 1994]. Subjects performed a primary task and were told to respond by hitting a key when they noticed movement of one of two small icons on either side of the top of the display. The icon was a small bar which grew and shrank vertically in an smooth, oscillatory fashion. Amplitude, side and velocity of the movement were varied. There was no effect for amplitude or side, but increases in velocity led to an increase in the number of quick responses and a decrease in the number of long ones. The good average response times indicated that subjects had no trouble noticing the interruption without any reported irritation factor. Even the slowest times were acceptable, suggesting that motion of this kind is a reasonable "attention getter".

One way of using simple animation is in illustrating a simple procedure. Baecker and Small animated icons to identify and explain their function [Baecker and Small 1990]. The advantages of animation were particularly noticeable when the small size of icons meant a low resolution of information (i.e., intricate depiction was impossible). Ambiguity was reduced and users remembered the function of the particular icon better.

McCrickard and Stasko investigated how animated information could be used to maintain peripheral awareness [McCrickard et al. 2000]. While subjects browsed through on-line text, additional information would appear in a secondary window in one of three ways: the words would fade slowly in, scroll across the window, or suddenly appear ("blast in"). None of these cues was found sufficiently distracting to impede the primary task, but as might be expected from the theory of perceptual onset [Hillstrom and Yantis 1994] the blast was the most effective in getting attention.

3 Experiment Motivation

The experiments we report here were designed to address a number of questions that relate to the use of motion as a cognitive tool for managing attention. A dual task design was used for ecological validity: the idea was to simulate situations common in current desktop environments where the user is engaged on a primary task that takes most of her attention. We are interested in the kind of situation awareness where a change in an icon is used to signal some event, such as the arrival of mail, new users in a conference, or system events like a printer jam.

Experiment 1 investigated how moving icons compare to both colour and shape in attracting user's attention. We used a large screen display to address the issue of how far in the periphery motion can be effective compared to colour and shape. Large displays are becoming increasingly common as the focus for work-group activities; we believe that most of the results also apply to desktop displays, especially in multiple-monitor configurations. Both detection rates and detection times were measured. Experiment 2 addressed the issue of how different types of motion compare in effectiveness. We were particularly interested in how *traveling* motion, where some icon moves over a large distance, compared to *anchored* motion where an icon moves about a fixed point. Moving banners are a form of traveling motion and we suspect that they are especially distracting. Experiment 2 measured response time and detection rate and used Likert scales to measure the degree to which different types of moving icons were distracting or irritating.

4 Experiment 1: Cue Awareness

This two part experiment had the purpose of comparing the effectiveness of different kinds of motion to colour change and shape change in alerting users across a wide visual field populated with icons. A wide field of view was used to investigate both near-field and far-field conditions. The first part (Experiment 1A) compared colour cues to two linear motions (up and down) of the same frequency but different amplitudes. The second part (Experiment 1B) compared shape cues to the same motion cues. We measured the error rate and response time for detection (noticing that something had changed). Subjects performed both studies in a single session; ordering was counter-balanced. We had five hypotheses for this experiment:

H1: Motion detection rates are higher than colour detection rates and detection times are shorter.

H2: Motion detection rates are higher than shape detection rates and detection times are shorter.

H3: Colour icon detection rates fall off markedly with distance and times increase.

H4: Shape icon detection rates fall off markedly with distance and times increase.

H5: Smaller motions lead to lower detection rates and longer detection times.

4.1 Experiment Description

Most of the method was the same for 1A and 1B. We describe this common method first.

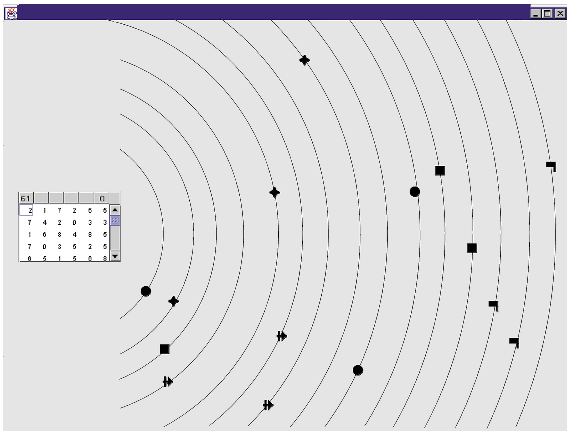

Figure 1. One trial of Experiment 1A. The stimulus arcs were not displayed.

Screen Layout. A wide rear-projected screen was used. The dimensions of the projector screen were 115 cm x 86 cm. The resolution of the screen was 800 x 600 pixels. The subject was seated in front of the screen such that the stimuli subtended a field of view from 8 to 39 degrees of visual angle.

The screen was located in a graduate research lab and the overhead fluorescent lights were dimmed for the experiment. No other special considerations were applied, so that subjects were often doing the experiment while other work was going on the lab with normal (moderately quiet) noise levels.

Figure 1 illustrates the screen layout. The primary task area was placed at either the left or the right of the stimulus window such that it was vertically centred and had a horizontal margin on each side of 50 pixels.

4.2 Primary Task

Subjects were asked to carry out a simple editing task in a window which was located either to the left or the right on a larger window. The small window contained a scrollable table of numbers from 0 to 9 and the subject was instructed to find as many 0s as possible and replace them with 1s. A static counter in the upper left hand corner showed the total number of 0s in the table; a running counter in the upper right hand corner indicated the number of 0s currently found and replaced by the subject. Subjects could use the arrow keys and/or the mouse and scrollbar to navigate through the table.

4.3 Secondary Task

The larger window contained 15 icons, of which one might change according to one of the cues. In a fifth of the trials nothing would happen. Upon detecting a change subjects were instructed to hit the CTRL key, thereby ending the trial. Each of the 15 icons was randomly positioned on an arc at fixed radial distance from the centre of the task window, as illustrated in Figure 1. Icons were positioned in near and far conditions such that the **near** targets were positioned on arcs 1-5 and the **far** targets were positioned on arcs 11-15. The target was randomly determined for each trial from the respective set of 5 icons. None of the icons on the arc 6 through 10 was ever a target. Each icon was bounded by a rectangle of 14 x 14 pixels. This corresponded to roughly one degree of visual angle at the viewing distances we used.

Cue onset occurred at some second between 5 to 20 seconds after the trial started. Cue onset was randomly selected from this 15 second range for each trial. Each cue lasted 5 seconds. If no detection was indicated the trial timed out after 30 seconds.

Experiment Subjects: 12 SFU students participated in the study. There were 6 males and 6 females. None were colour-blind although 5 wore glasses.

4.4 Experiment Design

This 5x2 design resulted in 10 conditions of which each subject performed 8 repetitions, totalling 80 trials per subject. Two of these conditions were NO_CUE so that in 20% of the trials nothing happened. The ordering of conditions was random for each subject. Trials were combined into 4 blocks of 20 trials each. The task position was counter-balanced for left and right position and changed with each block. An equal number of subjects started with the task in the left position and in the right position. Each block was subject-initiated.

All subjects were given a training block of 10 trials with all cues before each study so that the subject was comfortable with the primary task and had seen all cues before the experiment.

Motion types. There were two motion conditions. In the high amplitude condition the icon moved smoothly up and down along a path twice its own height with sinusoidal motion (HIGH_AMP). In the low amplitude motion the path length was the height of the icon (LOW_AMP). Frequency was roughly 3 Hz.

Experiment 1A: Colour vs. motion. In Experiment 1A two colour signals were evaluated together with the two motion signals. 6 icon shapes were used and all were initially coloured black (see Figure 2). Icon shapes were randomly assigned on each trial. The colour signals were a colour change to RED (RGB 255,0,0) or GREEN (RGB 255,255,0).

Experiment 1B: Shape vs. motion. In Experiment 1B two shape-change signals were evaluated together with the two motion signals. The icons were all the same circular shape but of 6 different colours: red, green, blue, cyan, yellow, white or black. The two shape cues had the circle changing to either the X or upright FLAG shape used in Experiment 1A (colour was not affected).

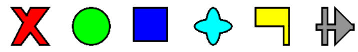

Figure 2. Icon shapes

4.5 Results: Experiment 1A

The results from experiment 1A are summarized in Figure 3 showing detection error rates and detection times respectively. While all cues performed well in the near condition, detection times were faster with the moving icons and error rates were lower in the far condition. As predicted, colour detection fell off in the periphery for both red and green icons. The mean error rate for colour was 5.5% in the near condition and 24% in the far condition. An analysis of variance showed this difference to be highly significant ($F(1,11) = 13.398$, $p = .00027$). This was not the case for the motion cues, where there was nearly a 100% detection rate for motion in both the near and far condition.

A more dramatic difference between colour and motion is evident in the detection times. All of the detection times for motion were around 1 second but the detection times for colour averaged 2.3 second in the near and 4.6 seconds in the far condition. Cue type was highly significant in both locations ($F(4,44)=55.045$, $p=0$). Again, the near far difference for colour was also highly significant ($p<0.001$).

4.6 Results: Experiment 1B

The pattern of result for shape is very similar to that obtained for colour and is summarized in Figure 4. As with colour the detection rate fell off in the periphery (from 96 to 80%) and this difference was statistically significant ($F1,11 = 14.41$, $p=.0001$). The detection time also showed a large near far difference for shape but not for motion, increasing from 2.0 seconds to 4.4 seconds, while times for motion remained constant at about 1.0 seconds.

These results confirm our hypothesis that motion is more effective than either colour or shape change in attracting user attention, especially in the visual periphery. Our fifth hypothesis that motion amplitude affects detection was not supported: there was no significant difference in either experiment between

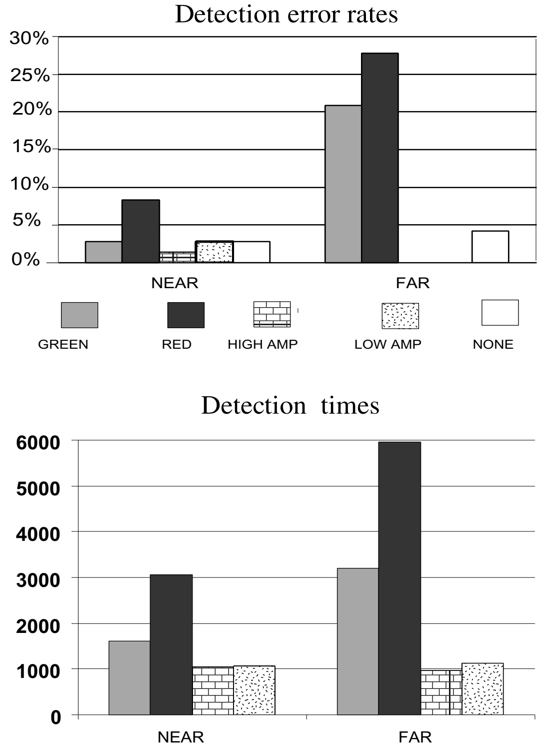

Figure 3. Mean detection rates and times: Colour vs. motion

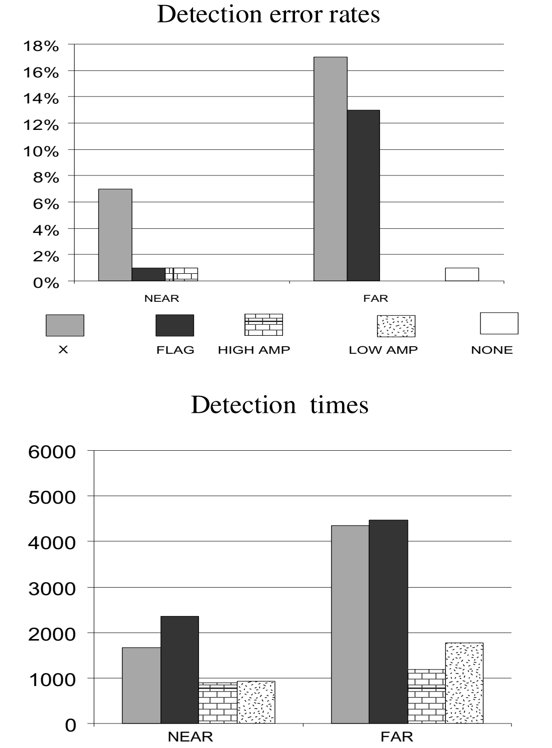

Figure 4. Mean detection rates and times: Shape vs. motion

the two motions.

5 Experiment 2: Distraction

A second experiment was designed to evaluate detectability, distraction and irritation properties of different types of moving icons in desktop environments. Three different primary tasks were designed to demand different levels of attentional focus. Detectability was measured by detection rate and time. Distraction and irritation were rated on separate 5-point Likert scales. We considered four motion types in two major categories: *anchored* and *traveling*. Anchored motions such as those used in Experiment 1 are characterized by small trajectories around ("anchored" on) the icon origin. Traveling motions involve large trajectories in which the object leaves its original position and "travels" through several degrees of visual angle. Our intuition is that traveling motions demand more attention because there is a cognitive act of *tracking* involved in addition to detection. We had four hypotheses.

H1. Detection times and distraction ratings vary with task load (the most demanding task would show the lowest distraction rating and highest detection times);

H2. Detection times are greater with slower motions and distraction is less;

H3. Detection times are less with traveling motions than with anchored motions; and

H4. Traveling motions are more distracting than anchored motions.

Screen Layout. A dual-task design was used with different primary tasks and a secondary task of detecting moving icons. The primary task was centred in a single full-screen window which was framed by a border of 32 icons. Icon shapes and colours were the same as those described in Experiment 1. Shape and colour were randomly set each trial but position was constant. Each icon was bounded by a rectangle of 16x16 pixels. A standard 21" monitor was used. Figure 5. shows one screen layout.

5.1 Trial Description

Each trial consisted of two phases: the task phase and the rating phase. In the task phase the subject engaged in one of three primary tasks for a period of 4.5 minutes. During this phase there were 8 motion cues, each lasting 10 seconds. Cue timing was evenly distributed across 8 30-second "envelopes" with a randomized onset in each envelope from 5 to 15 seconds, such that the effect was random but no cues occurred less than 10 seconds or more than 30 seconds apart. Cue-icon assignment was also random but evenly distributed such that there were always two cues from each of the top, left, bottom and right

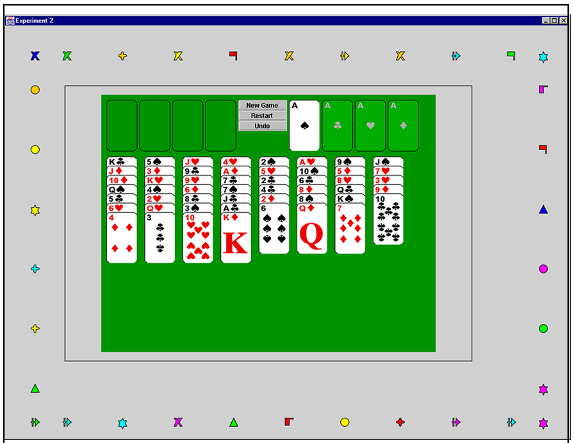

Figure 5. Experiment 2 Screen with Solitaire task

sides. No icon was used twice in a trial. Subjects were instructed to concentrate on the primary task and to indicate detection when they noticed a cue. When the trial ended (by timing out), the subject was presented with a rating screen in which a single icon unique to the rating phase appeared in the upper left corner and a rating panel appeared in the centre of the window. Each motion cue was then briefly replayed and rated by the subject.

5.2 Primary Tasks

Three primary tasks were used: browsing and studying on-line text, playing a variant of Solitaire (FreeCell) and playing Tetris. In the text task, subjects were instructed to imagine that they had a class the next day in the particular subject and that they had to know this material before they went to class. Four different texts were selected to be outside the normal topic scope of the subject population. Solitaire is a game in which the user can be quite engaged but events are completely user-driven; diverting attention pauses the game. Tetris, on the other hand, is played against the machine and the user must intervene continuously; the game does not stop when the user does. We hypothesized that Tetris would be the most engaging task (command the most attention) and that the text task would be the least engaging.

5.3 Secondary Tasks

In the first phase of the trial subjects were instructed to simply indicate detection of a moving icon by hitting the CTL key. The icon did not stop moving upon the detection event. In the rating phase of the trial, subjects replayed a shorter version of each cue in random order and rated each on a 5-point Likert scale for each of the following four criteria: how distracting the motion was; how distracting it would it be if it persisted; how irritating it was; and how irritating it would it be if persisted. As the irritation and "longer" ratings mirrored the distraction trends, we report only on distraction in this paper. Cue ordering was random and timing was subject-initiated: the next cue was only played when the subject had answered all the questions and requested the next cue.

5.4 Motion Cues

Four motion types (*shapes*) were used:

1. LINEAR, in which the icon moved smoothly up in a sinusoidal motion and then "jumped" back to the origin (*anchored*);
2. POPOUT, in which the icon zoomed smoothly from starting size to twice the starting size and then jumped back to the starting size (*anchored*);
3. BLINK, a standard on-off cycle (*anchored*); and
4. TRAVEL, in which the icon moved across the screen at a constant rate either from right to left (if the icon were in the top or bottom location) or from top to bottom (if the icon were in a left or right position), leaving the screen at one side and wrapping around to the other (*traveling*).

Each motion type was implemented in two frequencies: SLOW (30 frames/sec., roughly 1HZ) and FAST (15 frames/sec., roughly 2HZ), resulting in 8 distinct motion cues. Amplitude for the anchored motions was the same as Experiment 1.

5.5 Experiment Design

Since all 8 motion cues were seen each trial, the primary condition was the task condition. Each subject performed 12 trials in a session: 4 blocks of 3 trials each. A block contained one trial of each task condition. Task ordering was counter-balanced and each subject had one block starting with each task type and one more randomly selected block. Thus each subject saw each cue in a given task condition 4 times.

Experiment Subjects. Fourteen SFU students served as subjects. There were an equal number of males and females. None were colour-blind.

5.6 Results and Discussion

Figures 6 and 7 summarise the detection results of Experiment 2. We hypothesised the fast cues would be more quickly detected than the slower cues, but pairwise comparisons of significant differences in cue detection times by task from a post-hoc Tukey analysis (Table 1) failed to support this except for the slow blink, which had a much greater failure-to-detect rate. Task plays a part in determining how efficiently cues are detected: in particular, the differences between many cues are less pronounced in the two games tasks than in the text condition. Overall, linearly moving cues (LINEAR and TRAVEL) were detected most efficiently. Analyses of

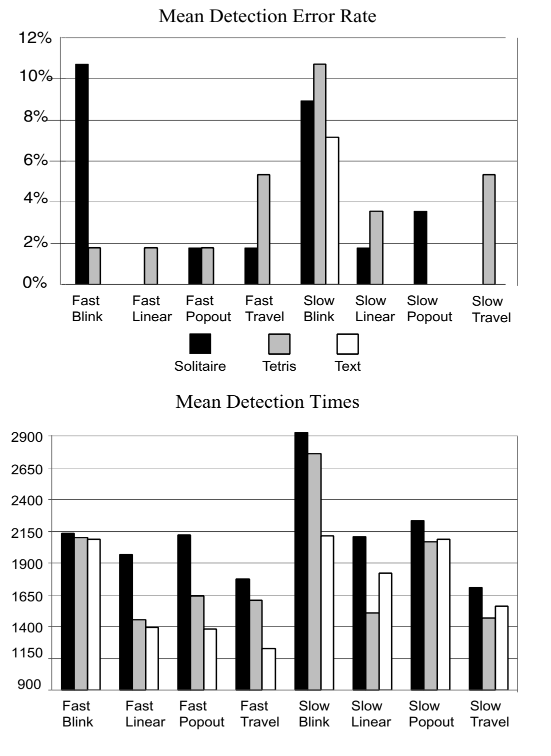

Figure 6. Ex. 2 detection error rates and times

	FB	FL	FP	FT	SB	SL	SP	ST
FB								
FL	■				✦✢■		■	
FP	■				✢■		■	
FT	■				✦✢■		■	
SB								
SL					✢			
SP								
ST					✦✢			
✦: FreeCell ✢: Tetris ■: Text								

Table 1: Pairwise comparisons of detection times: a task symbol indicates that the row cue had a faster detection time than the column cue.

variance in detection time show task (p<.00007) and cue (p<.0003) effects to be highly significant. There were no subject-cue interactions but as expected there were subject-task interactions.

Surprisingly, task had much less effect on distraction ratings (Figure 7). Cues in the text task were considered slightly more distracting, but this is not a significant effect. Cue shape, rather than task or frequency, clearly dominates. Blinking is the least distracting, followed by linear, popout and finally traveling trajectories. Although some subjects

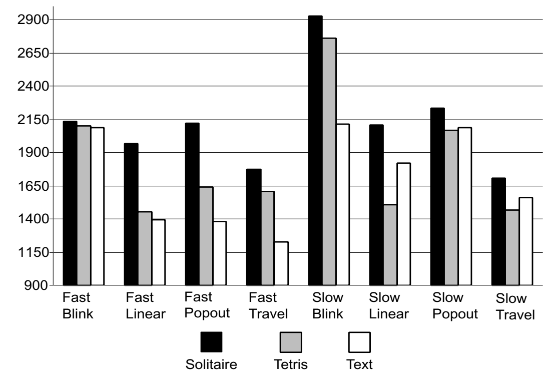

Figure 7. Distraction ratings

reported that their judgement of what was distracting changed as the experiment session progressed, there was no indication that when a trial occurred had any effect on the results.

An analysis of variance showed cue type to be highly significant (F(7,77)=91.92, p=0). As expected there was a subject-task interaction for distraction rating. Since the 5-point scale is a relative measure, it is revealing to consider significant differences in cue distraction ratings from a Tukey pairwise comparison (Table 2). From this it is immediately apparent that

	FB	FL	FP	FT	SB	SL	SP	ST
FB		■	✦✢■	✦✢■				✦✢■
FL			✦	✦✢■				✦✢■
FP				✦✢■				✦
FT								
SB		✦✢■	✦✢■	✦✢■			✦✢■	✦✢■
SL			✦✢■	✦✢■			✦	✦✢■
SP				✦✢■				✦✢■
ST								
✦: FreeCell ✢: Tetris ■: Text								

Table 2: Pairwise comparisons of distraction ratings: a task symbol indicates the row cue is less distracting than the column cue.

the two TRAVEL cues are the most distracting of the cue set, and that the popout cues, especially the fast, were considered the next most distracting. In terms of our hypotheses, the results show the following.

1. Motion shape rather than frequency had a major effect on both detection and distraction.
2. The traveling motions were the most quickly detected overall. In Tetris, both the TRAVEL and the LINEAR cues had similar superior times. However, these cues in Tetris had detection rates inferior to the popout cues. There may be issues of perceptual interference between cue motion cues and game motion. This demands

further study.

3. Traveling motions were always much more distracting than anchored motion. Blinking was considered the least distracting, especially the slow blink.
4. There was a task effect on cue detection but it was insignificant in the actual distraction ratings. People generally found all cues more distracting in the text task.

6 Conclusion and Discussion

Our findings have a number of implications for the use of animated signals in human-computer interfaces. They suggest that motion has several advantages as a notification mechanism. It is significantly better than the traditional static codes of colour and shape in designing icons used to attract a user's attention, especially in the periphery. Our results showed that the percentage of undetected targets increased dramatically from 6% to 25% with the peripheral colour targets, whereas the failure-to-detect with motion was less than 2% in both the near and far field. Moreover, the high rate of detection even in the more attentionally demanding tasks suggests that motion is effective over a wide range of locations, types and amplitudes. Even the least efficiently detected cue, the slow blink, had a worst-case mean response time of less than 3 seconds and was detected 89% of the time within the 10-second window, indicating good accessibility even when the primary task is demanding.

However, we did find differences in the ease with which people could be distracted from the primary task, although the results were not exactly what we anticipated. Although we had expected that Tetris would be the task most engaging of attention and our subjects anecdotally said that is was, the objective measures did not support this. Indeed the measured response times were longest for Solitaire, suggesting that this demanded the most attention. This suggests that such motion cues can be used to gauge task engagement. In any case our results show that even with highly demanding tasks, motion can be readily used as an alert.

Finally, while all the tested motions were effective as signalling mechanisms some are clearly more distracting to the user. Traveling motions which involved both detection and tracking were substantially more distracting than the anchored motions. The popout motions were also (although less) distracting, probably because they elicit sudden perceptual onset [Hillstrom and Yantis 1994]. These findings confirm our experience that animated banners and popping images are not comfortable visual elements on a screen where one is trying to work but are effective if one in fact wants to dominate the user's attention. Overall. the slow linear motion would appear to be a good compromise. It was rated among the least irritating and distracting but it elicited good response times and detection rates.

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