41.2: The Effect Of Edge Filtering On Vision Multiplexing

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Abstract

We developed a video filter that produces cartoon-like images consisting of bipolar white and black transitions at luminance edges of the input video, for use in augmented-vision devices. When tested in an inattentional blindness experiment it had no effect on the detectability of unexpected events, but did affect speed of responses to the attended task Response time improved when the unattended scene was filtered and degraded when the attended scene was filtered.

1. *Introduction*

Many devices developed in our lab for visually-impaired people employ vision multiplexing – the simultaneous presentation of more than one view to one or both eyes [10]. For example, images on a TV screen are magnified around the current center of interest in the scene, to aid people with poor visual acuity [4]. Since much of the magnified scene is off screen, superimposing an edges-only view of the full scene, allowing attention to be divided between the magnified and full-scene edge views, might provide context. In another example, a head-mounted device (HMD), consisting of spectacles with a small video camera and a see through display in the center of one spectacle lens, presents a wide-angle minified view combined with the normal see-through vision. The minified view helps a person with severe peripheral vision loss notice potential hazards, as well as aiding orientation [2, 13]. The minified view can be processed to produce a cartoon-like edges-only display ([6, 13, 14]).

A person's ability to make use of multiplexed visual information and avoid confusion is central to the utility of such devices. In a classic experiment, Neisser & Becklen identified the phenomenon they termed *inattentional blindness* [9]. Inattentional blindness is the *inability* to maintain awareness of events in more than one of two superimposed scenes. Subsequent experiments have confirmed the robustness of this effect, with an entire book devoted to it [7]. An example of its operational significance was given by Haines [5], where pilots watching augmented flight path information in the head-up display of a landing simulator missed seeing another airplane intruding on the runway. Further studies have probed how similar the two scenes can be and yet still be distinguished (very similar; [8, 12]), or how expectations and cognitive load affect detectability (they do; [1, 3]). In our lab, we are seeking ways to mitigate inattentional blindness so that, for example, a pedestrian user of the HMD we are developing for people with restricted visual fields would notice a car visible first in the minified view.

In this study we investigated the effect of edge filtering on inattentional blindness and on the ability to follow superimposed/multiplexed scenes. First we closely reproduced parts of the original Neisser & Becklen [9], and then treated one or both scenes with edge filtering. We found no evidence that edge filtering affected the detection of unexpected events. However, filtering the *un*attended scene did improve performance of the attended task, as measured by response time, whether the attended task was filtered or not, while filtering the attended scene reduced performance of the attended task, whether the unattended task was filtered or not.

2. *Methods*

2.1 Games

36 normally-sighted subjects (visual acuity 20/30 or better) between the ages of 19 and 35 years were shown video segments of two different games superimposed on one another; a ballgame in which three players ran around in a circle and tossed a basketball among themselves, and a hand-slapping game in which the hands and forearms of two players were seen as one player tried to slap the outstretched hands of the other. A subject was instructed to follow one of the games carefully. Attention to the game was ensured by asking the subject to click once each time the ball was passed (either directly or with a bounce) or once each time a slap was attempted (whether successful or not). Odd, unexpected, events were introduced in the unattended scene, and, post trial, carefully worded questions were asked to determine if the events were noticed (without prematurely alerting the subject to the existence of unexpected events).

Trials were scored for hit accuracy, average response time, and whether or not the subject detected and properly identified an unexpected event. Response time was measured as the time between an actual slap attempt or pass and the time the subject responded by clicking the mouse. A response was considered an accurate hit if the response occurred within a half-second window around the time of the actual slap or pass plus the subject's average response time for accurate hits in that trial (determined iteratively).

Four different takes (separate video tapings) of each game, without unexpected events, were used to minimize familiarity with the action of the attended task. Each take had a 15-second lead-in for synchronization (with two bounces or finger snaps), followed by 60 seconds of play. In all cases, the attended game included 30 true passes or slap attempts, although that detail was not shared with the subject.

Three different unattended scenes with unexpected events ("UEs") were taped for each game. Only one take of each UE scene was needed. In one ballgame UE scene, about halfway through the play period, a man juggling three balls entered the scene at the right, strolled to the center of the ballgame, juggled in place for a few seconds, and strolled off to the left. Meanwhile, the ballplayers continued as usual, passing the ball 30 times during the minute of play (Figure 1).

In a second ballgame UE scene, about halfway through the minute of play, a woman strolled through, carrying an open umbrella. She was in the scene for about 8 seconds as the ballgame continued around her.

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In a third ballgame UE scene, at about 20 seconds into play one of the players threw the ball out of the scene. The players continued to fake play for the next 20 seconds, as if they still had a ball. About 20 seconds before the end of play the ball was tossed back in and they then used it as usual.

The 3 handgame UE scenes all had the play interrupted briefly at about 20 seconds and again at 40 seconds. In one, the players shook hands. In another, they tossed a small ball back and forth, and in a third they played an odd/even finger choose-up game.

Figure 1: An example of an unexpected event. A juggler strolls through the unattended ball game, pausing mid screen.

2.2 Edge filter

A modified ValueVision filter (DigiVision, Inc, San Diego, CA) was used to produce cartoon-like edges-only video. The luminance component of the camcorder S-video signal was processed through the filter, using its bipolar binary mode [11]. The bipolar mode is unique to this modified filter. The nominal off-edge output of the filter is gray. Each detected edge is represented by both a positive-going and negative-going transition from the nominal value. Bipolar mode is especially effective in the superposition situation, as it ensures that edges will show against both light and dark backgrounds.

Figure 2a shows white and black edges on a field of gray produced by the edge filter. Figure 2b shows the effect of the bipolar edge scheme we employed, while Figure 2c shows that white-only edges are less visible.

2.3 Presentations

The play period of each presentation had a superimposition of a handgame scene and a ballgame scene. Either, neither, or both scenes might be edge filtered. The superimposition was performed with video editing software. If both scenes of a presentation were to be in full color (neither edge-filtered), they were simply mixed equally. If both were to be shown as edges only, track threshold settings selected just the white edges (i.e., those with video luminance higher than the nominal gray output of the filter) from the black/gray/white edge-filtered video of each scene and merged them, yielding the white edges from each scene over a black background.

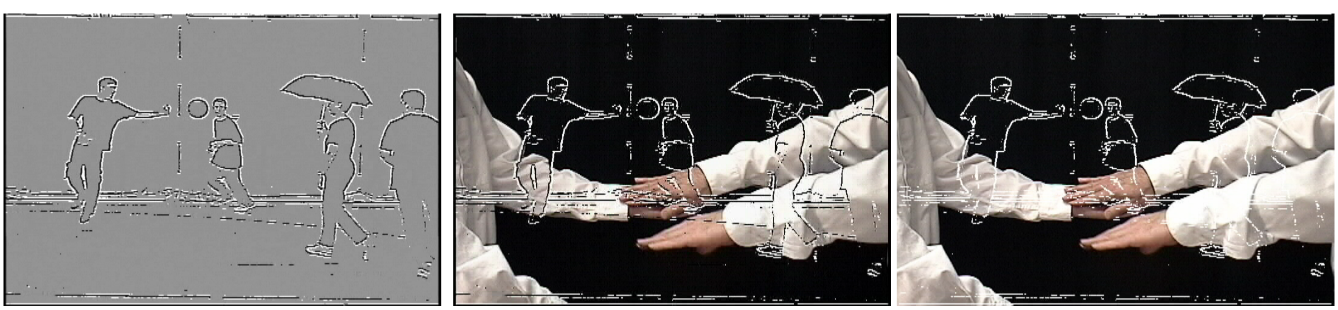
If just one of the scenes was to be shown in edge-filtered mode, masks were used to let the color video through wherever the filtered video was gray, and otherwise showed the white or black edges. Contrast was set high in this process to preserve crisp edges.

In all, the experiment design called for the creation of 16 single-scene presentations and 124 overlaid presentations.

2.4 Experiment design

The experiment was balanced along several dimensions, requiring the testing of 36 subjects. Each subject was presented with a different combination and ordering of presentations. The subject watched the presentations on a 15”-diagonal TV monitor from about 1 m and responded via a mouse button. Together with the pseudo-randomized order of presentations, the design ensured that the experimenter did not know which trials included unexpected events and could not give subconscious cues to the subject.

The subjects viewed up to 26 trials, although only eight of those trials provided the data used in the analyses. In each trial, the subject was given instructions about the task, shown a presentation, and then asked follow-up questions. The subject was asked to click the mouse once for each of the synchronization bounces or snaps, and then once for each event (toss or slap attempt) in the subsequent game. The subject was told that the first several trials are just practice trials. The first four trials of a session familiarized the subject with the games, edge filtering, and overlaying, and provided practice at the attended tasks. No unexpected events were shown. The key trials were 5 through 12, all of which were overlaid presentations. Six of those trials included unexpected events, with each different UE scene shown only once. The randomized inclusion of two trials without unexpected events helped to reinforce the unexpectedness of the other trials and further blind the experimenter. The order of the



a b c

Figure 2: (a) Raw edge filter output for the umbrella woman unexpected event, showing light and dark edge transitions. (b) Bipolar edges superimposed on a full-color scene. Note how the bipolar edges permit visibility of the edges over both very bright and very dark portions of the background image. (c) White edges alone are insufficient; visibility is minimized over bright areas.

unexpected events appeared random, but was carefully balanced through the use of six different digram-balanced 6x6 Latin squares. Each row of a square identified the UE order for one session. All that the experimenter knew and told the subject was which game was to be attended.

Four possible edge-filtering combinations were used in the critical presentations: Full color attended and unattended scenes; full color attended scene and edge-filtered unattended scene; edge-filtered attended scene and full color unattended scene; and both attended and unattended scenes edge-filtered. Each of the first three combinations was used with each game's unexpected event trials in a session. Since the Edge/Edge combination is not of interest in the devices we are considering, it was used for the two trials that did not include unexpected events. The edge-filtering order was also balanced across sessions and pseudo-random within a session. Finally, the use of the four non-UE takes for each game was balanced and randomized, with each take used once as an attended scene in trials 5 - 12, and one take for each game used as the unattended scene in the two non-UE trials.

The introduction and first two questions asked after each trial presentation led the subject to believe that the purpose of the experiment was to determine how filtering affects the difficulty of the attended task, not that we were interested in how often unexpected events were noticed. The key question after each presentation was "Was there anything worth noting in the background video that was distracting or interfered with following the game?" Based on the response to that question, the experimenter scored the trial as an event detected correctly, detected partially, vaguely sensed, or unseen.

To ensure that detections were scored properly, questions asked after trial 12 mentioned each of the unexpected events and asked if the subject had noticed any of them but didn't think them worth mentioning. Descriptions of three plausible events that had not been shown were included to detect cheating. Then, each of the presentations with unexpected events the subject had not identified was shown again (optional trials 13 – 18), and the subject was instructed to watch, but not bother clicking the mouse. In most cases, all of those events were then noticed, and the subject was asked if the unexpected event had been seen on an earlier trial. Finally, for those events that the subject still hadn't identified, just the brief event portion of the scene was shown, in full color and without overlay, and the subject was asked if that had been seen on the first round of trials. Two scenes of the ballgame with unexpected events that had been mentioned after trial 12 but never seen were included to catch cheating (yielding optional trials 19 – 26). Since the experimenter was masked as to the unexpected events being shown, it was possible that the subjects' identifications of unexpected events were misinterpreted. After each session the experimenter had an opportunity to adjust the scoring of any trials that later questioning proved incorrectly marked.

2.5 Results

For all statistical analyses $p \leq 0.05$ was noted as indicating statistical significance.

Unexpected events were detected 123 (57%) of the 216 times they were shown in trials 5 - 12, as determined by immediate or later questioning. Figure 3 shows the number of subjects who detected a given number of unexpected events.

We found no significant effect of edge filtering on detection, $\chi^2(2, 216) = 0.79$, $p = 0.67$. Power analysis showed that we had a 24% chance of revealing a 10% difference in detection rates, 70% chance for 20% difference and 97% chance for 30% difference. Analyzed separately by game, we found no effect of edge filtering on the number of ballgame UEs detected, Cochran's $Q = 2.15$, $p = 0.34$, or on the number of handgame UEs detected, $Q = 0.09$, $p = 0.96$.

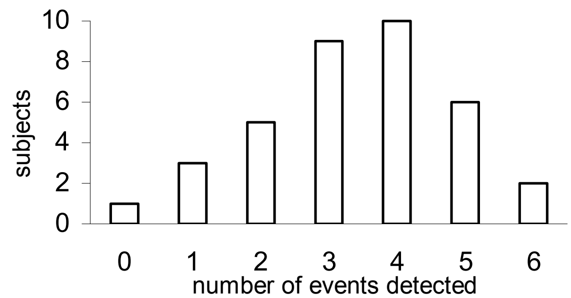


Figure 3: Frequency of detection of unexpected events by subjects. Only 2 out of 36 subjects detected all 6 unexpected events.

Edge filtering did affect response time, RMANOVA $F(3, 105) = 5.52$, $p < 0.001$, as shown in Table 1. F_r, Friedman analysis of variance by ranks, showed that hit accuracy, which averaged 96.7%, was not affected by filtering, $F_r = 1.2$, $p = 0.76$.

Attended handgame take showed no significant effect on hit accuracy, $F_r = 2.3$, $p = 0.52$, but attended ballgame take did, $F_r = 10.1$, $p = 0.018$. This was likely due to the difficulty of seeing a pass when a player in the foreground obscured it; it took longer for subjects to realize that a pass occurred.

Table 1: Effect of filtering on attended task response time in msec. (±std dev). Response time to the attended task improved if the unattended task was filtered and degraded if the attended task was filtered.

		Unattended Scene	
		Full color	Edge filtered
Attended Scene	Edge filtered	532 (±84)	522 (±96)
	Full color	500 (±97)	496 (±100)

Handgame and ballgame take both affected response time, RMANOVA $F(3, 105) = 22.7$, and 82.2, respectively, $p < 0.001$.

Unexpected event scene had a strong affect on detectability $\chi^2(5, 216) = 54.8$, $p < 0.001$. Table 2 shows the detection rate by scene. Response time was not affected by handgame UE scene RMANOVA $F(2, 70) = 0.43$, $p = 0.65$, nor ballgame UE scene, $F(2, 70) = 0.35$, $p = 0.71$. Similarly, hit rate was not affected by ballgame UE scene, Fr = 2.05, p = 0.36, and perhaps marginally by handgame UE scene, Fr = 3.84, p = 0.15. Some subjects commented that some of the handgame motions were particularly distracting.

Table 2: Frequency of detection by treatment and event type, out of 12 trials each.

Att'd/Unatt'd	Full/Full	Full/Edge	Edge/Full
Juggler	10	7	10
Lost ball	3	2	2
Umbrella	8	8	3
Choose-up	9	10	9
Handshake	4	3	4
Ball toss	10	10	11

3. *Discussion*

Finding no effect of edge filtering on unexpected event detection was somewhat disappointing, as we hoped that using edge filtering would help a low-vision user of an augmented vision system notice hazards. We are encouraged, however, by the degree that edge filtering of one of two overlaid scenes does help distinguish them, as evidenced by the shorter reaction times of the Full/Edge condition, as this should make it easier to switch attention between them at will. The differences in detectability of the various unexpected events we used may help identify effective scanning and training techniques that could be used with the low vision aids we are developing, but that will require considerably more study.

While we did not test subjects with white-only edges in addition to bipolar edges, it is immediately apparent that the bipolar edges are easier to see, especially against the white sleeves of the handgame players. The fact that the edges appear white in some places and black at others apparently did not disturb the subjects. Indeed, no one even mentioned noticing the shift.

Augmented displays of the type described in [2, 6, 13, 14] can not benefit from bipolar edges, as the video image is strictly additive; where the see-through view is bright, the augmented view can not superimpose black. That is not the case in a purely video configuration, as in [4] and this study, so there may be reason to pursue a video "see-through" HMD configuration instead of using an optical see-through technique.

4. *Acknowledgments*

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