Multiple Object Tracking with blink-contingent scene changes

Deborah J. Aks[1], Harry H. Haladjian[1,2], Zenon W. Pylyshyn[1], & Alex S. Hakkinen[2]

[1]Rutgers Center for Cognitive Science, New Brunswick, NJ; [2]Department of Psychology, Rutgers University, New Brunswick, NJ

VSS 2009 Naples, Florida

1. Abstract

Previous studies have shown that if objects disappear from view for up to a few seconds during Multiple Object Tracking, performance is unimpaired - provided objects reappear where they had disappeared, rather than where they would have been had they continued moving along their motion trajectories. Keane & Pylyshyn (2006) suggest this might be due to the sudden disappearance of objects causing their locations to be encoded in working memory. In the current experiments, we made object disappearance occur during an eye blink to examine whether a more natural (perhaps transient-free) disappearance might reduce the difference between same location and extrapolated location reappearance. (In a separate poster we describe an alternative test of whether transient-free disappearance shows a difference during the disappearance gap.)

In Experiment 1, we examined same-location vs. extrapolated-location reappearance during an eye blink. Observers performed a standard MOT task (four targets, eight nontargets). On a random half of the trials, the objects halted during spontaneous blinks and continued to move for the remaining trials. Results indicate that blink-contingent halting of objects produces fewer tracking errors, but this effect diminishes with practice.

Experiment 2 controlled for the amount of time during which the objects were invisible: the objects disappeared during eye blinks but remained invisible for fixed durations extending beyond the blink itself (150, 300, 450, or 900 ms). We also controlled when blinks occurred with a simple sound to signal observers when to blink during each trial. This voluntary blink induced the change in object motion (halting or continuing along trajectories). The results revealed superior tracking performance in the halt conditions, with lower performance as disappearance duration increased.

These results support Keane & Pylyshyn's (2006) conclusion that trajectory extrapolation is not used in tracking but the most recently sampled location may be encoded.

2. Background

Multiple Object Tracking (MOT) is insensitive to many object properties such as color, shape, and size and can be effectively tracked without coding such properties and when they move behind occluding events (Scholl & Pylyshyn, 1999; Scholl, Pylyshyn, & Franconeri, 1999).

Is MOT also insensitive to spatiotemporal properties, such as speed, location and displacement over time? E.g., targets that disappear briefly (up to 900 ms) are tracked better when they reappear at their locus of disappearance rather than their predicted positions (Fencsik, Klieger, & Horowitz, 2007; Keane & Pylyshyn, 2006). Such evidence against motion extrapolation suggests that the most recently sampled object position may be maintained when objects disappear (but see Iordanescu, Grabowecky, & Suzuki, 2009).

The primary research questions motivating the current experiments:

- **Do transients from the disappearance of items trigger location-coding in MOT?**
- **Is the encoding and updating of object locations used in tracking targets?**
- If so, **what type of location-code: motion extrapolation or position of last sample?**

To investigate these questions, **we use a novel blink-contingent methodology where the item-state during blinks (ISDB)** may change: items "halt" or continue moving during eye blinks, which allows us to examine natural, intrinsically-generated disruptions of the visual scene without inadvertently cueing the object change with item transients (as in Keane & Pylyshyn, 2006).

3. Method

Participants:

- Rutgers students participated in a 60-min session for course credit or remuneration.

Apparatus & Stimuli

- Standard MOT task with 4 targets and 8 non-targets, which were discs with a diameter of ~ 2 cm (~1.85° viewing angle).
- **Blink-contingent scene changes**: items may change during an eye-blink (item-state during blink, or ISDB) to test the effects of transient-free disappearances.
- Eye tracking and computer equipment: video-based IR eye-tracking system EyeLink 1000™ (SR Research, Canada) with temporal resolution of 1,000 Hz.
- Experiments were programmed in SR Research Experiment Builder™ and presented on ViewSonic™ G225fb 21" CRT monitor (120Hz refresh rate).

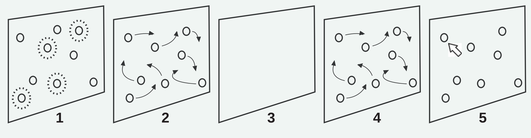

Figure 1. Experiment 1 set-up. Panel 1 shows an initial display of identical circles cued as targets. Panel 2 depicts random movement of the circles. Panel 3 depicts the disappearance of objects during an eye-blink, which return at the offset of a blink (Panel 4). In Panel 5, the observer selects the tracked targets with a computer mouse.

General Procedure:

- Each subject was calibrated to the eye-tracker at a fixed position of 62 cm from the screen using a chin rest.
- Subject were told to track targets and identify them at the end of the trial using a mouse. Immediately following each selection, feedback was provided with a green (correct) or red (incorrect) square appearing around the selected item.
- While performing MOT task, subjects either were not instructed to blink (Exp 1 used background fan to increase blink rate), or were instructed to blink in synchrony with a sound tone (Exp 2).

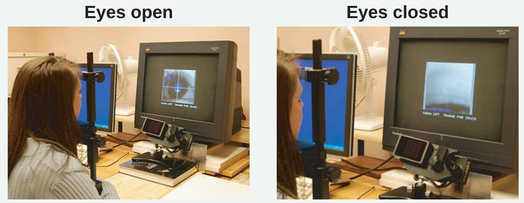

Figure 2. Eye-tracker setup for blink-contingent scene changes.

4. Results

Exp 1: Is MOT sensitive to object-location during blink-contingent item changes?

On a random half of the 5-sec trials, items stopped moving during the subject's spontaneous blinks and resumed when eyes opened. These involuntary blinks were mostly triggered by a background fan (pilot test showed fan increases blink frequency).

Results

- **Blink-contingent halting of objects yields fewer tracking errors** (see Figure 3).
- **Blink-induced-blindness**: ~1% of subjects reported noticing the blink-contingent item halting when they were asked about it during the experiment debrief.

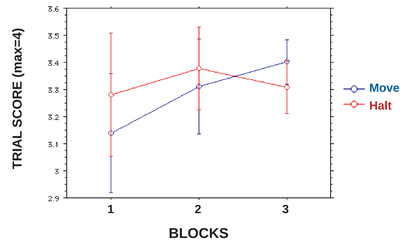

Figure 3. Results from Experiment 1 (n=19). ISDB may only have an effect on MOT performance early in the experiment (Block 1: trials 1 to 42 shown on left) where there were slightly (M=3.5%) fewer errors when items halt during blinking (Block * ISDB interaction: F=5.46, p<.01). Otherwise, with more practice (in later blocks) there is no effect of ISDB. Error bars are SEM.

Exp 2: What is the effect of item disappearance duration on tracking?

This experiment also tests the effect of eye-blinks as both interrupt and trigger for changes to object movement. Blink frequency and duration was controlled by a simple auditory cue that signaled the subject to blink once during a 5-sec trial. Objects disappeared during eye-blinks and remained invisible for fixed durations. The primary manipulations were the **Disappearance Durations (DD) of 150, 300, 450, or 900 ms** (includes blink period and subsequent black-out period) and a **blink-induced change in object motion or ISDB** (i.e., halting vs. moving along trajectories).

Results

- Better tracking performance when items "halt" rather than "move" during their brief disappearance (see Figure 4). This replicates Exp 1 and Keane & Pylyshyn (2006).
- The visual system does not seem to use trajectory information during MOT.
- Tracking impairment increases with disappearance duration, and this impairment grows more in movement trials.
- These results imply that the **location information of the most recent sample may be preserved** (not due to a transient when items disappear).
- Since impairment grows with DD, disappearance time may degrade memory of an object's index (or location-code for prior sample).
- Memory decay may be compounded by object displacement the further it is along the extrapolated trajectory. Future experiments further explore this possibility.

4. Results (Continued)

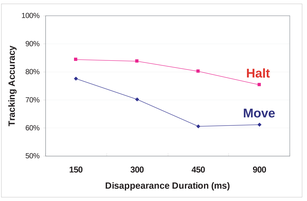

Figure 4. Results from Experiment 2 (n=8). ANOVA indicates differences between halt and move conditions (F=142.4, p<.01), disappearance durations (F=24.5, p<.01) and interactions between type and DD (F=6.1, p<.01).

5. Conclusions

- **Trajectory extrapolation is not used in tracking**; instead, the **most recently sampled location** may be encoded.
- **Have we ruled out transient explanation?** Perhaps not all information is suppressed during eye blinks or subsequent black-out periods.

Additional Thoughts...

- **Blink-induced blindness:** during spontaneous blinking experiment, less than 1% of subjects noticed object change triggered by the blinking.
- Current experiments are testing for the amount of displacement ("rewind", "normal", and "fast-forward" conditions); preliminary results show that tracking is sensitive to displacement, and support previous findings that "halt" or "rewind" conditions are less impaired than "fast-forward".
- Future experiments will include object or screen masking to further evaluate the effect of transients on tracking.

6. References

Fencsik, D., Klieger, S., & Horowitz, T. (2007). The role of location and motion information in the tracking and recovery of moving objects. *Perception & Psychophysics, 69*(4), 567-577.

Iordanescu, L., Grabowecky, M., & Suzuki, S. (2009). Demand-based dynamic distribution of attention and monitoring of velocities during multiple-object tracking. *Journal of Vision, 9*(4), 1-12.

Keane, B., & Pylyshyn, Z. (2006). Is motion extrapolation employed in multiple object tracking? Tracking as a low-level, non-predictive function. *Cognitive Psychology, 52*(4), 346-368.

Scholl, B., & Pylyshyn, Z. (1999). Tracking multiple items through occlusion: Clues to visual objecthood. *Cognitive Psychology, 38*(2), 259-290.

Scholl, B., Pylyshyn, Z., & Franconeri, S. (1999). When are spatiotemporal and featural properties encoded as a result of attentional allocation? Paper presented at the Association for Research in Vision and Ophthalmology.

7. Acknowledgments

This research was funded by Rutgers University Office of Academic Affairs. We would like to thank Chris Kourtev, Robyn White, and Allan Kugel for their assistance with this project.

For more information: daks@rci.rutgers.edu
http://ruccs.rutgers.edu/finstlab/