

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/266557947>

Saccadic Inhibition in Complex Visual Tasks

Chapter · January 1999

DOI: 10.1007/978-1-4757-3054-8_35

CITATIONS

42

READS

58

2 authors, including:



Eyal M Reingold

University of Toronto

123 PUBLICATIONS 6,015 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Scene Perception from Central to Peripheral Vision [View project](#)



Effects of image blur and clarity on visual attention [View project](#)

SACCADIC INHIBITION IN COMPLEX VISUAL TASKS

Eyal M. Reingold and Dave M. Stampe

Department of Psychology
University of Toronto
100 St. George Street
Toronto, Ontario, Canada M5S 3G3

1. INTRODUCTION

Several gaze contingent studies that used a fixed delay between physical eye movements and a display change documented a dip in the fixation duration distributions (e.g., Blanchard et al. 1984; McConkie et al. 1985; van Diepen et al. 1995). In a study by van Diepen et al. (1995), a moving mask paradigm was employed in which subjects searched line drawings of everyday scenes for non-objects. The appearance of the mask was delayed relative to the end of a saccade (beginning of fixation) by 17, 46, 76 or 121 msec. All fixation duration distributions in the masking conditions exhibited a dip with longer masking delays resulting in the dip occurring at longer fixation durations. In contrast, a no-mask condition did not produce a dip. Similar effects in reading were reported by Blanchard et al. (1984), and McConkie et al. (1985). In both these studies the text was masked at a fixed delay from the end of the saccade, and the fixation duration distributions exhibited dips. McConkie et al. (1992) interpreted these dips as reflecting a disruption to automatic, parallel encoding or registration processes that are time locked to the onset of the visual pattern on the retina. Processing disruption causes an eye movement disruption after a constant transmission delay in the neural system.

An alternative explanation to the processing disruption hypothesis is that the display change produced saccadic inhibition with maximum inhibition occurring at a constant latency following the onset of the display change. We will refer to this as the saccadic inhibition hypothesis. There are several differences between these two contrasting interpretations. The saccadic inhibition hypothesis postulates a low-level effect that should occur in any task involving saccadic eye movements, and regardless of the relevance of the display change to the task being performed. In addition, the profile of saccadic inhibition should be identical regardless of the delay between the end of saccade and the appearance of the display change. In contrast, the process disruption hypothesis predicts differences across tasks because different tasks are likely to involve different encoding

processes. According to this model, processes are likely to differ during the time course of fixations, and consequently, a display change earlier in a fixation should result in a different amount of disruption relative to a display change which occurs later during the fixation.

The purpose of the present paper was to disentangle these two alternative explanations. We recorded eye movements from subjects performing a visual search task or a reading comprehension task. In each of these tasks we employed two paradigms. In the first paradigm, the display change occurred at a fixed delay following the end of a saccade (beginning of fixation). We will refer to this as the Fixed Delay Paradigm (henceforth FDP). The FDP is in essence a gaze contingent paradigm. Two fixed delays of 110 msec and 158 msec were used. In addition, we developed another paradigm which will be referred to as the Random Delay Paradigm (henceforth RDP) in which the display change could occur at any point in time, thus at a random delay from the end of saccade (beginning of fixation). To summarize, three experimental conditions were used in each task: FDP 110 msec, FDP 158 msec and RDP. The saccadic inhibition hypothesis predicts an identical inhibition profile across these three conditions in each task whereas the processing disruption hypothesis predicts differences across conditions.

2. METHOD

2.1. Subjects

Two groups of 10 subjects were tested. One group participated in the visual search experiment and one group in the reading comprehension experiment. All subjects had normal or corrected to normal vision, and were paid \$10.00 for a single one hour session.

2.2. Apparatus and Display Generation

The eyetracker employed in this research was the SR Research Ltd. EyeLink system. This system has high spatial resolution (0.005°), and a sampling rate of 250 Hz (4 msec temporal resolution). The EyeLink headband has three cameras, allowing simultaneous tracking of both eyes and of head position for head-motion compensation. By default, only the subject's dominant eye was tracked in our studies. The EyeLink system uses an Ethernet link between the eyetracker and display computers for real-time saccade and gaze position data transfer. The system also performs saccade and blink detection on-line for the FDP paradigm. In the present study the configurable acceleration and velocity thresholds were set to detect saccades of 0.5° or greater.

Displays were generated using an S3 VGA card and a 17" ViewSonic 17PS monitor. The display had a resolution of 360 by 240 pixels, with a frame rate of 120 Hz. At the 60 centimeter viewing distance the display subtended a visual angle of 30° horizontally and 22.5° vertically.

A 9-point calibration was performed at the start of each block of trials, followed by 9-point calibration accuracy test. Calibration was repeated if any point was in error by more than 1° , or if the average error for all points was greater than 0.5° . Before each trial, a black fixation target was displayed at the center of the display. The subject fixated this target and the reported gaze position was used to correct any post-calibration drift errors. The background of the target display had the same luminance as the image to be displayed during the trial, to minimize pupil size changes.

Display changes were generated by displaying a transient image beginning at a vertical retrace, and restoring the normal display 4 retraces (33 msec) later. The transient image for the visual search study was a gray field matched in luminance to the picture presented during the trial. In the reading experiment the transient image was a black screen.

In the FDP condition, a display change was generated at a fixed delay of either 110 or 158 msec after the end of each saccade made by the subject. These delays were verified using an artificial eye and an optical sensor. In the RDP condition the interval between consecutive display changes varied randomly between 250 to 350 msec in the visual search task and between 300 to 400 msec in the reading task. Subjectively it was very difficult to distinguish between the three experimental conditions.

2.3. The Visual Search Task

In this task subjects searched for 4 targets embedded in grayscale images of residential interiors. Average brightness across images was 27 cd/m^2 . Targets were 0.5° by 0.5° checkerboard patterns with 35% contrast, and were locally matched in luminance to the picture background in order to make search difficult and generate numerous saccades per trial. Subjects were allowed up to 30 seconds for the search. If subjects located all the targets before the deadline they terminated the trial with a button press. A total of 64, 64 and 128 trials were used in the FDP 110 msec, FDP 158 msec, and RDP conditions respectively. Trial order and the pairing of stimuli to conditions were randomly determined for every subject.

2.4. The Reading Comprehension Task

Subjects read a short story for comprehension and enjoyment. The text was presented in black (brightness = 4 cd/m^2) on a white background (brightness = 68 cd/m^2). Proportional spaced fonts were used with an average of 2.2 characters per degree of visual angle and an average of 10 lines per screen. A total of 12, 12 and 24 screens were read in the FDP 110 msec, FDP 158 msec, and RDP conditions respectively. The pairing of screens to conditions was determined randomly for every subject. Screens were pages of text in the story, and were presented in the same order to all subjects. When subjects finished reading a screen they pressed a button to proceed to the next screen.

3. RESULTS

Histograms of fixation duration distributions collapsed across all subjects in a given condition are plotted in Figure 1. These show that the FDP conditions in both the visual search task and reading comprehension task replicated the results obtained in previous gaze contingent studies. In particular, the fixation duration distributions for the FDP conditions exhibited a dip. In both tasks the location of the dip across the two delay conditions (i.e., 110 vs. 158 msec) was displaced by approximately the difference between the delays (48 msec). In contrast, no dip was seen in the histograms of fixation duration distributions for the RDP condition in either task.

Whereas the fixation duration distributions for the RDP versus the FDP conditions appear on the surface to be very different, a re-plotting of the results reveals a striking similarity. This is shown in Figure 2 which plot the proportion of saccades by latency after

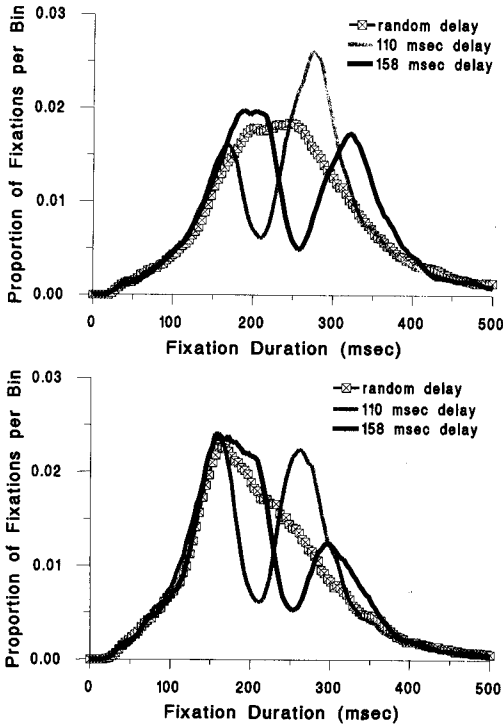


Figure 1. Histogram of fixation duration distribution by experimental condition and task. Top panel = visual search. Bottom panel = reading comprehension. Bin size = 4 msec.

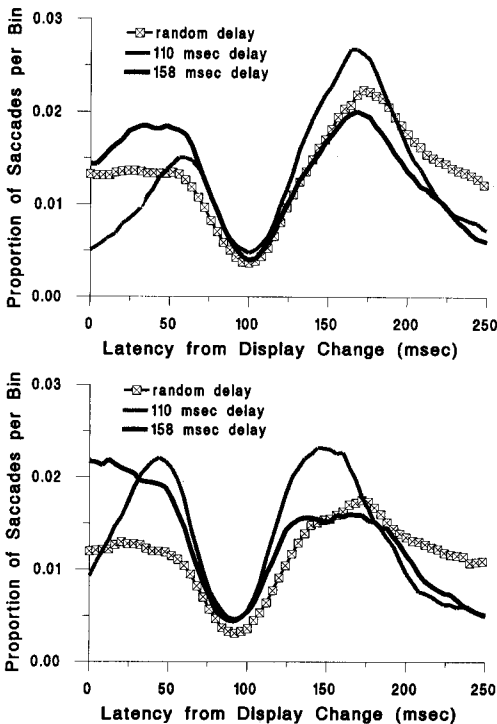


Figure 2. Proportion of saccades as a function of the latency from display change by experimental condition and task. Top panel = visual search. Bottom panel = reading comprehension. Bin size = 4 msec.

Table 1. Mean Latency (msec) to the center of the dip by experimental condition and task.

Condition	Latency to dip (in msec)	
	Visual search	Reading
Fixed delay, 110 msec	91.6 (4.3)	98.4 (5.1)
Fixed delay, 158 msec	89.2 (4.1)	99.2 (4.9)
Random delay	91.2 (5.7)	99.6 (5.2)

These correspond to the center of the dips in Figure 2. Standard deviations are shown in parentheses.

the display change, using saccades and display change data from the eye movement file and collapsing across all subjects in a given condition. For the two FDP conditions this is equivalent to aligning the fixation duration distributions by subtracting the value of the delay from each fixation duration and plotting values greater than zero. As can be seen in Figure 2 the dip is present and appears to be similar in shape and latency for all of the FDP and RDP conditions in both tasks.

Although the dip is quite similar across all three conditions, the pattern before and after the dip differs. This occurs because the two FDP conditions depend on the underlying shape of the fixation duration distribution. That is, a fixed delay causes the dip to occur at a particular point along the continuum of fixation durations. In contrast, the RDP pattern reflects a condition in which the saccade to display change delay varies continuously, and consequently a wide range of fixation durations are affected (hence the absence of a dip in the fixation duration distributions in this condition). Accordingly, only the RDP condition reveals the true nature of the saccadic interference effect. An inspection of this condition in Figure 2 indicates that for the first 50 msec following the display change the proportion of saccades remains flat. In all likelihood these saccades are unaffected by the display change and therefore may serve as a baseline. At a later point the proportion of saccades decreases below baseline constituting the dip and then increases above baseline constituting the peak. Finally, following the peak the proportion of saccades returns to baseline levels.

To perform statistical tests on the latencies to the center of the dip, histograms of saccadic frequency by latency from display change were produced for each subject and condition, and the latency of the center of the dip was measured for each histogram. The results are given in Table 1, which shows the average latency and standard deviation across subjects for each condition in each task. Comparisons between the two FDP conditions and the RDP condition using t-tests indicated no significant differences across all conditions within the same task.

4. DISCUSSION

The results of the present study are consistent with the saccadic inhibition hypothesis and are difficult to reconcile with the processing disruption hypothesis. In both the visual search and reading comprehension tasks, and across the FDP and RDP conditions, a specific pattern of saccadic frequency is produced following a display change. This was independent of the precise timing of the display change during fixations. The pattern is clearly visible in the RDP condition in Figure 2, and can be decomposed into three intervals. Immediately following the display change, saccadic frequency is stable and is prob-

ably unaffected by the display change. This interval can serve as an estimate of baseline saccadic frequency. The second interval (the dip) indicates saccadic inhibition (i.e., saccadic rates below baseline). The third interval (the peak), reflects recovery from saccadic inhibition (i.e., saccadic rates above baseline).

The RDP methodology introduced here has several advantages over traditional gaze contingent paradigms (i.e., FDP) for studying the saccadic inhibition phenomena. First, the technical implementation of gaze contingent methodology is challenging and expensive in terms of both software and hardware, and consequently may not be widely available to researchers. Second, the RDP reflects a continuous rather than a discrete manipulation of saccade to display change delay. Consequently the RDP reveals the pattern of saccadic inhibition independent of the shape of the fixation duration distribution. Finally, the RDP allows estimation of the baseline saccadic frequency, which enables the computation of additional measures such as the magnitude and duration of the dip and the peak. We are currently evaluating a variety of dip and peak measures. In addition, research employing the RDP is being conducted in our lab to assess the influence of stimulus factors (i.e., the nature of displays and transient images) as well as observer factors (e.g., attentional and strategic factors) on the pattern of saccadic inhibition.

The current findings of saccadic inhibition in complex visual tasks must be compared with findings from previous psychophysical and neurophysiological studies. Several psychophysical studies reported inhibition or slowing of saccades following the presentation of a visual event which was displayed at the same time or after the presentation of the saccadic target (e.g., Ross and Ross 1980, 1981; Walker et al. 1997). Walker et al. (1997) suggested that the neurophysiological locus of the saccadic inhibition they observed may be related to inhibitory processes in the superior colliculus (e.g., Dorris and Munoz 1995; Munoz and Wurtz 1993). Further studies employing a variety of psychophysical and neurophysiological paradigms are required to converge on an adequate theory of saccadic inhibition.

ACKNOWLEDGMENTS

Preparation of this paper was supported by a grant to Eyal M. Reingold from the Natural Science and Engineering Research Council of Canada. We wish to thank Elizabeth Bosman her helpful comments on an earlier version of this paper. We also thank Esther Meisels for testing the subjects.

REFERENCES

- Blanchard HE, McConkie GW, Zola D, Wolverton GS (1984) Time course of visual information utilization during fixations in reading. *J Exp Psychol Hum Percept Perform*, 10:75–89
- Dorris MC, Munoz DP (1995) A neural correlate for the gap effect on saccadic reaction times in monkeys. *J Neurophysiol* 73:2558–2562
- McConkie GW, Underwood NR, Zola D, Wolverton GS (1985) Some temporal characteristics of processing during reading. *J Exp Psychol Hum Percept Perform*, 11:168–186
- McConkie GW, Reddix MD, Zola D (1992) Perception and cognition in reading: Where is the meeting point? In: Rayner K (ed) *Eye movements and visual cognition: Scene perception and reading*. Springer Verlag, NY, pp 293–303
- Munoz DP, Wurtz RH (1993) Fixation cells in monkey superior colliculus. I. Characteristics of cell discharge. *J Neurophysiol* 70:559–575.

- Ross LE, Ross SM (1980) Saccade latency and warning signals: Stimulus onset, offset, and change as warning events. *Percept Psychophys* 27:251–257
- Ross SM, Ross LE (1981) Saccade latency and warning signals: Effects of auditory and visual stimulus onset and offset. *Percept Psychophys* 29:429–437
- van Diepen PMJ, De Graef P, d'Ydewalle G (1995) Chronometry of foveal information extraction during scene perception. In: Findlay JM, Walker R, Kentridge RW (eds) *Eye movement research: Mechanisms, processes and applications*. Elsevier, Amsterdam, pp 349–362
- Walker R, Deubel H, Schneider WX, Findlay JM (1997) Effect of remote distractors on saccade programming: Evidence for an extended fixation zone. *J Neurophysiol* 78:1108–1119