A Contingent CRT Display for Saccadic Adaptive Control Experiments.

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1. Introduction

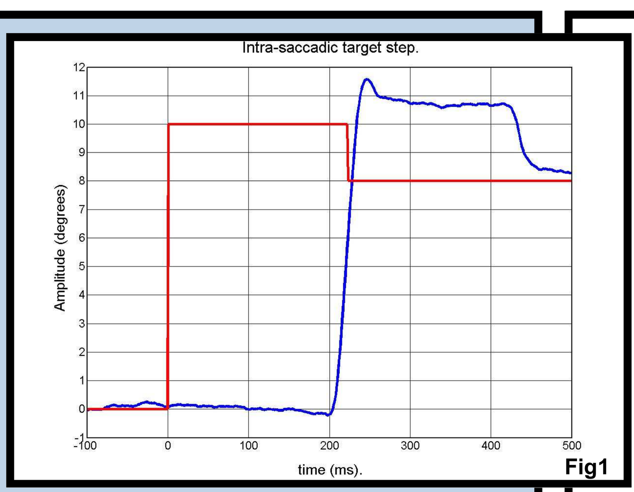

Fig1

Understanding saccade adaptive control requires that an error be introduced into the post-saccade visual signal. This is normally achieved using an intra-saccadic stimulus change during the ongoing saccade (The intra-saccadic target step paradigm).

Unfortunately, the restricted availability and choice of saccade contingent displays has limited research in this area. A natural and underexploited choice for such a stimulus presentation system is a computer controlled CRT display.

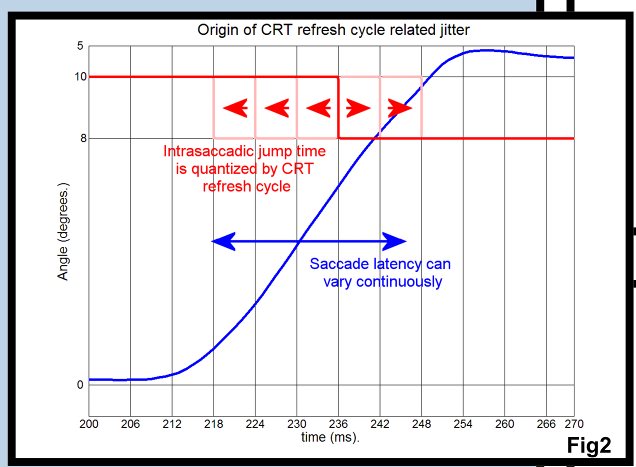

Fig2

Due to the fact that saccades have variable latencies, and CRT displays have deterministic refresh rates, any saccade-contingent change in a display will have jitter relative to the saccade start. Moreover, commercial CRT refresh rates tend to be slow so it is possible that a display change may occur in a frame after a saccade is terminated.

We have developed a new contingent CRT system using the ViSaGe visual stimulus generator to generate saccade-contingent display changes. We demonstrate the viability of the system by empirically measuring the jitter and by eliciting adaptive changes in saccade gain in human subjects.

2. Saccade Contingent Display

The system is based around the ViSaGe visual stimulus generator, which consists of a custom graphics system on a host PC connected via USB and DVI to an external interface electronics package. This performs video generation as well as analog and digital I/O processing using its integrated DSP.

The host PC is able to processes stimulus presentation control scripts on a frame by frame basis with hard real-time guarantees.

Analog and digital data captured by the system is buffered, filtered, and passed back to the host PC using two USB channels: A high-capacity, high-delay (50-200ms) 1 kHz channel, and, concurrently, a low-capacity, low delay (<1ms) once-per-frame channel.

We used a 21'' Sony GDM F520 CRT display running at a refresh rate of 167Hz. A differentiating FIR has been implemented that can be uploaded to the ViSaGe DSP. Six differentiated samples, proportional to eye velocity, are received once-per-frame. (approx 6 ms frame period). The kHz bulk channel is unaffected by this custom filter.

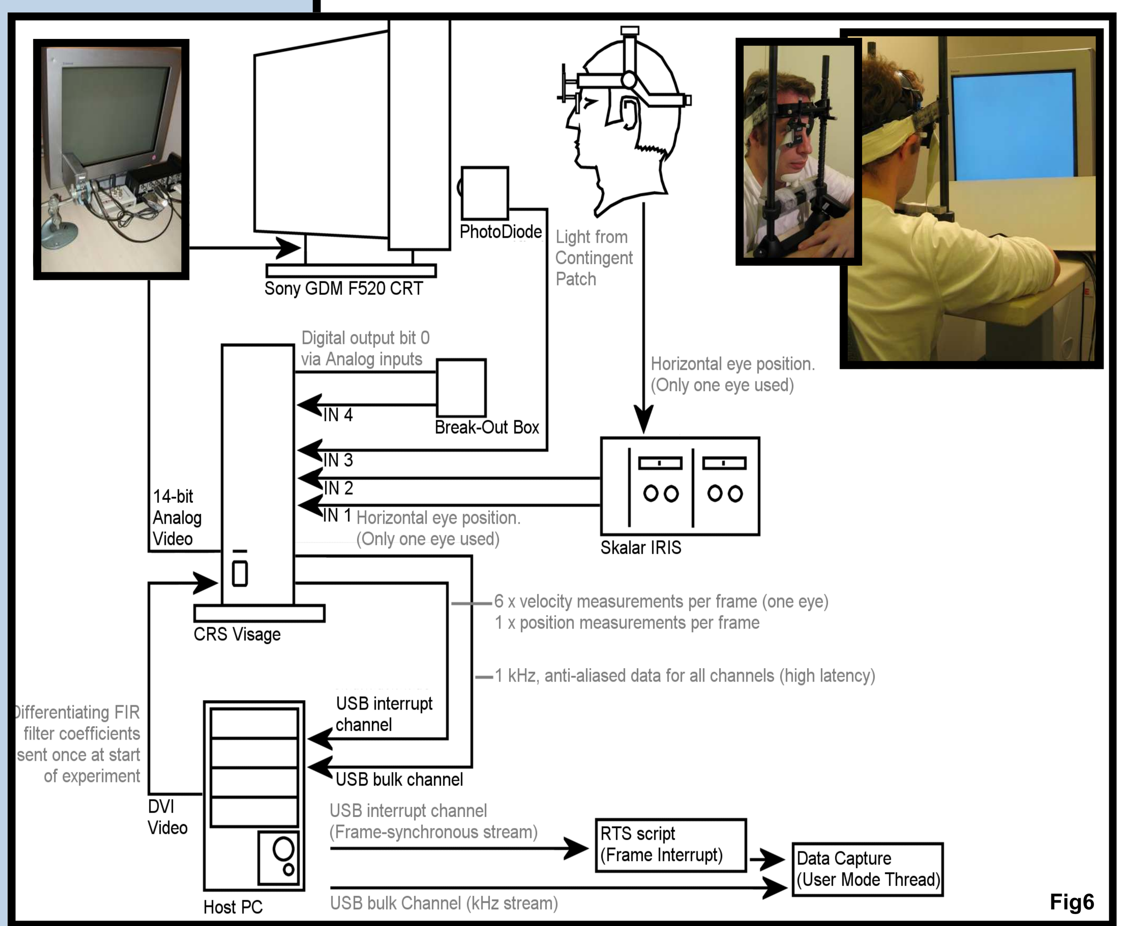

Fig6

The display is changed contingent upon the filtered velocity signal exceeding a previously calibrated threshold, however the display is not updated until the next video frame. Eye position was measured using an infrared limbus tracker (Skalar IRIS system) and sampled at 1kHz.

For the purposes of this trial, the display change was limited to selecting pre-drawn video pages from a predefined sequence. This allows us to introduce more complex stimuli without affecting the basic functionality of the saccade contingent display .

3. Jitter characterisation

Our first goal was to measure the actual jitter in the CRT display relative to the saccade onset. In order to ensure the veracity of the measurements, we employed two separate schemes.

A high speed photodiode was used to record the stimulus display change. The output of the photodiode was compared to the output of the IRIS eye-tracker using a digital storage scope. This measure was independent of the ViSaGe. The delay measured was between 15 and 25 ms.

To fully characterise the system, we generated histograms by recording a digital marker output at the start of the contingent display change together with eye position data.

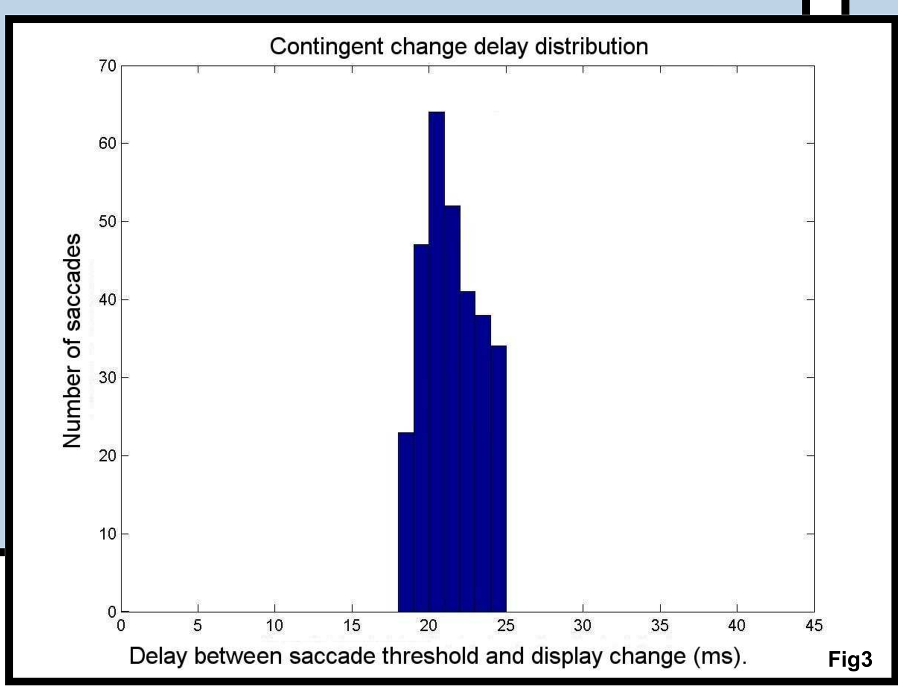

Fig3

Mean and (standard deviation) amplitude for final 25 primary saccades from each experimental phase for all subjects.

Subject	PREADAPT	ADAPT	RECOVERY
EW	10.9º (1.0)	8.9º (1.3)	9.8º (0.9)
KM	8.9º (0.7)	7.7º (0.8)	8.6º (1.0)
MH	11.2º (0.7)	8.2º (1.0)	9.7º (0.8)
PS	8.4º (1.1)	6.9º (0.9)	7.6º (0.5)
RG	11.9º (1.1)	10.0º (1.4)	10.4º (1.8)
SE	8.7º (1.2)	7.0º (1.2)	9.3º (1.5)
WP	9.4º (1.5)	7.7º (1.6)	10.8º (0.9)

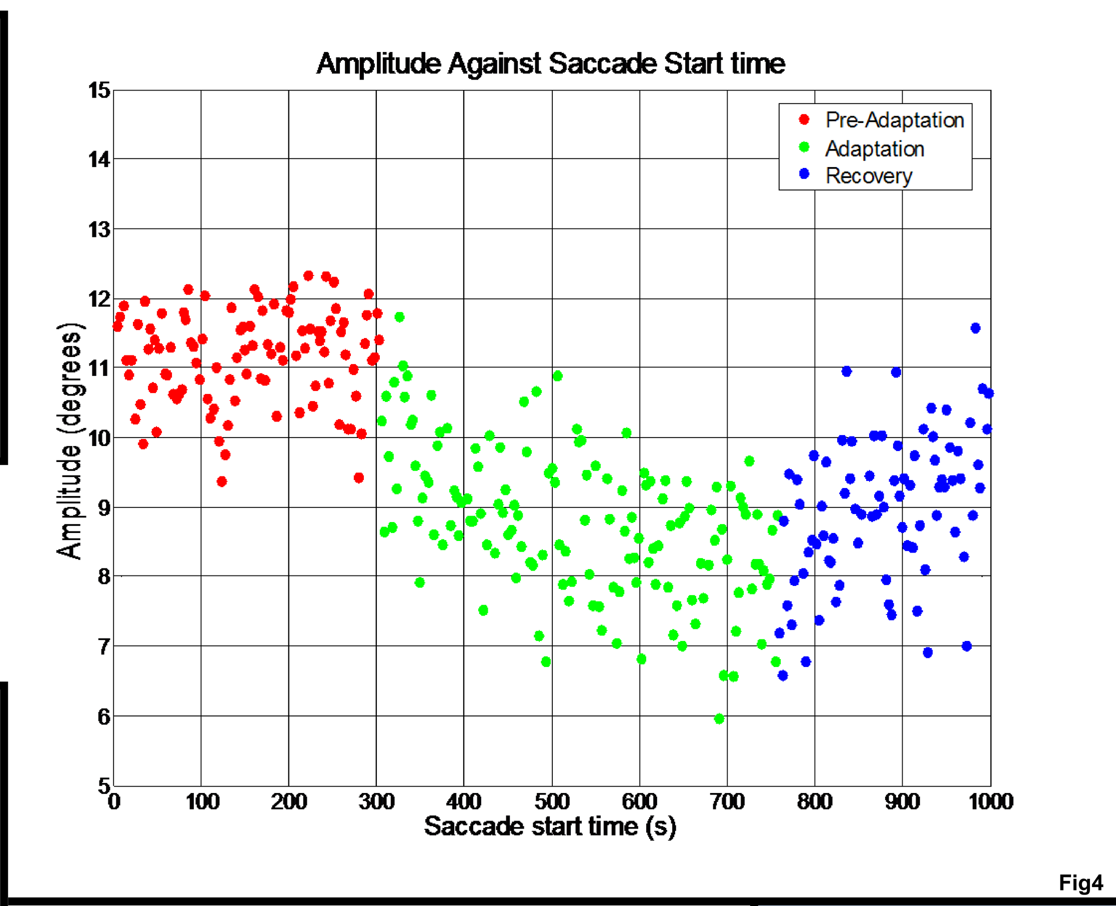

Fig4

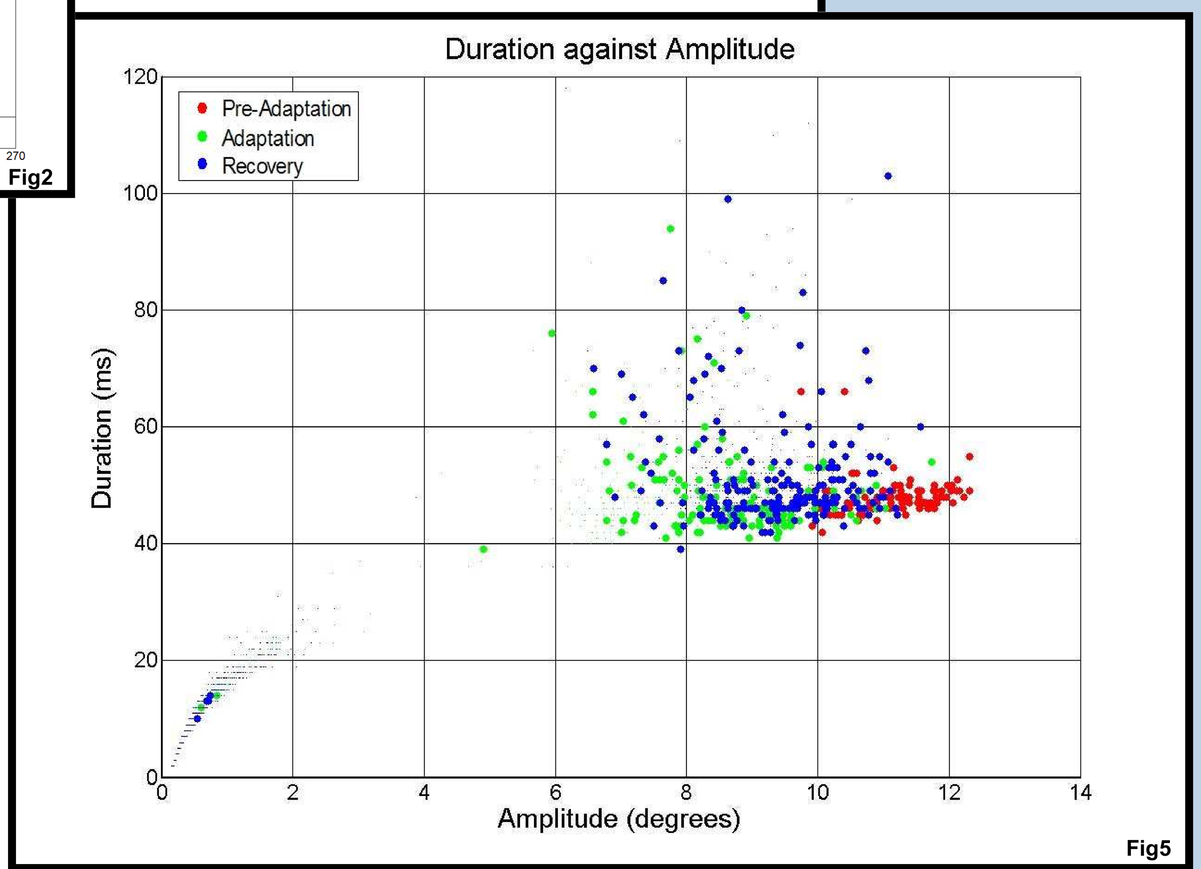

Fig5

4. Methods

Seven male subjects aged between 26-42 were tested using a simple intra-saccadic backwards-step adaptive control paradigm to a single eccentricity.

The stimulus consisted of a red dot on an equiluminant grey background.

In order to minimise the number of predictive primary saccades, the fixation duration was randomised between 1 and 3 seconds. The fixation point was extinguished simultaneously with the appearance of a target at an eccentric location +10 degrees to the right of the fixation point.

The experiment had three phases:

PRE-ADAPT: 100 simple (non-contingent) target displacements from a central fixation point to a +10 degree target and back. This phase allows us to measure the amount of amplitude variation present in the absence of adaptation, and to check for the presence of drift over a 5-minute period.

ADAPT: 150 saccade-contingent target displacements, initially going to the same +10 degree location, but jumping back to +8 degrees from fixation when a saccade was detected (velocity exceeded 50 degrees per second). This phase allows us to observe and measure the degree of adaptation.

RECOVERY: 100 simple (non-contingent) target jumps from a central fixation point to a +10 degree target and back. This phase allows us to observe some recovery from adaptation.

Eye movements were acquired with the Skalar IRIS limbus tracker, and the analog signal recorded and digitised using the ViSaGe (see Saccade Contingent Display).

The IRIS output voltage was calibrated to eye position both prior to and immediately following the experiment using a smooth pursuit method. Care was taken to ensure linearity of the IRIS output. The contingent display velocity threshold was calculated based on the prior calibration.

5. Results

Of the seven subjects tested. All showed some degree of saccadic amplitude adaptation. No subjects reported seeing the intrasaccadic target displacement. One subject reported being aware of some manipulation of the stimulus, but was unable to specify its exact nature.

The mean amplitude of the primary saccade was calculated over the final 25 saccades from all three experimental phases. The results are summarised in the table below left.

For each subject, primary saccade amplitude was plotted against time. In six of the seven subjects, a marked reduction in saccade amplitude is evident during the ADAPT phase. In some subjects, almost all of the adaptation occurs during the first 20-30 saccades. A typical plot is shown in figure 4. Interestingly, three subjects also showed a systematic change in primary saccade amplitude during the PRE-ADAPT phase.

6. Discussion

The results demonstrate that it is indeed possible to induce adaptation of saccade amplitude using a CRT display. Although display change jitter is a potential problem, we have shown that the maximum delay from threshold is 25ms. This means that we can easily change the display during a 10 degree saccade (typical duration ~ 50ms).

It is possible that the jitter may have unexpected effects on adaptive changes. However our second experiment clearly demonstrates that our system does indeed induce adaptive amplitude changes. It can be seen from the results that primary saccade amplitude has adapted to the final target location, and the amount of amplitude change is consistent with the backwards step target location. The time course of the adaptation is also consistent with that previously reported, consequently, we are confident that this saccade contingent display is a valid technique for investigating saccadic adaptation.

The presence of gain changes during the pre-adapting phase is some cause for concern. There are two possibilities for this gain change: The first is that this is true adaptation resulting from the reduced complexity of the stimulus and experimental conditions. The highly localised targets providing an error signal not normally available during visual scanning. It is also possible that these changes could be due to the nature of the instrumentation used: Since the IRIS system is sensitive to changes in subject posture; subject movement and displacement of the sensors may contribute to amplitude changes seen, confounding measurements of the degree of adaptation.

In this initial study we have used a very simple stimulus similar to previous published experiments. However, the advantage of our system is that the CRT offers the potential to display much more complex spatially and temporally structured stimuli. This simple validation will enable us to develop new and more complex experimental designs to explore the nature of the visual error that drives saccade adaptation.

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