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The influence of bright background flicker during different saccade periods on saccadic performance☆

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Abstract

We investigated saccades from central fixation to targets at 5° to the left or right. These targets were red laser points of light with an intensity unmodulated in time (referred to as steady), while a bright background (76 cd/m^2) was illuminated by a special fluorescent lamp, the output of which were series of light pulses (at frequencies of 50 or 100 Hz) that were presented only during certain periods, in synchrony with the saccade: e.g. during fixation of the central target, or during the latency (i.e. the period from target onset to saccade onset), or during the execution of the saccade; otherwise, the background luminance was steady. We observed a mean increase in latency of about 23 ms when 50 Hz flicker pulses occurred during the latency alone. This result is interpreted in terms of saccadic inhibition [Reingold & Stampe, (2000) In: Kennedy, Radach, Heller, & Pynte (Eds.) Reading as a perceptual process. Elsevier, Amsterdam]: our bright background flicker during the latency may have produced longer latencies, similar to the remote distractors in the model of Findlay and Walker [Behav. Brain Sci. 22 (1999) 661]. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Eye movements; Saccades; Flicker; Displays; Saccadic inhibition

1. Introduction

The studies reviewed below suggest that flickering displays may disturb saccadic eye movements, in some conditions even at frequencies near or above the critical flicker fusion (CFF) limit: i.e. when the intermittent light is not perceived as flickering, and the display appears to be stable. This issue is not only relevant for the understanding of the oculomotor control mechanisms, but may also have practical implications since intermittent light of luminaires, television, or visual displays at computer workstations may contribute to eye strain (Lindner & Kropf, 1993; Wilkins, 1995). Effects of flickering bright targets on a black background have been investigated by Kennedy and Murray (1991, 1996), Macknik, Fisher, and Bridgeman (1991), Montegut, Bridgeman, and Sykes (1997), Wilkins (1986). However, visual displays at computer workplaces usually have dark characters on a bright background; therefore we investigated saccadic effects induced by a flickering bright visual field. With a size and luminance similar to that found at computer screens, the bright-background CFF ranges between about 50 and 100 Hz for different subjects (Bauer, 1987; Burr, 1991; Jaschinski, Bonacker, & Alshuth, 1996) with the mean near 75 Hz.

Several studies have reported that the intermittency of a bright background can affect saccadic eye movements, as described in Section 4 (Baccino, 1999; Kennedy & Murray, 1993, 1996; Kennedy, Brysbaert, & Murray, 1998; Krummenacher, 1996; Wilkins, 1986). The measured parameters of saccades were the amplitude, the velocity, and the latency, i.e. the period between target onset and initiation of the saccade. However, the observed effects on these saccadic functions differed among studies, so that the underlying mechanisms are still unclear. It should also be noted that some researchers were unable to replicate the

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effects of flicker on saccade amplitude (e.g. Boschman & Roufs, 1994; Krummenacher, 1996). The reason for discrepancies between results of different studies may be that effects appear to be modulated by a variety of factors such as stimulus parameters (contrast polarity, eccentricity), type of task (saccades to targets, reading, cognitive demand), and, possibly, individual susceptibility.

Further, previous research did not answer the question of which moment in time during saccadic control is most sensitive to disruption due to flicker. Several possibilities may exist. First, flicker during the fixation period (before the saccadic target is presented) may affect the active fixational mechanism that keeps the eyes at a fixed point in space. West and Boyce (1968) found that microsaccades during fixational eye movements were triggered by flicker pulses; thus, any disturbance of the fixation mechanism may affect the subsequent saccades. Second, flicker during the latency may disrupt the process of saccade programming, since most of the oculomotor control is determined during the saccade latency (Rayner, 1998). More specifically, the constant intervals between the flicker light pulses (of 10 and 20 ms for flicker frequencies of 100 and 50 Hz, respectively, in the present study) may disturb the saccade programming periodically; thus, the disrupted saccade onset may have a fixed temporal phase-locked relationship to the series of pulses, as reported by West and Boyce (1968) for fixational microsaccades (however, at much lower flicker frequencies). Third, the execution of a saccade may be a critical period since the saccade amplitude and velocity have been reported to increase as a function of the number of light pulses that occurred during the flight of the saccade (Baccino, 1999).

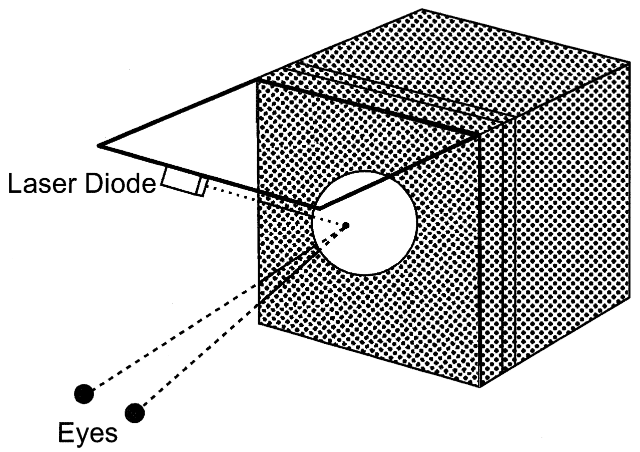

Fig. 1. Experimental setup with the housing containing the circular fluorescent lamp behind the circular milk glass screen. Three laser diodes (only one is shown for clarity) were mounted on a frame so that the beam was directed onto the screen and produced points of red light at the centre and 5° left or right.

The aim of the present study was to differentiate between these different possible mechanisms that may account for the disturbance of saccades due to intermittency of light presented in certain temporal phases of a saccade. The presentation of flicker only during fixation, latency, or saccade execution is not possible with CRT screens, which must necessarily be scanned at a certain (lower or higher) frequency in order to present an image on the screen. We therefore built an experimental display with a fluorescent lamp that can be operated with any temporal wave-form of the input current: i.e. pulsating current results in intermittent light while DC current produces light unmodulated in time, referred to as steady light. This feature allowed us to produce a bright background with series of light pulses (of 50 or 100 Hz) only during specific periods of the eye movement, i.e. (1) during fixating the central target, (2) during the latency, (3) during fixation and latency, or (4) during the execution of the saccade. Before and after these periods, steady light of the same mean luminance was presented. A control condition with steady light during the complete trial provided a reference that allowed us to evaluate the effects of flicker at different frequencies. Saccades were induced to the right and to the left of a central fixation point by presenting red target points of light unmodulated in time (projected from laser diodes).

2. Methods

2.1. Fluorescent lamp display and laser diodes

As shown in Fig. 1, subjects observed binocularly a circular milk-glass screen (diameter 19 cm, or 17° at the viewing distance of 63 cm) that was back-illuminated by a circular fluorescent lamp of 32 cm diameter. The lamp was built into a box that contained a hollow sphere with a white surface to give a homogeneous distribution of white light. Richez and Meyer (1977) used a similar fluorescent lamp display for the investigation of flicker perception. For the purpose of the present experiment a fluorescent lamp has the advantage that either steady or flickering light can be produced by providing the lamp with current that has an appropriate temporal profile. We were able to use a special fluorescent tube that was purpose-made for research (Cavonius & Estévez, 1975) by the manufacturer Philips (Eindhoven, Netherlands) about 30 years ago, which had a special phosphor with a short decay time (no serial number of the phosphor is available). To describe the phosphor characteristics, we measured the step light response with a fast photo-detector (built by our laboratory) when the lamp was operated with a 50 Hz square-wave signal. This and the other temporal luminance profiles of the experiment were computer-

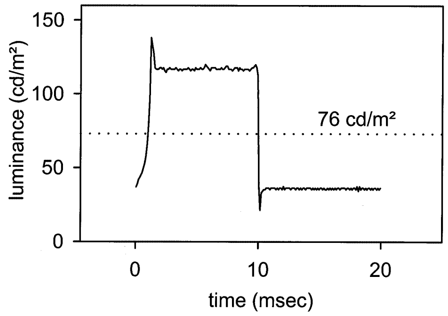

Fig. 2. Dynamic light measurement of the fluorescent lamp for a square-wave current to describe the response characteristic of the fast phosphor (see text for details).

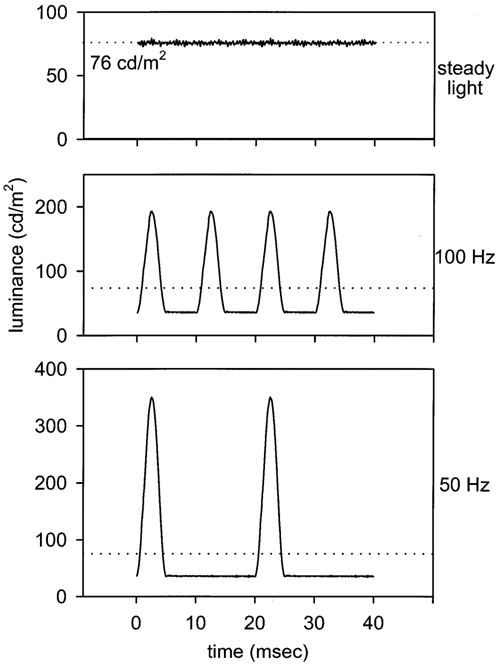

Fig. 3. Dynamic measurements of series of light pulses used in the experiment with frequencies of 50 and 100 Hz with steady light as a reference. The amplitude of the light pulses was adjusted to always have the same mean luminance (shown by the horizontal line). Between the pulses, the light intensity did not reach zero since a certain minimum luminance had to be maintained to prevent extinction of the lamp.

controlled by a function generator board that operated the lamp via a power-supply unit including a feedback control circuit. The dynamic light profile was measured in relative units and calibrated on the basis of measuring the time averaged light intensity with a Hagner photometer. Fig. 2 shows that in the off-duty period of the square-wave the light intensity did not reach zero, since a certain minimal DC current had always to be provided to prevent extinction of the lamp; thus luminance never fell below a value of 36 cd/m^2. The on-duty light level was adjusted to have the same average luminance of 76 cd/m^2 as during the experiment. As a result of the electronic feedback control, some ripple in light intensity occurred when the signal was switched on or off abruptly. The light intensity reached its maximum 1.5 ms after the onset of the duty cycle (at $t = 0$) and its minimum 0.5 ms after the end of the duty cycle. These measurements show that the lamp phosphor was fast enough to produce light pulses of a few milliseconds.

For the experiment we wished to produce light pulses as short as possible with the present lamp to simulate those from CRT screens. We generated lamp light pulses shown in Fig. 3 with a duration at half intensity of 2.5 ms (for comparison, a Sony 15sf VGA Color CRT has a light pulse duration of about 1 ms, as measured in the same way). At flicker frequencies of 50 and 100 Hz, we used the same time course of these light pulses, but varied the temporal gap between the pulses (as is the case on CRT screens). The amplitude of the light pulses was adjusted at each frequency to always have a time-averaged luminance of 76 cd/m^2 as seen by the subject. Since the light pulses had to be superimposed with the DC-light component, we did not have a full temporal modulation. To quantify the amount of light modulation in cases of non-sinusoidal time courses we calculated the flicker-index which is defined as the integrated light profile above mean luminance divided by the integrated light profile above zero, both relative to one period. This flicker index was 0.41 and 0.32 at the frequencies of 50 and 100 Hz, respectively.

The screen was weakly illuminated by the dim room lighting (provided by an incandescent lamp) and induced a constant luminance level of about 1 cd/m^2, which is negligible relative to the 76 cd/m^2 generated by the lamp display. On this display, the light stimuli pulsed at the same moment in time across the whole screen, while on CRT screens the electron beam scans the screen from the top to the bottom.

To stimulate saccadic eye movements on the blank white screen, three laser diodes were installed at a frame above the screen (Fig. 1), so that three red points of light (about 2 mm in size) could be projected on the centre of the screen and 5° horizontally to the right and to the left, respectively. This laser light was unmodulated in time. The intensity of these points of laser light was measured by placing neutral density filters into the laser beam until detection threshold was reached; the intensity was 1.8 log unit above threshold, which was clearly visible. No other saccadic stimuli than these red laser light points on the bright background were given. Alternately, the central fixation point and the right or the left target point was switched on. After the fixation point was presented for 1000 ms, the target immediately appeared for 500 ms. Thus, it was the signal for subjects to trigger a saccade to the target and then back to the central fixation point.

2.2. Eye movement recording system

Eye movements of the right eye were monitored by means of an infrared photoelectric system (Bouis, Karlsruhe, Germany; described in Beauvillain & Beauvillain, 1995) which determines the centre of gravity of the infrared light reflected by the pupil; thus the system is not sensitive to changes in pupil size. The system provided a near-linear output in the range of horizontal visual angle of $\pm 6°$, where the accuracy was better than 6 minutes of arc. The participant's head was constrained by use of a dental composition bite bar and forehead and chin frame. The signal was digitised every millisecond using a Lab-PC 12-bit A/D Converter (National Instruments) and recorded for off-line analysis. The measuring system used two computers, connected by their parallel ports: one controlled the lamp display and the other collected the eye movement data.

We detected the onset and offset of each saccade online during recording with the following velocity-based algorithm (Stampe, 1993): at each sampling point in time (t_i) we tested two logical conditions on the actual eye position signal $S(t_i)$ in millivolts, i.e. $\text{abs}[S(t_{i-3}) - S(t_i)] > T_{\text{sacc}}$ and $\text{abs}[S(t_{i-1}) - S(t_i)] < T_{\text{fix}}$. If both conditions were fulfilled, a sampling point is assumed to fall within the course of a saccade. The first condition is fulfilled when the voltage exceeds a chosen threshold value of $T_{\text{sacc}} = 12$ mV; the second condition with $T_{\text{fix}} = 10$ mV prevents stretching of saccades and erosion of the fixation following the saccade; this resulted in a threshold velocity of about 30°/s. The signal of the detected saccade onset was sent to the other computer in order to change the light online in each trial dependent on the actual moment of saccade onset. The detected end of the saccade was used to determine saccade amplitude.

Calibration of the oculometer was carried out before each block of trials by a five-point calibration procedure. Some of the saccades had to be removed from the data set because of eye blinks, drifts and glides; these saccades, which were 15% of the total, were replaced by mean values of the corresponding condition to avoid missing values in the statistical analyses.

2.3. Experimental conditions and design

The experimental conditions are illustrated in Fig. 4: series of light pulses (at either 50 or 100 Hz) were presented either (1) during the period of fixation of the central target (called fixation period), (2) during the period between the target onset and saccade onset (called latency), (3) during both the fixation and the latency period, or (4) during the execution of the saccade and the following period while the eyes fixated the target at 5° eccentricity (saccadic execution). In addition to these eight flicker conditions, in a reference condition we presented steady background light during the entire trial. The time averaged luminance was the same (76 cd/m^2) for steady light and the periods with 50 or 100 Hz flicker pulses.

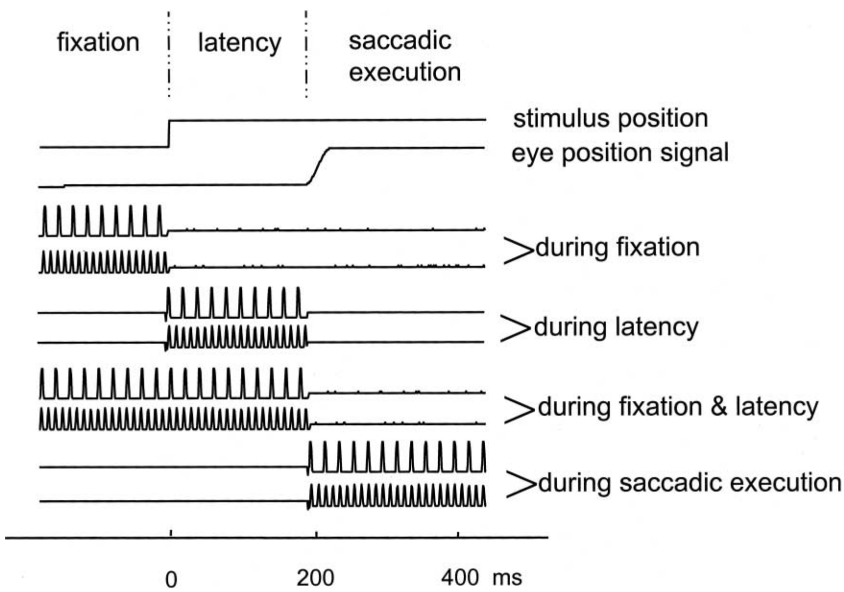

Fig. 4. Illustration of the series of light pulses presented only during specific periods in the course of a single eye movement trial: (1) during the fixation of the central target position, (2) during the latency, (3) during both fixation and latency, and (4) during both the execution of the saccade and subsequent view on the target. The series of flicker pulses had a frequency of either 50 or 100 Hz, with corresponding pulse-to-pulse periods of 20 or 10 ms, respectively. In the reference condition, no flicker pulses at all were present during a complete eye movement trial, i.e. steady light (unmodulated in time) was given during fixation, latency, and saccade (not shown). These flicker conditions refer to the bright background, while the targets always had steady red light from the laser diodes.

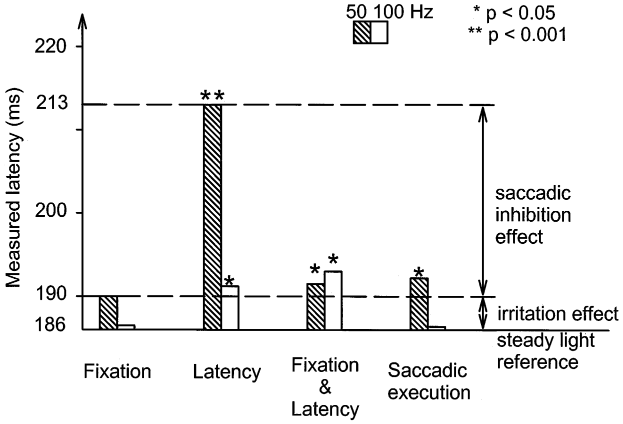

Fig. 5. Mean saccadic latency of the 44 subjects in the experimental conditions comprising flicker pulses of 50 or 100 Hz (dashed or open bars, respectively) presented in the eight flicker conditions: (1) during fixation of the central target, (2) during the latency, (3) during both fixation of the central target and the latency, and (4) during the execution of the saccade. These latencies are plotted relative to the reference latency of 186 ms, measured with steady light during the complete trial, comprising the fixation, latency and execution of a saccade. Asterisks indicate significant results. The saccadic inhibition effect and the irritation effect are explained in the text.

On ordinary CRT screens with a bright background, 50 Hz flicker is clearly visible for nearly all observers, but 100 Hz flicker is not, since the average CFF frequency is near 75 Hz in these conditions (Bauer, 1987; Burr, 1991; Jaschinski et al., 1996). On CRT screens the pulses of light are presented continuously (otherwise no image is visible); in the present experiment, however, the background luminance was switched abruptly between steady light and short series of light flashes. Any such switch was visible, even with flicker pulses of 100 Hz, since it also includes frequency components well below CFF, as predicted by Fourier analysis. As a consequence, this switching of background light was perceived by the subjects as a momentory discontinuity, although the mean luminance was always the same. This effect is inevitable if one wishes to introduce series of light pulses into these short periods during saccadic performance. Thus, the present study did not include a condition of non-visible continuous flicker.

For each of the nine experimental conditions, a block of 26 trials was made during which saccades were made to the right or left target in random order. After each block, participants were allowed to take a short rest of several minutes. All nine blocks were made during a single experimental session, counterbalanced using a Latin square across subjects. The experiment included 44 subjects. The subject's vision was normal or corrected-to-normal (contact lenses only).

Analyses of variance with repeated measures were calculated on the saccadic accuracy and latency, with Greenhouse–Geisser corrections of the levels of significance. The within-subject factors were the eight flicker conditions in Fig. 4 and steady light as a control.

3. Results

3.1. Saccade amplitude

The amplitude of saccades can be described by the accuracy, i.e. the difference between target amplitude and the amplitude of the saccade (both in degrees of visual angle). We found a main effect of the nine experimental conditions on accuracy [$F(8, 344) = 2.41$, $P < 0.01$]. Paired comparisons showed that only one condition was significant: 50 Hz flicker pulses presented during both the fixation and the latency period induced a significantly [$F(1, 43) = 4.84$, $P < 0.05$] larger undershoot of $-0.28°$ than the reference condition of steady light (-0.19 deg). Thus, in this condition the saccades were shorter than with steady light.

3.2. Saccade latency

Fig. 5 shows the mean latency depending on the period during which the flicker pulses of 50 or 100 Hz were presented, i.e. during the fixation period, the latency period, the fixation and latency period, or the period of saccadic execution. As a baseline we used the latency of 186 ms that was found when steady light was present during the complete trial. We found a significant main effect of the nine experimental conditions [$F(8, 344) = 13.06$, $P < 0.001$]. The graph suggests that the saccade onset was most strongly delayed when 50 Hz flicker pulses were presented only during the latency. This prominent effect (27 ms relative to steady light) was highly significant [$F(2, 86) = 29.61$, $P < 0.001$]. Five of the seven other flicker conditions showed smaller, but (nearly) significant delays relative to steady light: during fixation [$F(1, 43) = 3.72$, $P < 0.06$ at 50 Hz], during fixation and latency [$F(1, 43) = 4.87$, $P < 0.033$ at 50 Hz and $F(1, 43) = 6.41$, $P < 0.015$ at 100 Hz], during the latency [$F(1, 43) = 5.47$, $P < 0.024$ at 100 Hz], and during saccadic execution [$F(1, 43) = 5.63$, $P < 0.022$ at 50 Hz]. The last finding on saccade execution cannot be a direct functional effect for causal reasons, since flicker pulses during the saccade cannot have affected the latency of the same saccade. But it can be explained if we consider that within each block we presented 26 trials with the same flicker condition. Thus, the steady light block did not comprise any flicker pulses, while during the eight other blocks a flicker condition was presented. The repetitive visible switching between periods of flicker and steady light during the course of the block may have irritated the subjects and in this way produced longer latencies even when 50 Hz flicker pulses were presented during the saccade, i.e. after the latency. Such irritation effects may have occurred also during the other flicker conditions.

We estimated the average irritated latency as the mean across all flicker conditions (except for 50 Hz flicker pulses during the latency) and found that it was significantly longer by 4 ms than the latency during steady light [$F(1, 43) = 6.39$, $P < 0.025$]. The effect of 50 Hz flicker pulses during the latency, however, exceeded significantly the amount of the irritation effect, by a much larger duration of 23 ms [$F(1, 43) = 31.70$, $P < 0.001$]. Therefore, we conclude that 50 Hz flicker pulses during the latency induced a clear functional prolongation of latencies by about 12%. This exceeded the prolongation of about 2% that may have occurred due to unspecific irritation of subjects arising from the visible intermittency and switching between light conditions during the blocks of trials.

In order to test whether a possible phase-locking between the series of the 50 Hz light pulses (with periodic intervals of 20 ms) and saccade onset may exist, we calculated for each saccade the time interval between saccade onset and the last light pulse during the latency, which served as a temporal reference of the series of pulses. This time interval is equivalent to the remainder of the latency divided by 20 ms (also called modulo), e.g. for a latency of 174 ms it is 174 ms/20 ms = 8 remainder 14 ms. Fig. 6 illustrates the distribution of this time interval, which can assume values up to 20 ms for the 50 Hz flicker condition. However since this observed distribution did not differ significantly from an equal-probability distribution [$\chi^2(19) = 14.75$, n.s., $n = 20$ categories], no evidence was found for phase-locking to the 50 Hz flicker pulses.

4. Discussion

The main results of the present study were the approximately 12% increase in saccadic latency when 50 Hz flicker pulses were presented only during the latency and the about 2% smaller saccade amplitude when 50 Hz flicker pulses were introduced into both the fixation and the latency period. The former result gives clear evidence that the saccadic disruption induced by flicker occurred during the critical period of latency. As described above, the switching of background luminance between steady light and flicker pulses of 50 or 100 Hz was—inevitably—visible during all flicker trials of the present experiments; this appeared to have irritated the subjects and produced a small but significant prolongation of latencies of about 4 ms. The present design has the advantage that this unspecific irritation effect can be separated from the larger functional effect, i.e. the 23 ms longer latencies when 50 Hz pulses were presented during the latency.

The present approach allows us to investigate the specific moment in time when flicker light pulses may affect saccadic performance. However, this implies that a direct comparison of our results with those of previous flicker studies using CRT screens is difficult for three reasons: (1) on CRT screens, flicker pulses are continuously present during all phases of an eye movement, (2) our lamp display pulsed at the same moment in time across the whole screen, while a CRT screen is scanned by the electron beam, and (3) a steady-light reference condition is not possible with CRT screens for technical reasons. Despite these discrepancies between CRT screens and the present conditions, the following similarities in results were found and are discussed as follows, first for saccadic amplitude and then for latency.

Kennedy et al. (1998) investigated simple saccades to small targets presented left or right of central fixation at different eccentricities on a bright background CRT screen: Compared to frequencies of 75–100 Hz, the saccade amplitudes were smaller both at lower (50–70 Hz) and higher (110–125 Hz) refresh rates. The amount of these effects was about 2%. This curvilinear pattern of result cannot be tested in the present study since we used only two frequencies, 50 and 100 Hz. However, we observed 2% smaller saccades, when 50 Hz flicker pulses were presented during both fixation and latency. Thus, despite some differences between these studies, they have in common that low flicker frequencies of 50–70 Hz induced smaller saccades. This appears to be a worse saccadic performance, since our effect was found in relation to a steady light control condition and since Kennedy et al. (1998) reported more right-going refixations at 50 Hz, which may compensate the shorter saccades. It should be noted that the opposite effect on saccade amplitude was found by Kennedy and Murray (1993, 1996); they used a task that involved looking at three words in turn: after fixating the centre character of a prompt word for 1 s, subjects were required to perform a saccade to target word 1 and from there to target word 2. With a bright flickering background, the amplitude of the entry saccades into word 2 was shorter

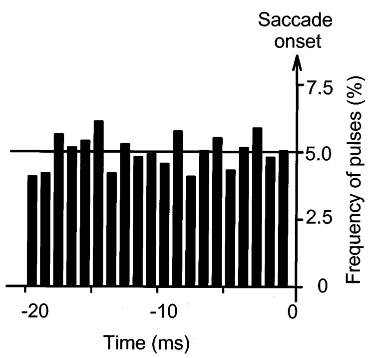

Fig. 6. Relative frequency (%) of the last 50 Hz flicker pulse during the latency relative to the onset of the saccade at $t = 0$. The horizontal line illustrates the null hypothesis of an equal-probability distribution (44 subjects).

at 100 and 125 Hz as compared to 50 Hz. Further, more corrective saccades, especially right-going, within-word, refixations, were found at 100 Hz than at 50 and 75 Hz, which may have compensated for the shortening of the saccades. However, this task of simulated reading was more complex than the simple saccades to peripheral targets discussed above.

The largest effect in the present study was the approximately 12% increase in saccadic latency when 50 Hz flicker pulses were presented during the latency itself. The following two previous studies of simple saccades to peripheral targets gave comparable results (with continuous flicker on bright background CRT screens). Krummenacher (1996) reported longer latencies at 50 Hz than at 70 and 90 Hz. Kennedy et al. (1998) found in their Experiment 2 that latencies were longer at 50 and 75 Hz as compared to 100 and 125 Hz (in their Experiment 1, however, no significant latency effect was found). Thus, longer latencies due to 50 Hz flicker was observed in three independent experiments. These observations can be interpreted in view of the following saccade studies that did not deal with flicker per se, but with single flashes of light. Walker, Deubel, Schneider, and Findlay (1997) presented, in the moment of target onset, points of light as distractors at different locations in the visual field and found longer latencies whenever the distractor appeared at any location remote from the target. Reingold and Stampe (2001) flashed a bright background area above and below a horizontal target area for 33 ms at a variable delay after target onset: saccades were inhibited by the flash. As a consequence, the latency distribution had a dip and, thus, the average latency was longer. The main decrease in saccadic frequency was found at a constant delay after the flash onset (80 ms). In our experimental conditions we had a series of ten flicker pulses of 50 Hz during a typical latency of about 200 ms, rather than a single flash. Thus, we cannot expect ten distinct dips in the latency distribution, but we found a corresponding increase in latency which could be explained in terms of saccadic inhibition.

Despite differences in experimental conditions, the studies of Walker et al. (1997) and Reingold and Stampe (2001) and the present experiment have in common that the light stimuli flashed in the periphery produced longer latencies, although the properties of the saccadic stimuli on the horizontal axis were not changed. To account for this so-called "remote distractor effect", Findlay and Walker (1999) included in their saccade generation model a separate "level 3" stage that represents the effect of peripheral visual events on the fixation system in the sense of slowing the triggering process. The neurophysiological correlate of this saccadic inhibition may be the superior colliculus (Gandhi & Keller, 1997) as suggested by Findlay and Walker (1999) and Reingold and Stampe (2000). This line of evidence suggests that the effect of bright background flicker may be a variant of a remote distractor effect.

Following the observation of Walker et al. (1997) with a single distractor flashed at the moment of target onset it is possible that our (visible) switch between steady light and flicker at target onset might have contributed to the observed 50 Hz effect. However, this may not fully explain the large size of the 50 Hz effect reported, since only small and presumably unspecific irritation effects were found in other conditions with similar visible discontinuities at target onset, i.e. when 100 Hz flicker pulses were switched on at target onset after steady light during fixation and when flickering light of 50 or 100 Hz during fixation changed to steady light during the latency. Further, effects of light pulses in the course of the latency are plausible after the observations of Reingold and Stampe (2001) with a single pulse at variable delays during the latency.

The amount of increase in latency due to continuous 50 Hz bright background flicker on CRT screens was about 3% and 4% in the studies of Krummenacher (1996) and Kennedy et al. (1998), respectively. These effects are much smaller than the 12% increase with 50 Hz pulses during the latency alone, but comparable with the present conditions of pulses during fixation and latency (4%; relative to the steady light condition). We would expect a saccadic inhibition effect in the latter condition as well; but, while this 50 Hz effect during fixation and latency was significantly different relative to steady light, it was not separated from the irritation effect. This may suggest some kind of adaptive mechanism due to flicker pulses during fixation.

Due to the differences described above in the way of flicker presentation with CRT screens and the lamp display, the present results cannot be applied directly to the viewing conditions at a CRT at the workplace; further research is needed to investigate the extent to which normal CRT flicker may provoke longer latencies, not only with simple saccades to peripheral targets, but also in more complex visual tasks, e.g. reading. A further open question is whether saccadic performance is affected only by background flicker or perhaps also by flicker in luminance of the target.

In conclusion, the present data, interpreted in view of related research, suggest that a bright background flickering at frequencies of 50 Hz during the latency can be regarded as an area of remote distractors that inhibit, i.e. produce longer latencies in simple horizontal saccades. We did not find evidence for functional effects at 100 Hz.

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