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SUPPRESSION OF THE BLACKOUT DUE TO BLINKS

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Abstract—An eyeblink causes an almost complete occlusion of light entering the eye. Yet people scarcely notice their blinks and the subjective visual world remains continuous and stable. We first duplicated the optical effect of a blink with an appropriate decrement in the illumination of a Ganzfeld. Viewed with eyes open, this momentary dimming seemed much stronger than the physically equal one produced by lid closure during a real blink. We then found that subjective equality with the real blink could be attained when the open eyes viewed a decrement of reduced magnitude and duration. We infer that a voluntary blink is accompanied by a suppression that fills in the blackout that would otherwise be perceived.

INTRODUCTION

Blinking serves, along with lacrimation, to maintain the hygiene and oxygen exchange over the corneal surface of the eye (McEwen and Goodner, 1969; Moses, 1975). Blinks also protect the eye from injury by such objects as flying insects or unruly strands of hair. But the eyelids can only carry out these essential functions by blinding us, momentarily, to the visual scene. Typically, the blackout lasts for 100–150 msec (Lawson, 1948a, b; Gordon, 1951; Slater-Hammil, 1953; Kennard and Glaser, 1964) and occurs 10–15 times per min (King & Michels, 1957; Moses, 1975). Yet blinking is no more noticeable than is any other spontaneous activity such as breathing or swallowing.

In this paper we compare the subjective effects of a blink with those of a momentary dimming of the light when the eyes remain open. The hypothesis we are testing is that each blink initiates a suppression or corollary discharge (Sperry, 1950) of the sort that is known to accompany saccadic eye movements (Latour, 1962; Volkmann, 1962). We have already found, indeed, that a blink results in a momentary elevation of the visual threshold amounting to about 0.5 log unit under conditions that preclude masking or other visual events (Volkmann *et al.*, 1980).

In the present experiments we use a supra-threshold comparison procedure to assess the visual effect of an eyeblink. Our aim is thus to verify and quantify the common experience that a voluntary eyeblink does not seem to produce any noticeable interruption of vision. Our initial idea was to use the procedure suggested by Moses (1975) for simulating a blink:

> "In experimental situations, obscuration of vision of 0.003 sec or 1/100 of a blink duration is barely detectable by the subject at daylight levels of illumination; a darkening of the entire visual field for 0.03 sec by means other than spontaneous blinking is easily noticed. The continuity of visual sensation during the spontaneous blink is similar to the continuity of visual sensation during saccadic (rapid) eye movements when vision is also suspended to a large degree."

Specifically, we wished to produce in a Ganzfeld a momentary darkening of the entire visual field such that the subject, viewing it with open eyes, would judge its subjective effect to be similar to that produced by the momentary closure of the eyes during a blink. In preparation for this, we conducted preliminary experiments to determine the durations and magnitudes of light decrement due to typical voluntary blinks made by each of our subjects. We then used these measurements to set up simulated blinks in the Ganzfeld and found that our subjects all judged them to be of much greater visual impact than the corresponding decrements due to real blinks. Finally, by trial and error, we reduced both the duration and the magnitude of the simulated blinks so that they were a good subjective match for real ones.

In the main experiment, we chose a single value of duration of Ganzfeld darkening that the subjects were willing to accept for a qualitative simulation of a real blink. Using magnitude of decrement as the principal independent variable, we asked subjects to compare the visual effect of the Ganzfeld darkening with that of a real blink, following the sequence illustrated in Fig. 1. We thus were able to measure the subjectively equivalent light decrement, and so to infer the amount of suppression present during blinks.

PRELIMINARY EXPERIMENTS

Duration of pupillary occlusion during blinks. We measured the duration of visual interruption for each subject by the use of a Purkinje Image Eye Tracker (Cornsweet and Crane, 1973). This device was used to actuate a digital clock at the moment when the upper lid had descended far enough to occlude a portion of the light entering the pupil, at the beginning of the blink. The clock was stopped by the tracker at the moment when the lid had partially uncovered the

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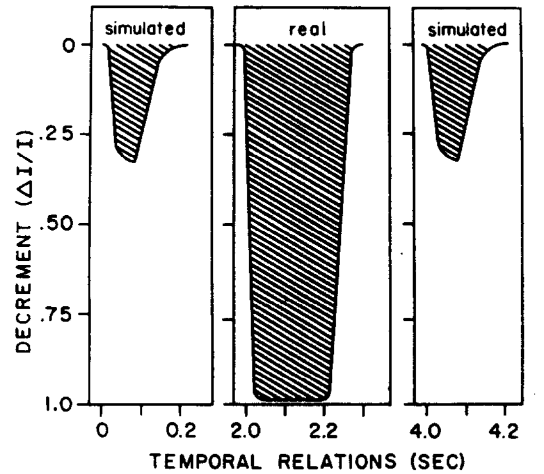

Fig. 1. Momentary decrements of light produced by a typical eye blink and by simulated blinks. The simulated blinks used in these experiments had the approximate dimensions of a 20 msec ramp onset, a 45 msec minimum and a 60 msec return to the level of steady illumination. The decrement (ΔI/I) was the independent variable that provided a range of simulated blinks, from those clearly stronger to those clearly weaker in their visual effect, than the real blink. The abscissa indicates the sequence of events on each trial. The shaded areas show (tΔI/I), the total quantity of light loss involved in real and simulated blinks.

pupil, near the end of the blink. In this way a sufficient number of voluntary blinks ($N = 50$) were sampled to give an estimate of the mean and standard deviation of the occlusion time for each subject as shown in Table 1.

The optical effect of closure of the lids. The problem was to determine the relative amount of light (ΔI/I) absorbed by the upper lid as it covers the pupil. Our solutions, was indirect, but nevertheless gave a reliable estimate. It was to measure the absolute threshold of vision with the eyes open and with them closed. After at least 45 min in complete darkness, the subject was tested in a Ganzfeld that was evenly and indirectly illuminated by flashes of tungsten light. The flashes were supplied by an optical system having appropriate neutral density filters, a wedge and a shutter.

For each trial, the subject heard two successive openings of a Gerbrands shutter, set for exposure durations of 200 msec. The test flash was present during either the first or the second interval, and the subject judged which interval had contained the flash. Thirty such forced choices were made for each intensity of flash. With appropriate settings of the neutral density wedge we varied the flash intensity in 0.2 log unit steps, from nearly 100% correctly judged down to 50% (chance level). The order of presentation was randomized throughout. Finally, we plotted percentage of correct judgments against wedge setting, fitted a regression line to the data and inferred from this line the wedge density corresponding to a detection threshold defined by 75% correct judgments.

Having found detection thresholds with eyes open, we repeated the procedure with the eyes closed. Since the upper lid now covered the pupil, it was necessary to increase the intensity range of the flashes by removing some of the neutral density filters. Again the wedge was set to appropriate density steps of 0.2 log unit and again a detection threshold was found. We made the reasonable assumption that, under the Ganzfeld viewing conditions of this experiment, the open-eye and closed-eye thresholds represent the same amount of retinal illuminance. Our previous study (Volkmann *et al.*, 1980) had found little difference in the basic sensitivity of the retina in open-eye and closed eye conditions. We therefore inferred that the optical density of the eyelid was the only factor determining the difference in neutral density filter and wedge values corresponding to the detection thresholds for the open and the closed eyes. These optical densities and the equivalent decrements (ΔI/I) of light are shown in Table 1.

Table 1. Comparison of voluntary blinks with matching decrements of light

	Voluntary blinks					Simulated blinks (t = 85 msec)				
Subject	Occlusion time, t (msec) Mean	σ	Occlusion magnitude Eyelid density	Decrement (ΔI/I)	Net amount of light loss Log(tΔI/I)	Luminance level, I (ft-L)	Matching decrement (ΔI/I) at PSE Session 1	2	Net amount of light loss Log (tΔI/I) Session 1	2
D.J.U.	248	27	1.85	0.986	2.39	33.6	0.302	0.302	1.41	1.41
						0.2	0.251	0.380	1.33	1.51
						0.002	0.486	0.646	1.60	1.74
L.A.R.	190	53	2.66	0.998	2.28	33.6	0.347	0.339	1.47	1.46
						0.2	0.389	0.389	1.52	1.52
						0.002	0.513	0.513	1.64	1.64
R.C.T.	121	16	1.89	0.987	2.08	33.6	0.447	0.427	1.58	1.56
						0.2	0.437	0.525	1.57	1.65
						0.002	0.724	0.832	1.79	1.85

Subjective simulation of a blink. Our third preliminary experiment was done in direct preparation for the main experiment. We sought to simulate the qualitative visual effect of a blink by presenting the subject with a brief decrement in an otherwise steady illumination of the Ganzfeld. For this we used the fluorescent light sources and the associated control devices described below under the section on Methods.

Having found, in the first two preliminary experiments, the magnitude and duration of light decrement caused by the eyelids during a blink, we now duplicated this physical effect while the subject watched it with eyes open in the Ganzfeld. All of the subjects reported that the simulated stimulus had an enormously higher impact, both in light reduction and in duration. Merely reducing the attenuation of light did not suffice. The simulated blink then seemed to last much longer and to have two clearly perceptible transients, one as the light was dimmed and the other as it returned to its original brightness. Nor was it sufficient to make a drastic reduction in the duration of the simulated blink down to a few hundredths of a sec, while maintaining the original extent of light decrement. In this case the event became as weak as an eye blink, but appeared qualitatively different in that it seemed to be more abrupt and brief. Successful matching of real blinks was finally achieved when the simulated ones were given the characteristics shown in Fig. 1, namely a somewhat shorter duration and a much smaller decrement of the light.

MAIN EXPERIMENT

Viewing conditions

Ganzfeld viewing was provided by the interior surface of a globe formed by two hemispherical aluminum bowls, 61 cm dia and bolted together along their flanges. One bowl was cut away sufficiently to permit the subject to move his head into the sphere. A chin rest fixed the position of the head so that the eyes were at the approximate center of the sphere. After smoothing, the surface was spray-painted with matt white *Nextel* paint (3 M Co., St. Paul, MN) so that it appeared uniform throughout.

Illumination within the globe was supplied by three fluorescent lamps located symmetrically, above and to either side of the subject's head, in such a way that they provided nearly homogeneous light throughout the Ganzfeld without themselves being visible. Viewing was binocular, without a fixation point or eyepiece, so that the visual field was devoid of contour except for the blurred peripheral view of the subject's own nose and cheeks.

Photopic, mesopic and scotopic viewing were achieved by adjusting the lamps to produce mean Ganzfeld luminances of 33.6, 0.2 and 0.002 ft-L respectively. To produce the 33.6 ft-L level the current through the three lamps was regulated with the driver circuits of an "Iconix" tachistoscope. The lower levels were produced by covering each lamp with an opaque shield having multiple small apertures through which the necessary amounts of light could be diffused over the Ganzfeld.

Stimulus conditions

The stimuli consisted of momentary decrements (ΔI) in the intensity of light (I) entering the eye from the Ganzfeld. These decrements were produced by voluntary blinks or by simulated blinks. The subject's task was to compare the visual effects of these two stimuli.

The simulated blinks were produced by brief decrements in the light supplied to the Ganzfeld by the fluorescent lamps. A specially designed control circuit could be preset to produce a simulated blink consisting of a light decrement of any desired magnitude and duration.

Experimental procedures

We ran the experiments in such a way as to facilitate the comparison between simulated blinks and real blinks. The subject was allowed to initiate all test stimuli. A push-button in his hand could be used to activate the preset decrement of light, and of course he could make a real blink as needed. During each run, a timer presented clicks at 2-sec intervals. After a warning signal, the subject presented himself with a light decrement at the first click, a real blink at the second, and another decrement at the third, as illustrated in Fig. 1. Note that the two light decrements are the same in magnitude and duration, but that the integrated size (crosshatched areas) of each is much less than that of the real blink.

For any given session, the Ganzfeld was set to one of the three levels (I) of luminance that were used in these experiments. After a series of practice trials, the subject was given a total of 20 trials, for comparison of a voluntary blink with the simulated ones, at each of four or five values of ΔI, presented in random order. On each trial the subject indicated whether he judged the real blink or the simulated ones to be stronger in visual effect. Thus, each session yielded a psychophysical function in which the percentage of real blinks judged stronger was plotted against log $\Delta I/I$ for the simulated blinks with which it had been compared. The point of subjective equality between real and simulated blinks was taken as the value interpolated from a fitted line of regression at the 50% point.

Voluntary blinks vary somewhat in the extent of lid movement and duration of occlusion of the pupil (see Table 1). During each session the blinks were monitored by use of the electroblepharogram (the EBG described by Volkmann *et al.*, 1980) and displayed on a storage oscilloscope. Subjects were instructed to blink normally, but occasionally an EBG of unusually large or small size was noted. On these few trials the subject's judgment was not recorded and the trial was later repeated.

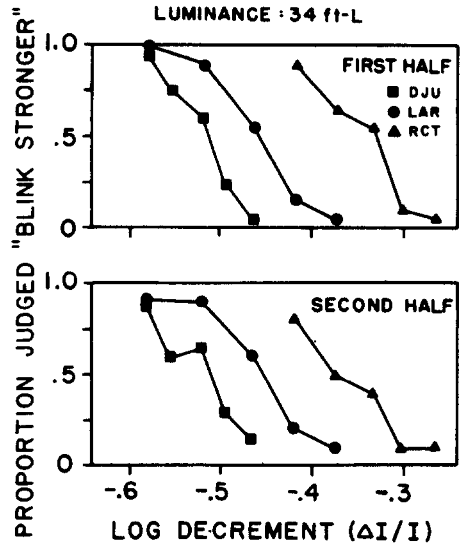

Fig. 2. Proportion of real blinks judged "stronger" than simulated blinks as a function of the simulated blink decrement (ΔI/I), for three observers and for the first and second halves of this experiment. The steady level of luminance upon which the decrement was imposed was 33.6 ft-L. Each plotted point is the result of 20 trials.

Nine experimental sessions were run with each of three subjects. The first three sessions, one on each level of luminance, were for practice. The order of the luminances for the six sessions was bright medium, dim, dim medium and bright.

RESULTS

The data of the main experiment are illustrated by Fig. 2, which summarizes the psychophysical judgments at the 33.6 ft-L level of luminance. It is clear that the subjects' judgments of the effects of the voluntary blinks are related in an orderly fashion to the decrement (ΔI/I) of light in the simulated blinks with which they were compared. Individual differences are relatively large, and in some cases there is a shift in results from the first session to the second. Nevertheless the main effect stands out clearly: simulated blinks, in order to match real ones, must have not only a briefer duration but also a much smaller degree of light decrement. Similar psychophysical functions were obtained at the 0.2 and 0.002 ft-L levels of luminance.

In Table 1, we show the decremental stimuli (ΔI/I) for the simulated blinks that are at the point of subjective equality (PSE) with the real blinks. Also shown are estimates of the total integrated light decrements (tΔI/I, corresponding to the shaded areas in Fig. 1) characteristic of the simulated blinks and the real blinks with which they were equated. At this PSE, the ratio of real blink area to simulated blink area is taken to be an index of the degree to which the visual effectiveness of blinks has been suppressed.

Figure 3 presents a summary of the degrees of suppression measured for each of the two sessions on each of the three luminance levels with the three subjects in this experiment. This figure makes clear the fact that suppression occurs at all three levels of luminance, though it may be somewhat smaller at the lowest level.

DISCUSSION

Our main conclusion is that eyeblinks seem to produce an extremely small visual effect. The qualitative effect can be described as one of filling in the very extensive gap in light that actually reaches the retina while the upper lid occludes the pupil. Subjects are able to quantify this effect by a visual comparison of blinks with momentary decrements of luminance viewed with open eyes in a Ganzfeld. But the blink effect is successfully simulated only when both the

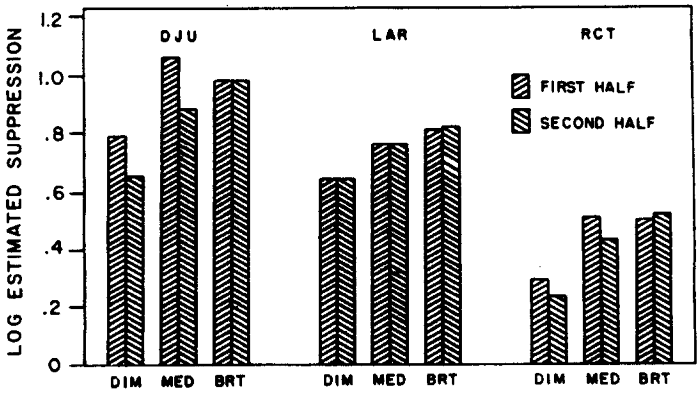

Fig. 3. Estimated suppression associated with blinks for three subjects, for the three levels of steady illumination and for the first and second halves of this experiment. Suppression was estimated by comparing the ratio of (tΔI/I) for a real blink and for the simulated blink at the point of subjective equality. This figure shows that substantial amounts of suppression are found throughout all conditions of the experiment, despite individual differences, variations from one session to another and the fact that our estimates are based upon the somewhat arbitrary index of (tΔI/I).

duration and the depth of the light modulation are greatly reduced from those characteristic of the blink.

It seems reasonable to conclude that voluntary blinks are accompanied by a suppression with characteristics like that associated with saccadic eye movements. We therefore agree with Moses that this suppression may serve to enhance the "continuity of visual sensation" while the eyelid carries out its necessary duty of protective custody for the cornea. The suppression appears to fill in both the magnitude and the duration of the blackout due to the lids. The adaptive value of this filling in may simply be that without it we would be harassed 10–15 times per min by profound blackouts due to blinks.

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