Notes and Comment

Sclera color and reports of afterimage persistence

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When a light pulse is flashed through a subject's pupil, retinal photoreceptors undergo a chemical bleaching process. When this occurs, subjects report perceiving an afterimage of the light pulse that is generally in the complementary color of the pulse (Hurvich & Jameson, 1957; Jameson & Hurvich, 1955; Uttal, 1973; Wallace, 1979). However, not all subjects report perceiving an identical afterimage. For example, Wallace (1979) recently assessed duration of an induced afterimage as a function of iris pigmentation (blue or brown) and wavelength of a light pulse used to bleach retinal photoreceptors. For blue-irised subjects, a yellow (Wratten 9) pulse produced the longest enduring afterimage, while a blue-green (Wratten 44A) pulse produced the shortest enduring afterimage. For brown-irised subjects, the reverse was the case. A yellow pulse produced the shortest enduring afterimage, and a blue-green pulse produced the longest enduring afterimage. These results were explained in terms of the possible role of the iris in selectively and differentially filtering various wavelengths of light as a function of its pigmentation. Such filtering subsequently affected reports of afterimage duration.

With individual differences existing for reports of an afterimage as a function of iris color, it is also possible that other anatomical features of the eye may contribute to differences in the perception and/or report of an afterimage. One such structure may be the sclera. Although it is considered to be "the white of the eye," it is in actuality pigmented differently for different individuals. For example, some subjects have yellow scleras (generally, subjects with dark-pigmented skin), while others have white scleras (subjects with white-pigmented skin). If sclera color does have an effect on afterimage duration, and if it serves as a filtering device in a fashion similar to that of the iris, a yellow light pulse perceived by a subject with a yellow sclera should produce an afterimage of shorter duration than that produced in a subject with a white sclera. A blue-green pulse was

expected to have a minimal effect on afterimage duration as a function of sclera color, since the human sclera is not blue and thus should not serve (as does a blue iris) as a filter for this wavelength of light.

METHOD

Subjects

Seventy-two brown-irised undergraduates enrolled in introductory psychology sections served as subjects. Only brown-irised individuals were employed because of the effect that this iris color has on the perception of an afterimage (Wallace, 1979) and because blue-irised subjects with yellow scleras could not be located. All individuals had normal, uncorrected visual acuity and normal color vision. Half of the subjects were selected for having yellowish-appearing scleras, while the remainder were chosen for having white-appearing scleras. This judgment was made by examining the scleras of each subject prior to experimental participation. Only subjects with definite yellow or definite white scleras were employed. If difficulty was experienced in making this determination, the subject was eliminated from the experiment.

Apparatus

The experiment was conducted in a 4.7 × 5.8 m completely lightproofed room. The apparatus was the same as that employed by Wallace (1979). This consisted of an electronic 2,000 beam cps Vivitar (Model 273) flash unit, which produced a pulse of approximately 1 msec duration. The unit was mounted on an adjustable stand that could be raised or lowered to permit the light source to be projected to the subjects' eyes from an eye-level position. The actual stimulus size was 6 min visual angle. This stimulus size was produced by totally masking the flash unit to permit light emission through only the small aperture. In addition, the stimulus was flashed through a yellow Wratten 9 filter (producing a bluish negative afterimage), a blue-green Wratten 44A filter (producing a yellowish negative afterimage), or a red Wratten 92 filter (producing a greenish negative afterimage).¹ Stability of the subject's head during the experiment was maintained with a Bausch & Lomb combination head- and chinrest.

Procedure

Each subject was led to the experimental room and was seated in a chair with a back support and an arm support. The chinrest was mounted on this arm support. The experimenter then adjusted the stand, upon which was mounted the Vivitar unit, to permit the aperture of the electronic flash to be at eye level with the subject. The room lights were then turned off, and the subject was permitted to dark-adapt for a 20-min period. Following dark-adaptation, the subject was instructed to gaze in the straight-ahead direction to observe a spot of light. The subjects localized this position by fixating toward the voice of the experimenter. A visual fixation point was not employed in order to eliminate any possibility of its serving as a stimulus that might produce an afterimage. The experimenter then triggered the flash unit to produce the light pulse from a viewing distance of 2.5 m.

Prior to a deployment of the light pulse, the subjects were instructed to try as hard as possible not to blink. Upon perceiving the flash, the subjects were instructed to report when an afterimage was first visible. This report was tape-recorded, and subsequent duration assessments of the afterimage were determined with a stopwatch. Each subject was exposed to a total of three

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flashes, with a 20-min intertrial interval to permit the subject to dark-adapt again. A trial was defined as the period of time from the initial observation of an afterimage to the time the initial afterimage was no longer visible. Only first afterimages were assessed. Any subject who failed to report perceiving such an afterimage on any trial was eliminated from data analyses and was substituted with another subject. Two subjects were so replaced—one in the yellow-pulse condition and one in the blue-green pulse condition.

RESULTS

The only dependent measure assessed was afterimage duration (in seconds). Other possible dependent measures, such as direction-change frequency and color-change frequency of the afterimage, have previously (Wallace, 1979) been shown not to be affected by either pulse color or anatomical feature color. As a result, they were not assessed here.

A preliminary trials analysis on the dependent measure failed to produce a significant effect. As a result, a 2 by 3 between-subjects analysis of variance (sclera color by filter color) was performed on the data averaged over the three exposure trials. This analysis produced a significant interaction between the two factors [$F(2,66) = 2.99, p < .05$].

The mean duration values for the various conditions are depicted in Table 1. For all subjects, regardless of sclera color, the afterimage produced in the yellow filter condition persisted for a significantly shorter period of time (Newman-Keuls, $p < .05$) than that produced in either the red filter condition or in the blue-green filter condition. In addition, afterimage duration was significantly longest in the blue-green filter condition (Newman-Keuls, $p < .05$). These results replicate the findings reported by Wallace (1979) for brown-irised subjects perceiving identical wavelengths of light pulses. However, duration of an afterimage when produced by a yellow pulse was significantly shorter (Newman-Keuls, $p < .05$) for subjects with yellow scleras as compared with those with white scleras. The afterimage duration within the yellow pulse condition was almost identical to that reported by Wallace (1979) when averaged across sclera color. A blue-green-filtered pulse and a red-filtered

pulse were not found to produce significant differences in the perceived duration of an afterimage as a function of sclera color.

DISCUSSION

The prediction concerning the effect of sclera color on afterimage duration of a light pulse was confirmed. Specifically, a brown-irised subject with a yellow sclera perceived the shortest enduring afterimage when it was produced by a yellow light pulse. One may thus speculate that, in addition to iris pigmentation playing a role as a selective filter of light wavelengths in the subsequent production of an afterimage, sclera color also plays such a role, but only for a yellow light pulse. As a result, a yellow pulse appears to be filtered by at least two anatomical features of the eye before it arrives at the retina to produce an eventual afterimage. Such filtering is highly selective, since it only occurs for a light pulse of a color that approximates the color of the iris and the color of the sclera. Therefore, the effect reported here is unique to brown-irised subjects with yellowish scleras.

Whether there are additional physiological structures of the eye that serve as sources of selective filtering (e.g., the cornea, the lens, the aqueous humor, the vitreous humor) of various wavelengths of light is not known. However, this would appear unlikely, given that there is only one additional feature of the human eye that is known to be differentially pigmented, other than the iris and the sclera, and that might have an influence on afterimage production and/or reports of afterimage duration. This is the fundus oculi, which includes the choroidal and retinal pigmentation layers and the pigmentation of the macula lutea. This area of the eye can vary in degrees of yellow pigmentation (Ishak, 1952a, 1952b; Silvar & Pollack, 1967). Because this area of the eye is a part of the retina, it is doubtful that it can serve as an additional selective filter of various wavelengths of light beyond the iris and the sclera.

The sensory physiology and chemistry that underlie the effect of sclera color and iris color on afterimage duration and production are obviously unclear. However, it does appear that both features play a role in selectively filtering light within a specific and narrow range of the visible spectrum. The exact range of the wavelengths that are selectively filtered has as yet not been established. Also, it is possible that the cornea, the lens, or the visual humors may have transmittance characteristics that are somehow correlated with iris color and scleral pigmentation. Therefore, before a substantive conclusion can be reached concerning the generality of the effect reported here and in a previous study (Wallace, 1979), this information needs to be determined.

Table 1
Mean Duration (in Seconds) of an Afterimage as a Function
of Sclera Color and Filter Color

Sclera Color	Filter Color					
	Yellow		Red		Blue-Green	
	Mean	SD	Mean	SD	Mean	SD
Yellow	17.56	7.95	33.09	9.14	42.53	5.77
White	26.52	6.32	33.55	9.37	41.84	6.35

Note—Filters used were Wratten 9 (yellow), Wratten 92 (red), and Wratten 44A (blue-green).

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NOTE

1. These particular filters were chosen because they were employed in the Wallace (1979) study, in which they were judged to be psychophysically equal in their effects on the perceived brightness of a light source. They were not physically equal in terms of percent of luminous transmission. The Wratten 9 filter has a dominant wavelength of 582.2 nm, an excitation purity of 90.5%, and an 82.4% luminous transmission. The Wratten 44A filter has a dominant wavelength of 491.9 nm, an excitation purity of 76.0%, and a 10.1% luminous transmission. The Wratten 92 filter has a dominant wavelength of 646.2 nm, an excitation purity of 100.0%, and a 4.8% luminous transmission. These colorimetric specifications are based on the 1931 CIE standard colorimetric and luminosity data (OSA Committee on Colorimetry, 1953).

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