The speed of macular recovery from photostress was measured as a function of age by subjective and objective techniques. The subjective procedures involved measuring the speed of recovery of habitual visual acuities after dazzling of the macula with a bright light. Macular function was assessed objectively by monitoring the development of the transient pattern VER after photostress. Both techniques indicated that the ability to recover from photostress decreased with age. However, the recovery of visual acuity and the restoration of baseline VER parameters had very different temporal characteristics. The time for restoration of baseline VER amplitude was usually several times longer than the time for subjective recovery of prestress visual acuity levels. Furthermore, subjects less than 30 years of age differed from the older group in that their recovery VER amplitudes tended to quickly surpass the baseline VER values, more so in the youngest age group. Most subjects over 30 did not show such super normal VERs and failed to recover baseline VER amplitudes within 60 sec after photostress. These observations suggest age-related functional differences in retrobulbar components of the visual system. Invest Ophthalmol Vis Sci 24:437–441, 1983

The macular photostress test (MPST) is useful in differentiating a maculopathy from an optic neuropathy. In this test the macula is dazzled for a few seconds with a bright light source such as a penlight or ophthalmoscope, and the time required for subjectively measured visual acuity to return to prestress levels is compared to normal recovery times. The recovery from photostress is dependent on the rate of photopigment resynthesis and the functional relationship between the photoreceptors and the retinal pigment epithelium (RPE). In the case of a maculopathy where the outer retinal layers and choroid are affected, a prolonged "photostress recovery time" (PSRT) will be measured. If the cause of reduced visual acuity has its origin in the ganglion cell layer of the retina or higher visual centers, the PSRT will be within normal limits. Thus the PSRT is prolonged in conditions such as central serous retinopathy,1 senile macular degeneration, and diseases of the RPE2 but normal in diseases affecting the optic nerve.3

The present report describes the use of the Visually Evoked Response4 (VER) to measure objectively the recovery of central vision after photostress.

Materials and Methods

Thirty-five healthy subjects (15 women and 20 men), ranging in age from 6 to 67 years, participated in this study. All subjects had clear ocular media, normal appearance of the fundus, and visual acuities of 20/20 or better in the test eye. Prior to experimentation each subject was adapted to the ambient room lighting (about 20 ft cd) for about 5 min. The MPST was performed according to a modified technique of Glaser et al.3 First, the visual acuity was measured for the test eye using a projector with Snellen optotypes (mean luminance of 53 cd/m², letter contrast about 80%), and then the test eye with a normally reactive pupil was dazzled with a penlight held approximately 2.0 cm from the cornea for 10 sec. In order to minimize variations in penlight intensity and their effect on PSRTs, the disposable variety of diagnostic penlights used over the course of this study was refrigerated between experimental sessions and the testing order of subjects in different age groups was randomized. The corneal irradiance values for light between 400 nm and 750 nm were measured with a Photodyne spectroradiometer and used to calculate retinal irradiance values according to the method of Sykes et al.5 The calculated retinal irradiance was about 2 μW/cm² for a 1.5-mm pupil. No correction was applied for light attenuation by the ocular media or fluctuations in accommodation. (This level of retinal irradiance was far below the photic cone damage threshold for primates,5,6 and far below the retinal irradiance level, allowing a "safe time" of 42 seconds for binocular indirect ophthalmoscopy in man.)7 During the photostress procedure each subject looked directly into the center of the penlight. If the subject wore glasses, they were lowered...
Results

The typical changes in the baseline VERs caused by the photostress procedure were a short-lived reduction or elimination of the P-1 component followed by an age-dependent increase in P-1. The magnitude of the reduction of P-1 was not related to the subject’s age. Figure 1 presents the VER records for two subjects in this study. Examination of the data for the 22-year-old female subject reveals that the P-1 component became more discernible with time after photostress and its amplitude, as measured within the time bracket (‘A’), increased for up to 75 sec after photostress. A similar increase in the amplitude of P-1 (bracket (‘B’)) was seen for the 38-year-old male subject, but the rate at which it increased was approximately 2.5 times slower. The rate of change in the P-1 amplitude was determined by the slope of the least squares linear regression line relating the amplitude of P-1 to the time after photostress. The linear regression analysis of the VER amplitude–time function for these two subjects was significant at the 1% level. The majority of subjects, 77%, showed a significant linear correlation for the VER amplitude–time function at the 1.5% level or better. Only 3 of 35 subjects did not show a significant correlation at the 5% level.

Figure 2 presents the VER amplitude plotted as a function of time for seven subjects, one from each of the age groups indicated on the right hand side. The slopes of the calculated linear regression lines (dashed lines) are seen to decrease with age. The most
Fig. 2. VER amplitude as a function of time after macular photostress for seven subjects, one from each of the age groups indicated on the right hand side. The horizontal arrows indicate the VER amplitude prior to photostress. The vertical arrows indicate the PSRT. The dashed lines are linear regression lines. Note the general decrease in the slope of the regression line with increasing age.

Fig. 3. Graph illustrating the PSRT as a function of the subject's age. The curve drawn between the data points is the nonlinear least squares regression line defined by PSRT = 5.4303 e^0.0166 Age

rapid recovery of the VER amplitude after photostress occurred in the youngest age group, while the slowest increase was seen in the oldest age group. Intermediate recovery rates were shown by the two individuals in the 10–19 and 20–29 age groups, while the four individuals falling into the above 29 age groups showed slower but nearly equal recovery rates.

The second major finding illustrated in Figure 2 is that the amplitude of P-1 continued to increase for many seconds beyond the PSRT, indicated by small upright arrows. Subjects below 50 years of age had PSRTs of 7.93 ± 2.67 sec, while subjects over 50 years of age had PSRTs of 15.2 ± 4.56 sec. The distribution of PSRTs according to age of the subjects is shown in Figure 3.

A third interesting finding was that the VER for all subjects less than 30 years of age not only returned to baseline value within 60 sec after photostress, but exceeded the baseline amplitude in the same time period. Whereas some individuals over 30 also showed a VER baseline recovery within 60 sec, 71% of the subjects in this age group did not regain baseline VER amplitude within the 75-sec time frame of the study. The relationship between age and the VER recovery rate for all subjects is shown in Figure 4. This figure illustrates a clear trend for the VER recovery rate to decrease with age. The most rapid decrease in the
VER recovery rate occurred between ages 6 and 40. Beyond 40, the recovery rate decreased more slowly.

Discussion

The finding that PSRTs increased with age supports earlier observations by Severin et al and Glaser et al who reported increased PSRTs in subjects over 40 and 60 years of age, respectively. The curved line in Figure 3 represents an exponential model for the PSRT-age relationship found in the present study. The model is defined by the equation: PSRT = 5.4303e^{0.0166 Age} and is significant at the 0.001 level. The implication of an age-dependent PSRT is that there is a nonpathologic deterioration of macular function with age.

The PSRTs reported herein are relatively short when compared to some of the normative data presented by other investigators. PSRTs reported in the literature range from 8 to 70 sec. The lack of standardization with respect to the intensity and duration of the bleaching light, the method used to measure visual acuity, and the chosen end point of the test undoubtedly account for this wide variation in PSRTs.

It is well known that physical and physiologic factors affecting the macula or macular-cortical pathways can alter the pattern VER. It was not surprising, therefore, that a light source inducing a transient central scotoma also caused a significant change in the pattern VER. It was surprising, however, that the PSRTs and the baseline VER recovery times differed greatly. The PSRT for all subjects was only 9.4 seconds (SD 4.2 sec), while the baseline VER recovery time was 37.7 seconds (SD 13.1 sec) in 23 subjects. The VER recovery time was indeterminate in 12 subjects as their VER amplitude did not return to baseline value within the experimental analysis time of 75 sec. This observation suggests that the MPST, and the VER recovery rate might be indices of separate physiologic processes with different temporal characteristics. The MPST may be an index of exclusively photochemical phenomena, wherein the rate of regeneration of foveal photoreceptor pigments is assessed. The continued increase in the VER amplitude after the recovery of the prestress visual acuity may reflect slower neurophysiologic processes secondary to photochemical events whereby spatial resolution mechanisms undetectable by standard clinical measurement of visual acuity are fine tuned. On the other hand, both tests may be indices of solely photochemical processes. The PSRT may indicate the time required to resynthesize sufficient photoreceptor pigment to permit high spatial resolution, a foveal function, while the continued increase in VER amplitude may indicate the rate of pigment regeneration in the parafoveal and macular areas.

Another surprising observation for all subjects less than 30 years of age was the increase in the VER amplitude beyond baseline value within 11.5 to 54 sec after photostress. Since monitoring of the VER recovery was restricted to a 60- to 75-sec period after macular dazzling, the time course of the VER recovery to baseline could not be specified. For subjects over 30 the VER exceeded baseline amplitude in 60 sec or less in only five cases. All others in this age group had indeterminate VER baseline recovery times since it could not be assumed that the VER recovery was a linear function beyond the 60- to 75-sec time frame. The physiologic basis for the VER surpassing baseline values is uncertain at the present time. Transient improvements in visual function following photostress have been reported in patients with pathologic pigmentary changes of the macula, and malnutrition. In these cases the improvement in visual acuity was presumed to be due to an increased oxygen supply to the photoreceptors second-
ary to transiently enhanced retinal circulation. However, in an earlier study, MacFarland and Halperin\textsuperscript{12} reported that photopigment regeneration was not significantly influenced by the level of oxygen in blood. More recently, Tengroth et al.\textsuperscript{9} decreased PSRTs by increasing the oxygen concentration in blood and concluded that this phenomenon was mainly due to the effect of oxygen on cerebral processes involved in vision. It would seem, therefore, that the mechanisms causing the super normal VERs are not retinal in origin but may reflect a rebound phenomenon occurring in retrobulbar visual pathways and visual cortex. That this phenomenon was not seen in most of the subjects over 30 may be attributed to non-pathologic senile processes affecting retrobulbar visual neurons.

The curved line in Figure 4 represents an exponential model for the VER recovery rate-age relationship. This model is defined by the equation: VER recovery rate $= +0.1745 e^{-0.00488 \text{Age}}$ and is significant at the 0.001 level. The progressive decrease in VER recovery rates with age likely reflects nonpathologic senile changes in the retina as well as the cerebral structures involved in vision. At the retinal level, there are both physiologic\textsuperscript{13,14} and morphologic\textsuperscript{15} degenerative changes that likely affect its functional capability. Just as pathologic changes in the macula produce abnormal pattern VERs,\textsuperscript{16} decreased functional reserves of the macula are also likely to affect the VERs. At the cortical level, neuron density decreases exponentially with age.\textsuperscript{17} While there is no precise way of relating gross morphologic changes in brain structure to functional changes in specific sensory modalities, it seems reasonable to assume that such a relationship does exist. Thus, the decreased VER recovery rate associated with increasing age may be, at least in part, the result of normal age-related structural changes in the brain.

Standard clinical tests of visual function are unlikely to detect nonpathologic senile changes in the retina or visual cortex because most tests are directed at measuring thresholds of various visual functions and not their performance reserve. A thorough assessment of visual function should, therefore, include dynamic testing procedures such as the MPST especially when the results of standard tests do not adequately explain a patient’s visual symptoms. Comparison of an individual’s PSRTs or VER recovery rates with age-related norms should provide an index of the “physiological age” of macular or cortical function. Significant discrepancies between a patient’s chronologic age and “physiologic age” should be viewed with suspicion as they may indicate incipient ocular disease.

**Key words:** Macular photostress test, photostress recovery time, transient VER, visual function and age, maculopathy, neuropathy, VER recovery after photostress.

**Acknowledgment**

The author thanks Dr. A. P. Cullen for assistance in spectroradiometric measurements.

**References**