1.0 Introduction

In this paper we will be discussing methods and mathematical models for identifying the loci of sensitivity losses that occur with age. The overall goal is to describe an approach to examining changes in the regulation of sensitivity in the aging visual system within the framework of formal models of adaptation. We will not be reviewing specific results from a wide range of experiments, but rather, we will be describing an approach to the understanding of sensitivity losses in the aging visual system that incorporates psychophysical results within the framework of formal models. This approach has been successful at identifying sites and mechanisms of alterations of sensitivity in retinal disease and may also be useful in analyzing changes that occur during visual development.

One function of the visual system is to maintain sensitivity to small differences in contrast over an enormous range of ambient illuminations. The difference in luminance from moonlight to bright sunlight is a factor of $10^{10}$. Although this ability is preserved, to a large extent, over the adult lifespan in persons in good ocular health, measurable declines in visual function have been observed in a number of laboratories. We wish to address three questions. First of all, what are the differences in sensitivity between young and old observers under any given set of luminance conditions? Second, what are the differences between young and old observers under changing luminance conditions? Third, what are the mechanisms underlying the above differences? The regulation of sensitivity, otherwise known as adaptation, has been actively investigated by psychophysicists and physiologists in recent years and much has been learned about the mechanisms that subserve this process. Much of what has been learned by these investigations can now be applied to visual development in general and the aging visual system in particular. The general approach of this paper is to describe psychophysical paradigms which may be used to test alternative hypotheses regarding sites and mechanisms underlying changes in visual sensitivity and sensitivity regulation occurring in the aging visual system. Specifically, we will demonstrate how these models can be applied to test hypotheses about receptoral vs. post-receptoral sites of sensitivity loss and about multiplicative vs. subtractive mechanisms of adaptation in aging.
Figure 1. Foveal cone increment thresholds replotted from Sturr et al. (1986). Threshold measured on flashed background (flash-on-flash). Closed circles: young observers, open circles, old observers in good ocular health. +/- 1 standard error of the mean is smaller than symbol size.

1.1 Age-related sensitivity losses

Recent psychophysical evidence exists for an increase in cone and rod absolute thresholds in the aging visual system (Birren et al., 1948; McFarland and Fisher, 1955; Luria, 1960; McFarland et al., 1960; Gunkel and Gouras, 1963; Sturr et al., 1986; Eisner et al., 1987; Werner and Steele, 1988; Werner et al., 1990; Sturr et al., 1991). Figure 1 is a replot of foveal cone thresholds from Sturr et al. (1986), measured over a range of background luminance, in young and old observers, in good ocular health. In this experiment the luminance for detecting a test probe presented at the onset of a flashed background field was measured. This is known as the flash-on-flash technique. At low background luminances, the elderly have thresholds that are higher than younger observers. This difference is diminished at the higher background luminance indicated by the convergence of the data points.

Figure 2 is another replot of data taken from Sturr et al. (1986), this time showing foveal cone thresholds measured upon a steadily presented adapting field. Similar to Figure 1, this plot shows differences between old and young observers at low levels of the adapting field. These differences are also diminished at the higher luminance levels of the adapting field.

Figure 2. Foveal cone increment thresholds replotted from Sturr et al. (1986). Threshold measured on steady adapting field (steady state). Closed circles: young observers, open circles, old observers in good ocular health. +/- 1 standard error of the mean is smaller than symbol size.