Spatiotemporal Description and Model of the Afterimage Process

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I Introduction

Color appearance modeling is currently restricted to spatiotemporally simple stimuli, but models for complex scenes are emerging, which will necessarily include aftereffects, such as the negative afterimage mechanism. There is evidence that both photopigment bleaching and post-receptoral processes contribute to afterimage formation[1]. The analysis of temporal and spatial contrast-sensitivity functions (CSF) for monochromatic lights may help reveal which elements of the spatiotemporal characteristics of the afterimage process are mediated by post-receptoral processes[1,2,3,4].

A contrast-sensitivity function (CSF) describes the frequency characteristics of the human visual system in a very similar way its modulation transfer function describes an optical system, shoving the attenuation of a sinusoidal input at a given frequency by the transferring system. In visual practice CSFs are measured and expressed as reciprocal values of perception thresholds of sinusoidal stimuli at different frequencies. CSFs are defined and widely used in both the temporal and the spatial domain, and can be defined for the afterimage process as well.

II Method

To measure the spatial frequency response (sCSF) of the afterimage process to monochromatic gratings, standard Gabor patches are used. Gabor patches consist of a superposition of a sinusoidal grating of different spatial frequencies and a Gaussian, blurring the high spatial frequency content at the edges and corners of the stimuli.

The Gabor patches used are vertical gratings of different intensities of narrowband (central wavelengths: 450, 570, 620 nm for possible cone signal separation) radiation emerging from a uniform background of the same spectral composition (achromatic contrast). The σ-value of the Gaussian mask was 0.15, independent of the spatial frequency value.

The task of the observer is to detect the afterimage after conditioning with a grating of a given contrast and spatial frequency. The beginning and the end of the conditioning interval is indicated by sounds of different pitch. The method of constant stimuli was being applied, results were analyzed with Probit-regression, thresholds and confidence intervals were derived from the contrast values corresponding to the p=0.5 intersection.

The temporal frequency response (tCSF) is determined with the 'lilac chaser'[5] optical illusion. This utilizes sequential cancellation of one of the multiple narrowband inducers arranged on a circular path thus creating the illusion of a moving afterimage. The inducers were Gabor-masked in order to remove spatial high-frequency content at the transient of edges.

Temporal response is determined by the minimal contrast at various angular velocities of the inducers at which afterimage formation is observable. Inducers were emerging from a uniform (narrowband) background of four different intensities. Five levels of angular velocities were tested, each 5 times in random order. The method of adjustment was being used. The observers were instructed to increase the intensity of the inducers until an afterimage was observable moving along the circular path.

III Results and Discussion

Spatial CSF

Fig. 1 shows the results of the spatial investigations. In coherence with other publications [1,2,3,4,6] the curves are low pass shaped with peak frequencies around 0,5-0,7 cyc/deg. The CSF of the negative afterimage crosses the detection threshold curve (not shown) around 0,5-1 cyc/deg in the individual cases. This indicates that pattern detection is aided by the afterimage process at low spatial frequencies in case of step-function stimuli and this is also supported by [3] as well as the results of the present temporal investigations.

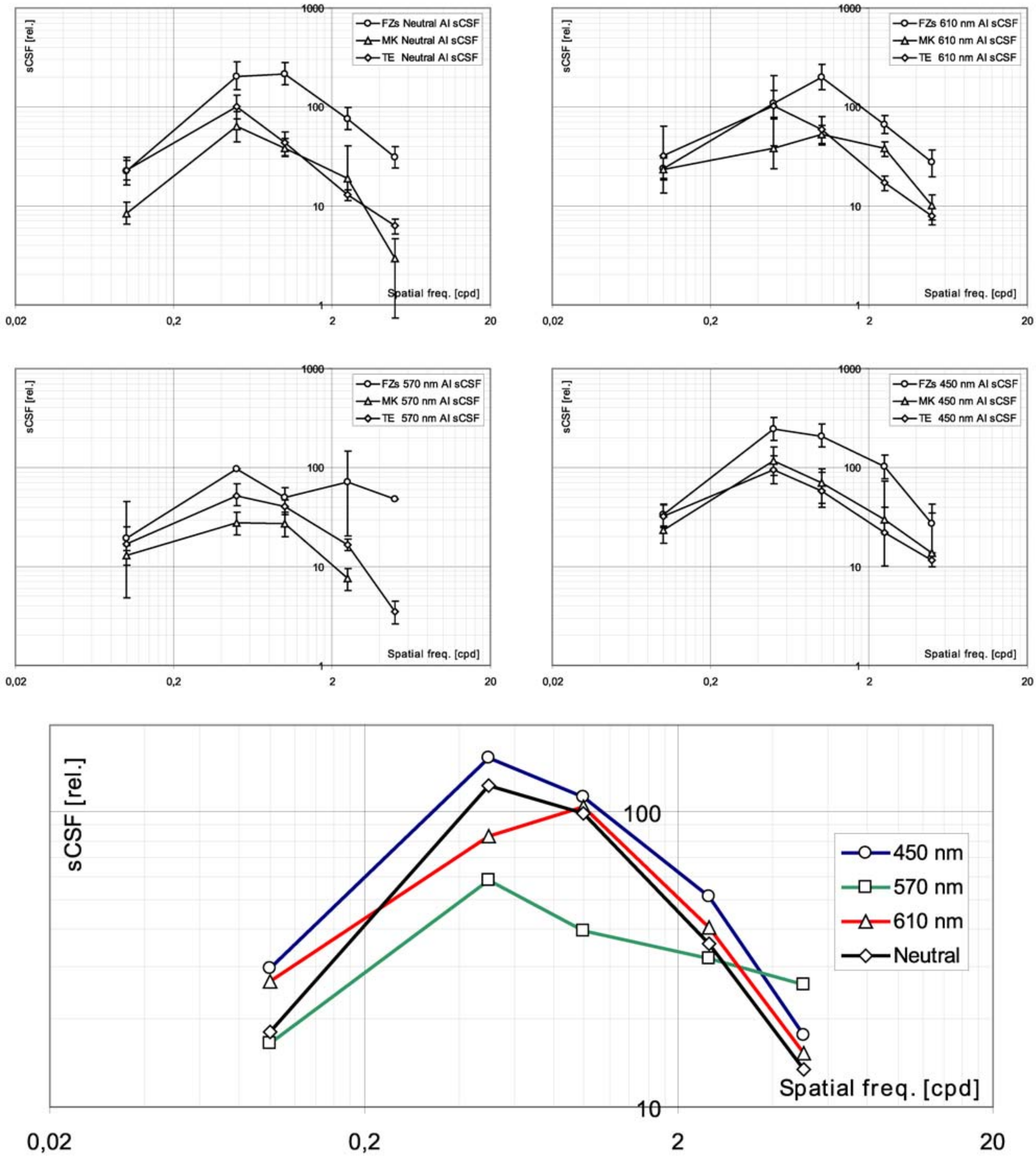

Figure 1: Spatial AI-CSF for the individual observers (top) and averaged (bottom)

Temporal CSF

With the above technique, two phases of afterimage formation can be separated. At very low contrasts an achromatic afterimage is observable, and this becomes tinged with the opposite hue as contrast is increased above a well-defined contrast value, where the chromatic afterimage – especially at high temporal frequencies – appears to lag behind the achromatic disc. This difference is most obvious at short (450 nm) wavelengths.

Results (see Fig. 2.) show low pass shape in the temporal domain for achromatic afterimages, similar to the case of spatial characteristics.

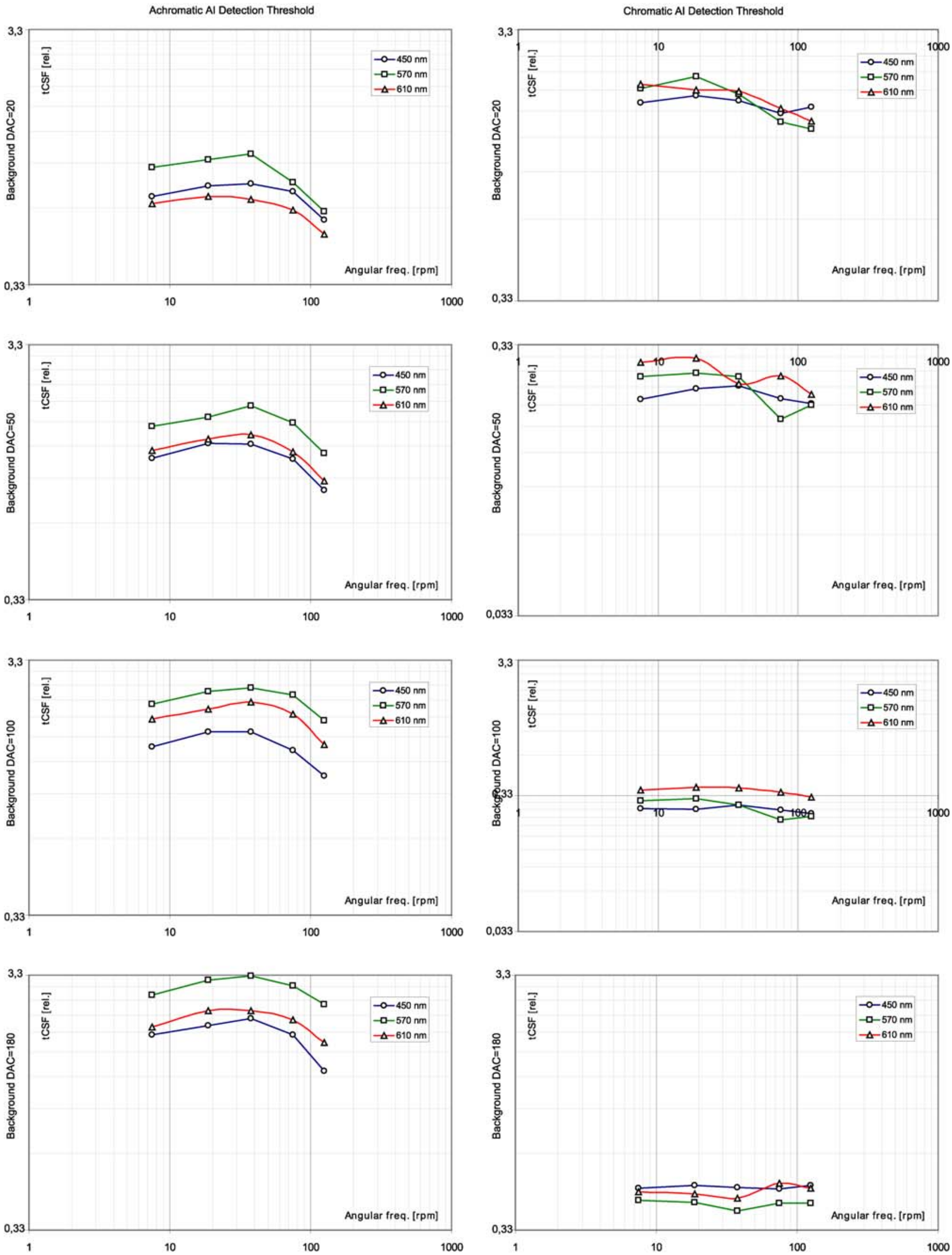

Figure 2: Temporal AI-CSF, monochromatic inducing, achromatic (left) and chromatic (right) afterimage

IV Conclusion

In possession of the current amount of data the actual form and coefficients of a simple computational model were determined in the form of FIR and convolution filters, which is currently able to exhibit the above measured spatiotemporal characteristics to a reasonable extent (Fig. 3.).

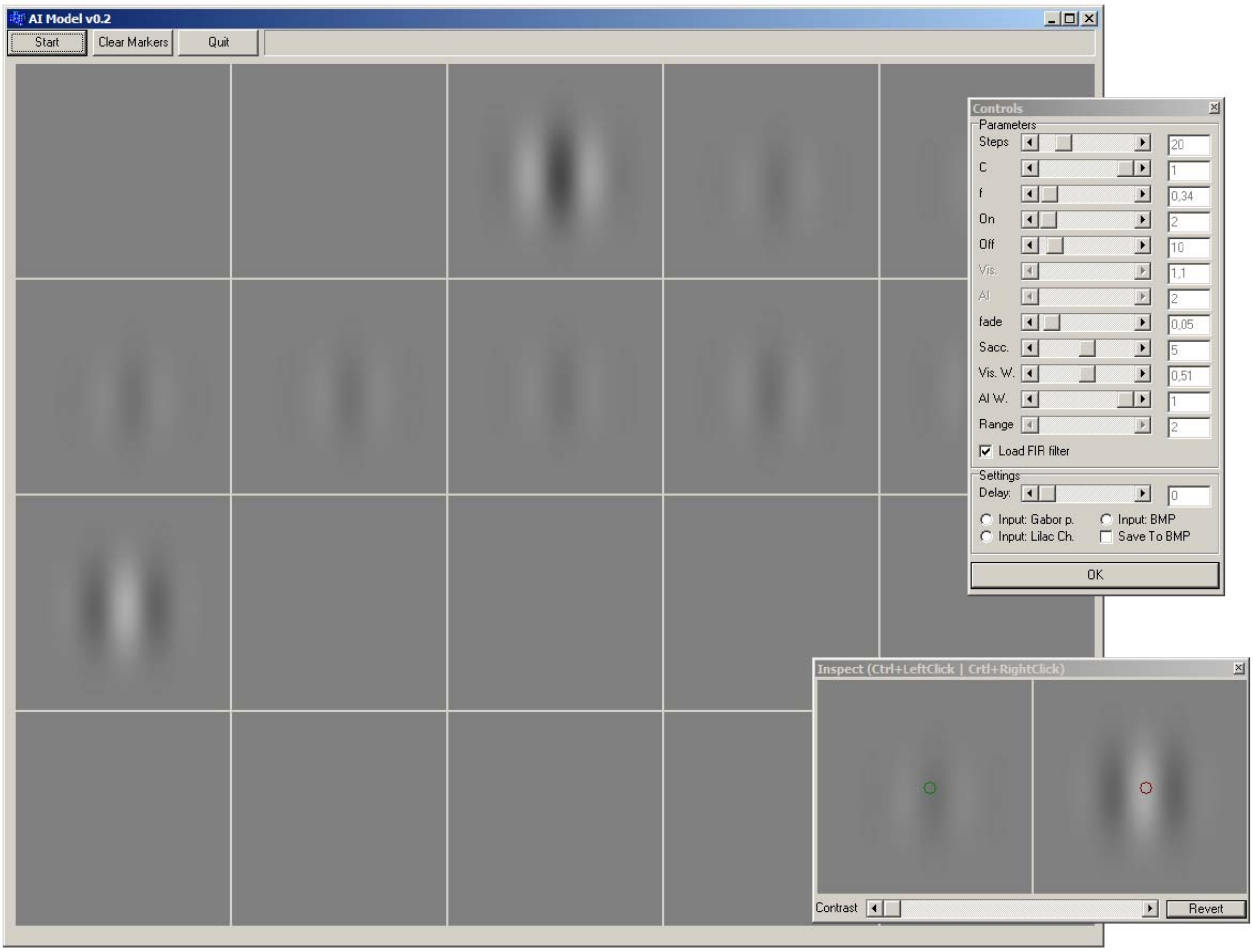

Figure 3: Model input and output

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