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ORIGINAL ARTICLE

# The effect of spherical aberration on visual performance and refractive state for stimuli and tasks typical of night viewing

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**KEYWORDS**
Spherical aberration;
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Night vision

**Abstract**
*Purpose:* The aim of this work was to examine the impact of Seidel spherical aberration (SA) on optimum refractive state for detecting and discriminating small bright lights on a dark background.
*Methods:* An adaptive-optics system was used to correct ocular aberrations of cyclopleged eyes and then systematically introduce five levels of Seidel SA for a 7-mm diameter pupil: 0, ±0.18, and ±0.36 diopters (D) $mm^{-2}$. For each level of SA, subjects were required to detect one or resolve two points of light (0.54 arc min diameter) on a dark background. Refractive error was measured by adjusting stimulus vergence to minimize detection and resolution thresholds. Two other novel focusing tasks for single points of light required maximizing the perceived intensity of a bright point's core and minimizing its overall perceived size (i.e. minimize starburst artifacts). Except for the detection task, luminance of the point of light was 1000 cd $m^{-2}$ on a black background lower than 0.5 cd $m^{-2}$.
*Results:* Positive SA introduced myopic shifts relative to the best subjective focus for dark letters on a bright background when there was no SA, whereas negative SA introduced hyperopic shifts in optimal focus. The changes in optimal focus were −1.7, −2.4, −2.0, and −9.2 D of focus per D $mm^{-2}$ of SA for the detection task, resolution task, and maximization of core's intensity and minimization of size, respectively.

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*Conclusion:* Ocular SA can be a significant contributor to changes in refractive state when viewing high-contrast point sources typically encountered in nighttime environments.
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**PALABRAS CLAVE**
Aberración esférica;
Detección;
Resolución;
Starburst;
Error refractivo;
Visión nocturna

**Efecto de la aberración esférica sobre el rendimiento visual y el estado refractivo para los estímulos y tareas típicos de la visión nocturna**

**Resumen**
*Objetivo:* El objetivo de este estudio fue examinar el impacto de la aberración esférica de Seidel (AS) sobre el estado refractivo óptimo para detectar y discriminar las luces brillantes de pequeño tamaño sobre un fondo oscuro.
*Métodos:* Se utilizó un sistema de óptica adaptativa para corregir las aberraciones oculares de ojos bajo cicloplegía, e introducir sistemáticamente cinco valores de AS para una pupila de 7 mm de diámetro: 0, ± 0,18, y ± 0,36 dioptrías (D) $mm^{-2}$. Para cada valor de AS se solicitó a los sujetos que detectaran un punto de luz, o resolvieran dos puntos (cada punto subtendía 0,54 minutos de arco de diámetro) sobre un fondo oscuro. El error refractivo se midió ajustando la vergencia del estímulo, para minimizar los umbrales de detección y resolución. Los sujetos realizaron además otras dos tareas observando un sólo punto luminoso y en las que tenían que maximizar la intensidad percibida del núcleo del punto luminoso o minimizar el tamaño de la imagen percibida (es decir, minimizar el ''starburst''). Excepto para la tarea de detección, la luminancia del punto de luz fue de 1000 cd $m^{-2}$ sobre un fondo negro con un valor inferior a 0,5 cd $m^{-2}$.
*Resultados:* La AS positiva introdujo cambios miópicos respecto al mejor enfoque subjetivo para letras oscuras sobre un fondo luminoso sin AS, mientras que la AS negativa introdujo cambios hipermetrópicos respecto al enfoque óptimo. Estos cambios fueron − 1,7, − 2,4, − 2,0, y − 9,2 D de enfoque por D $mm^{-2}$ de AS para la tarea de detección, la tarea de resolución, la maximización de la intensidad del núcleo y la minimización de su tamaño, respectivamente.
*Conclusión:* La AS ocular puede ser un factor que influye significativamente en los cambios en el estado refractivo, al visualizar las fuentes puntuales de alto contraste típicas de los entornos nocturnos.
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## Introduction:

Spherical aberration (SA) is a dominant higher-order aberration in human eyes[1,2] that creates local refractive errors proportional to the square of radial distance from the pupil center.[3,4] As a result, the pupil margin can be as much as 3 diopters (D) more myopic than the pupil center for an 8-mm diameter pupil, typical of nighttime viewing.[4] Inclusion of these more myopic regions as the pupil dilates, however, has little or no measurable impact on subjective refraction,[5–8] revealing that subjective refractions are dominated by the refractive state of the central pupil region.[9]

When refracted with high contrast small letters, even large amounts of experimentally added positive SA (with fixed pupil size and no accommodation) produced only minor myopic shifts in subjective refractive errors, and added negative SA produces small hyperopic shifts.[10,11] However, the magnitudes of these shifts varied significantly with the stimulus and the visual task used in the refraction procedure. For example, SA has its smallest effect when best focus is determined by optimizing letter acuity or by optimizing perceived quality of objects dominated by high spatial frequencies.[11] However, the effect of SA is much larger when optimizing perceived quality of stimuli dominated by low spatial frequencies.[7,11] The perceptual criterion used for optimizing focus is also important. The impact of SA on refractive error is greater when subjects optimized perceived contrast of letters than when optimizing perceived sharpness of the same letters. López-Gil et al.[12] observed a myopic shift in refractive error of eyes when changing the stimulus from a letter chart to a small bright point source viewed against a dark background. These changes were partially due to accommodation, but were correlated with the magnitude of SA in the different subjects' eyes, with a $R^2$ of 0.55.

Given the importance of stimulus, task, and criterion for determining refractive state in eyes with spherical aberration, we asked if the myopic shifts commonly reported by stargazers,[13–15] might be due in part to the presence of elevated positive spherical aberration (characteristic of large

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