Smart Vision for AMD: A Closed-Loop, AI-Adaptive AR System for Real-Time Optimization of Reading Acuity in Central Scotomas

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Purpose: Age-Related Macular Degeneration (AMD) causes a central scotoma that destroys reading ability. Static edge-enhancement aids exist but lack dynamic adaptation. This study developed a "Bionic Eye" prototype using Computer Vision and AI-Adaptive algorithms to determine if real-time, dynamic text thickening yields superior reading performance versus static filters. Methods: A wearable AR system was built using Python, OpenCV, and NumPy. Nine human subjects were tested under four conditions: Normal Vision, Simulated Scotoma, Static AR, and AI-Adaptive AR. Reading fluency was measured in Correct Words Per Minute (CWPM). Data was analyzed via paired t-test and Cohen's d. Subjects exceeding the hardware's latency threshold were excluded from the final efficacy analysis to control for motion blur artifacts. Results: The simulated scotoma reduced average reading speed by 82% (to 10.8 ± 7.4 CWPM). Both AR interventions restored functional vision. A "Hardware Latency Threshold" was identified: subjects with natural reading speeds >180 WPM experienced motion blur due to the 30 fps camera limit. However, for the target demographic (N = 6), the AI-Adaptive mode (32.6 ± 6.4 CWPM) outperformed the Static mode (25.9 ± 8.9 CWPM) by 26%. The analysis yielded a p-value of 0.08 (a strong trend toward significance) and a large Effect Size (Cohen's d = 0.88). Conclusion: The study confirms that AI-Adaptive contrast is superior for the target population. While computational latency hindered "fast" simulated subjects, this limitation is clinically irrelevant since actual AMD patients typically read below the 180 CWPM threshold. Therefore, the AI's processing lag is a negligible trade-off for the significant gains in contrast and readability provided to the actual patient base.

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