A Framework for Context-Aware Blink Interventions to Mitigate Digital Eye Strain

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Abstract

In today's digital workspaces, long screen time greatly reduces natural blink rates, making Digital Eye Strain (DES) a serious workplace health issue. Although many interactive tools have emerged, most current solutions still rely on fixed-timer alerts that frequently interrupt users and cause alert fatigue. To address this problem, this dissertation proposes a context-aware framework designed to keep blink rates steady within a target zone of 15-30 blinks per minute (BPM) while causing as little distraction as possible. This research presents three complementary studies. First, to find alert styles that do not distract users across different workspace setups, Phase 1 (N=11) introduced EyeWise, a prototype that evaluated different reminder alert styles between smartwatch and monitor. Results showed that while tactile smartwatch vibrations overwhelm users, peripheral visual cues are highly preferred because they preserve workflow continuity. Second, to move beyond the limits of fixed timers, Phase 2 (N=15) proposed EyeWise 1.1, a physiology-aware blink reminder system that uses real-time webcam tracking via the Eye Aspect Ratio (EAR) metric and an adaptive timing algorithm to send alerts whenever blink rates fall outside the target zone—whether too low or too high. Although this method successfully kept blink rates near target levels, user feedback revealed a critical Usability-Efficacy Paradox: alerts driven solely by blink rate changes frequently interrupted users during deep concentration, increasing their workload. This limitation motivated the need for a context-aware approach. Third, to resolve this conflict, Phase 3 (N=16) introduced EyeWise 2.0, a context-aware system that goes beyond blink tracking by also checking what the user is currently doing. Unlike Phase 2's blink-only alerts, this approach

uses a machine learning classifier to identify the user's active task—Reading, Watching, or other activities—and adjusts the reminder style through subtle screen-edge visual cues or soft audio chimes to match the workflow. By adapting interventions to the user's current task, this approach reduces unnecessary interruptions while maintaining blink rate targets. A 100-minute lab test showed that this method kept participants' blink rates at a median of 21.3 BPM and, compared to the physiology-aware system, reduced both the time pressure felt by users (Temporal Demand: 37.5% drop) and their overall effort (Effort: 32.7% drop) on the NASA-TLX workload scale, effectively reducing alert fatigue. Overall, this dissertation provides a tested framework and foundational design guidelines for the next generation of non-distracting, context-aware blink intervention technologies.