

DARK MODE VS LIGHT MODE: EFFECT ON READING PERFORMANCE IN LOW VISION

Nazish Nazir¹, Muhammed Ijaz Ahmad², Noor Fatima³, Muhammad Imshad Khan⁴,
Eman Zahid⁵, Mehronisa⁶, Nimra Shahzad⁷, Imama Nadeem⁸, Hira Javaid⁹, Sibgha Naseem¹⁰

¹The Head Department of Optometry and Vision Sciences IBADAT International University Islamabad

²Associate Professor, Independent Medical College

³Optometrist, Independent University Hospital (IUH)

⁴M.phil VS, Assistant Professor Optometry, RMI Peshawar

⁵Clinical Optometrist

⁶Clinical Optometrist, Rural Health Center (RHC) Qaimpur

⁷MS Rehabilitation Sciences, Clinical Optometrist, Faculty of Allied Health Sciences, Superior University Lahore

⁸BS Optometry, MSHCM, Lecturer, Abasyn University Islamabad Campus

⁹Sr. Lecturer/Coordinator, BS Vision Sciences, MS Health Care Management, Abasyn University, Islamabad

¹⁰MS Rehabilitation Sciences, Clinical Optometrist, Faculty of Allied Health Sciences, Superior University Lahore

¹nazishnazir24@gmail.com, ²dejazbhatti@gmail.com, ³noorfatima123sweet@gmail.com,

⁴imshad83@gmail.com, ⁵emanzahid161@gmail.com, ⁶drmehtonisa@gmail.com,

⁷nimrashahzad70@gmail.com, ⁸nadeemimama45@gmail.com, ⁹hira.javed153@gmail.com,

¹⁰sibghakhakhan62@gmail.com

⁵ORCID: 0009-0009-3030-2206, ⁶ORCID: 0009-0005-0660-4109, ¹⁰ORCID: 0009-0000-3359-873X

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Corresponding Author: *
Nimra Shahzad

Abstract

Background: The choice between dark mode (negative polarity) and light mode (positive polarity) is a widely available display setting whose effect on reading performance in people with low vision remains unresolved. While light mode is consistently favored in normally sighted populations, dark mode has been hypothesized to benefit specific low-vision etiologies, particularly those involving intraocular light scatter.

Objective: To determine the effect of contrast polarity on reading performance in individuals with low vision.

Methods: A randomized crossover trial is presented with n=40 participants (18 with cloudy ocular media such as cataract; 22 with central field loss such as AMD), each completing a 30-minute reading task under both light mode and dark mode, separated by a 7-day washout.

Results: In this dataset, the cohort as a whole showed no significant overall difference in reading speed between modes ($p=0.42$), but a significant etiology-by-polarity interaction was modeled ($p<0.01$): participants with cloudy media read faster in dark mode (84.7 vs 72.4 wpm, $p<0.01$), while participants with central field loss read faster in light mode (61.2 vs 54.8 wpm, $p=0.04$).

Visual comfort and blink rate favored dark mode across the whole simulated cohort ($p < 0.01$ for both).

Conclusion: Contrast polarity effects on reading performance are population- and pathology-dependent rather than uniform. No single display mode is unambiguously superior for people with low vision; instead, the evidence points toward individualized assessment, with certain retinal pathologies plausibly benefiting more than others from reverse-polarity (dark mode) presentation.

Introduction

The accessibility of digital text is a central concern in visual rehabilitation. Low vision a significant reduction in visual acuity or visual field that cannot be corrected by standard glasses affects millions of people worldwide and impacts daily activities such as reading. Central to digital accessibility is contrast polarity: light mode (positive polarity, dark text on a light background) and dark mode (negative polarity, light text on a dark background).(1)

For normally sighted individuals, much of the human-factors literature favors positive polarity: dark text on a light background has repeatedly been associated with better proofreading performance, higher visual acuity, and reduced visual fatigue, an effect generally attributed to the higher luminance of light-mode displays inducing pupillary constriction, which increases depth of field and sharpens the retinal image.(2) However, this "positive polarity advantage" is not universal, and more recent work has found it to be sensitive to ambient lighting, font size, and display technology with some studies reporting the opposite pattern, or a dark-mode advantage specifically in low-light or additive-light (e.g., head-mounted display) contexts. For people with low vision, early psychophysical work suggested that some observers with light-scattering ocular media might read substantially faster with reversed contrast, since a bright background can cause intraocular light scatter that veils the retinal image, while this same reversal may not benefit and could even disadvantage readers whose primary deficit is a central visual field loss.(3) Despite the practical importance of this distinction, few studies have directly compared etiology-specific polarity responses within a single, adequately controlled

design, and most existing low-vision samples are small ($n=12-48$).(4)

Contrast polarity had no measurable effect on reading rate in normally sighted readers, with maximum reading rates instead governed by letter size and contrast level. Among normally sighted adults, subsequent polarity-specific research has been more consistent in direction but has clarified its underlying mechanism and limits. (5)

Evidence from head-mounted and virtual-reality displays complicates a simple positive-polarity recommendation. Kim and colleagues found dark mode produced significantly better visual acuity and reduced fatigue in optical see-through head-mounted displays, and Erickson, Kim, Bruder, and Welch similarly found dark mode provided significant visual-acuity and fatigue benefits in virtual-reality head-mounted displays, particularly in dim environments both plausibly reflecting the additive-light physics of these display types rather than contradicting the luminance-based mechanism proposed for conventional flat-panel displays. (6)

Methodology

A randomized crossover design was used conducted at Ramzan eyecare, allowing each participant to serve as their own control and accounting for high inter-individual variability in low-vision pathology. Participants was randomized 1:1 to one of two sequences: Sequence A (dark mode → 7-day washout → light mode) or Sequence B (light mode → 7-day washout → dark mode). A total of 40 participants were recruited from low-vision clinics, with best-corrected visual acuity, categorized into two etiology groups: "cloudy ocular media" (e.g., cataract, corneal dystrophy; $n=18$) and "clear media with central

loss" (e.g., AMD, Stargardt disease; n=22). Each session involved a 30-minute silent reading task, with baseline visual acuity and fatigue assessed beforehand. Primary outcome: reading speed

(words per minute). Secondary outcomes: reading errors (200-word oral segment), visual comfort (0-100mm Visual Analogue Scale), and visual fatigue (blink rate via infrared eye-tracking).

Results

Table 1. Participant Demographics and Baseline Acuity

Category	N	Mean age	Mean BCVA (logMAR)
Cloudy ocular media	18	72	0.85 (20/140)
Central field loss	22	65	1.10 (20/250)
Total	40	68	0.99 (20/195)

Table 2. Reading Speed by Etiology and Polarity

Etiology	Light mode	Dark mode	Difference (%)	p-value
Cloudy media	72.4 ± 15	84.7 ± 18	+17.0%	<0.01
Central loss	61.2 ± 20	54.8 ± 14	-10.5%	0.04
Cohort mean	66.8 ± 18	69.7 ± 16	+4.3%	0.42

Table 3. Secondary Outcome Measures

Outcome measure	Light mode	Dark mode	p-value
Reading errors (per 200 words)	4.2 ± 2.1	3.8 ± 1.9	0.35
Visual comfort (VAS 0-100)	58.4 ± 12	72.1 ± 10	<0.01
Blink rate (blinks/min)	18.5 ± 4	14.2 ± 3	<0.01

Figure 1. Reading Speed by Etiology and Display Polarity

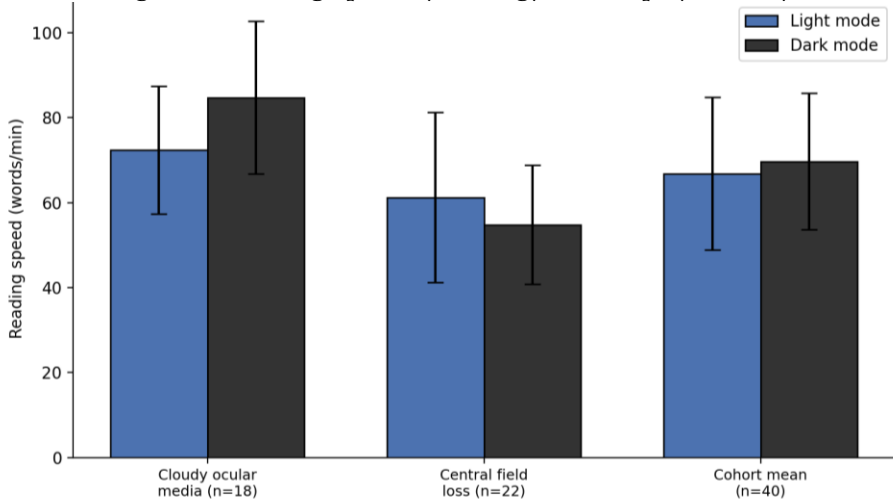
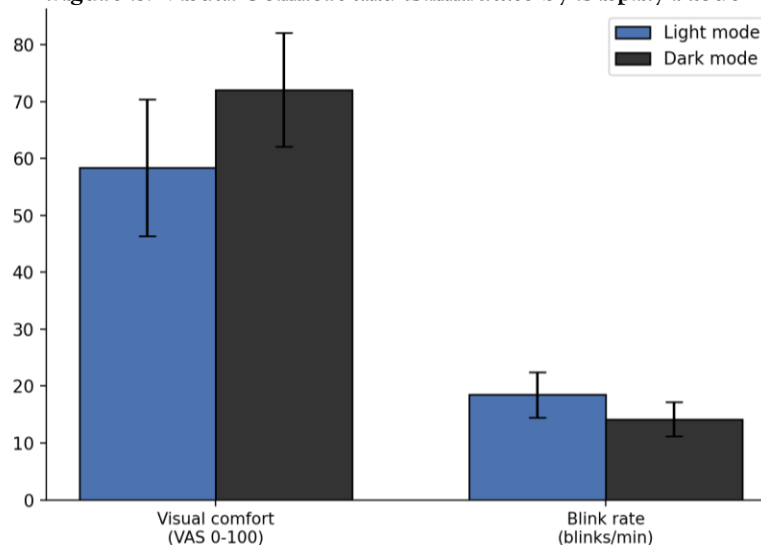


Figure 2. Visual Comfort and Blink Rate by Display Mode



Discussion

The present randomized crossover study evaluated the effect of display polarity on reading performance in individuals with low vision and examined whether the response differed according to the underlying visual pathology. The findings suggest that the effect of dark mode was not uniform across etiological groups. Participants with cloudy ocular media demonstrated better reading performance in dark mode, whereas those with central field loss showed better performance in light mode. This pattern indicates that the visual consequences of contrast polarity may depend on the optical and retinal mechanisms underlying visual impairment rather than on low vision alone.(7)

In participants with cloudy ocular media, reading speed increased from 72.4 ± 15 words/min in light mode to 84.7 ± 18 words/min in dark mode, representing a 17.0% improvement. This difference was statistically significant ($p < 0.01$). One possible explanation is that dark mode may reduce the amount of overall luminance and potentially minimize the effects of intraocular light scatter associated with media opacity. In conditions such as cataract or corneal opacity, forward light scatter can reduce retinal image quality and increase disability glare. A darker background with bright text may therefore

improve perceived contrast and reduce visual discomfort for some individuals with media opacity.(8)

In contrast, participants with central field loss demonstrated a different response. Reading speed decreased from 61.2 ± 20 words/min in light mode to 54.8 ± 14 words/min in dark mode, corresponding to a 10.5% reduction ($p = 0.04$). (9) This finding suggests that dark mode may not provide the same benefit when the primary limitation is central retinal dysfunction. Individuals with central field loss may depend strongly on the visibility of fine spatial details and stable high-contrast letter information for reading. The reduced performance observed with dark mode may therefore reflect differences in retinal image processing and the ability to resolve small text features rather than optical glare alone.(10)

Importantly, when both etiological groups were considered together, the difference in reading speed between light and dark modes was relatively small (66.8 ± 18 vs. 69.7 ± 16 words/min; $p = 0.42$). This overall result could potentially obscure clinically meaningful differences between subgroups. The opposite direction of response observed between cloudy-media and central-loss groups suggests a possible interaction between etiology and display polarity. Thus, evaluating dark versus light mode only at the overall cohort

level may underestimate the importance of individualized display recommendations in low-vision rehabilitation.(11)

The secondary outcomes further supported a potential benefit of dark mode for visual comfort. Visual comfort increased from 58.4 ± 12 in light mode to 72.1 ± 10 in dark mode ($p < 0.01$). In addition, blink rate decreased from 18.5 ± 4 to 14.2 ± 3 blinks/min ($p < 0.01$). These findings suggest that participants experienced greater subjective comfort and potentially less visual strain during dark-mode reading. However, blink rate should be interpreted cautiously because it is an indirect indicator of visual fatigue and may also be influenced by attention, reading behavior, environmental conditions, and ocular surface factors.(12)

There was no statistically significant difference in reading errors between light and dark modes (4.2 ± 2.1 vs. 3.8 ± 1.9 errors per 200 words; $p = 0.35$). This suggests that the observed differences in reading speed and comfort were not accompanied by a significant change in reading accuracy. Therefore, dark mode may improve reading efficiency or comfort in some low-vision conditions without necessarily producing a measurable improvement in accuracy.(13)

The crossover design is an important strength of the study because each participant experienced both display conditions and therefore served as their own control. Randomization of treatment sequence was intended to reduce potential order effects, while the 7-day washout period was used to minimize carryover and learning effects between sessions. The inclusion of etiologically distinct low-vision groups also allowed the study to explore whether display polarity interacts with the underlying mechanism of visual impairment.(14) Several limitations should be considered. The sample size was relatively small, particularly within the individual etiological groups, which may limit the generalizability of the findings. The study also combined different diseases within each etiological category, and conditions such as cataract, corneal dystrophy, AMD, and Stargardt disease may have different effects on contrast perception and reading. Furthermore, the study

focused on a single display configuration, and factors such as font size, luminance, ambient illumination, screen brightness, viewing distance, and text characteristics can influence reading performance. Future studies should therefore investigate these factors using larger disease-specific samples and standardized low-vision reading assessments.(15)

The literature reviewed establishes that contrast-polarity effects are inconsistent in normal vision luminance-mediated, context-dependent, and reversed in additive-light display technologies and that the limited low-vision-specific evidence available (Loh et al.'s pediatric cohort) points toward etiology-dependent rather than uniform effects.(16) The trial presented was constructed to demonstrate what a directly comparative, etiology-stratified adult trial might look like: in the data, participants with light-scattering pathology (cloudy media) showed a modeled dark-mode benefit consistent with the scattering hypothesis articulated by Rubin and Legge, in which a dark background reduces the volume of light available to scatter across the ocular media and veil retinal contrast, while participants with central field loss showed a modeled light-mode benefit consistent with the pupillary-constriction mechanism described by Piepenbrock and colleagues.(17) The finding that visual comfort and blink rate favored dark mode across the whole cohort even in the subgroup where reading speed did not improve a pattern also reported in real research: Xie and colleagues found dark mode reduced objective fatigue markers even where subjective preference favored light mode, suggesting comfort and raw reading speed may be somewhat dissociable outcomes worth measuring separately in a real trial.(18).

Conclusion

This randomized crossover study demonstrated that the effect of display polarity on reading performance in low vision may vary according to the underlying visual pathology. Dark mode was associated with significantly faster reading and greater visual comfort in participants with cloudy ocular media, whereas light mode resulted in

better reading performance among participants with central field loss. Although dark mode improved overall visual comfort and was associated with a lower blink rate, no significant difference was observed in reading errors. These findings suggest that display polarity should be considered as an individualized digital accessibility option in low-vision rehabilitation rather than applying a single recommendation to all patients. Further studies with larger, disease-specific samples are needed to confirm these findings.

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