West Pomeranian University of Technology in Szczecin

Contrast Computation for Improved Visibility and User Experience in Educational Interfaces

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Digital transformation in education opportunities and challenges

Growth of the e-learning market

- E-science market value in the US: $400 bilion. Forecast for 2032: $1 trillion.
- Key drivers: internet access, mobile devices, cloud-based technologies.

New challenges for educational interface design

- Balancing usability, readability, and visual appeal.
- Excessive contrast → cognitive overload.
- Low contrast → information may be missed.

Digital accessibility – still a major issue

- Only 3% of 1.3 million websites meet basic accessibility standards.

Why this study?

Motivation

Improper color selection in educational systems can reduce learning effectiveness and increase cognitive fatigue.

- High contrast improves visibility but may reduce user comfort.
- Low contrast may be more comfortable but carries the risk of overlooking important content.

Research aim

To find an optimal color balance by:

- Selecting an appropriate color contrast between user interface components.
- Enhancing interface visibility and usability.
- Supporting knowledge acquisition and reducing visual overload.

Experimental workflow

Step 1:
Assumptions and methodology

Step 2:
Results and color ranking

Step 3:
Practical application - ColoUR Picker Tool

Step 1: Assumptions and methodology

Experiment goal:

To identify color pairs that are the most noticeable and user-friendly, without causing visual fatigue or irritation.

Study procedure:

- 72 images, 9 color pairs.
- Experiment based on the forced-choice method.
- 35 participants; each comparison repeated 3 times.
- User behavior monitored with eye-tracking technology.
- Standardization and normalization of responses (ITU-R BT.500 standard).

Step 2: Results and color ranking

Users evaluated color pairs based on user-friendliness and visibility.

Color ranking:

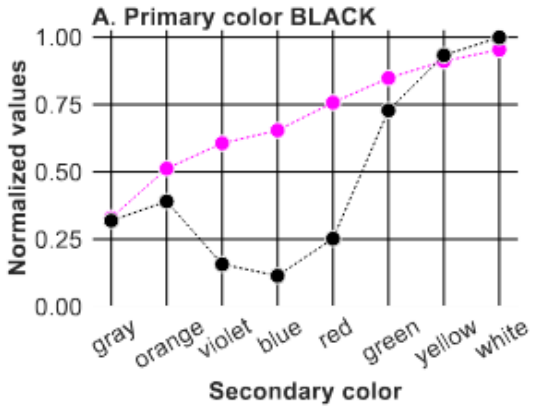
- Each color pair was assigned to one of four quartile ranges:
  - ⟨0–0.25) – least user-friendly.
  - ⟨0.75–1⟩ – most user-friendly and readable.
- User data were compared with WCAG contrast values.

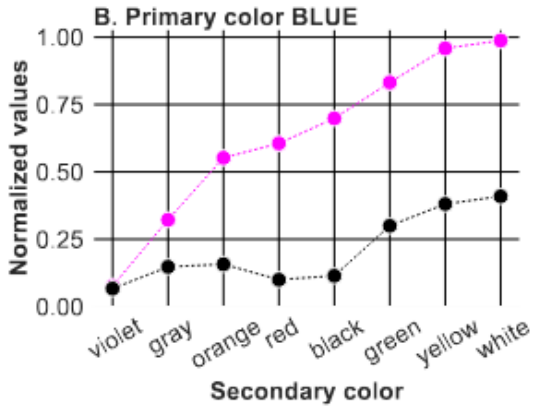
Key observation: Highest contrast ≠ highest user-friendliness

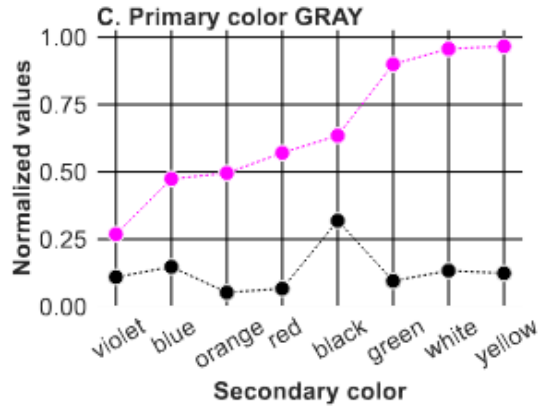
Color ranking

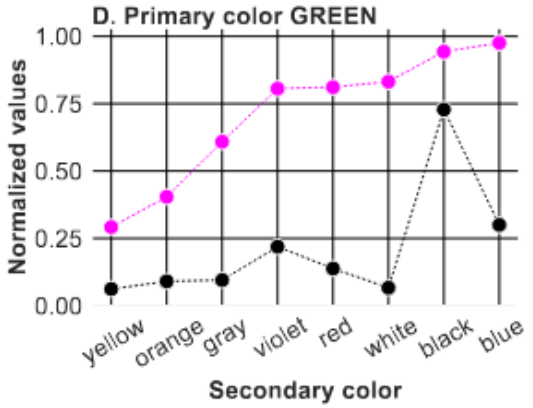
Plot pink:
Friendliness and visibility

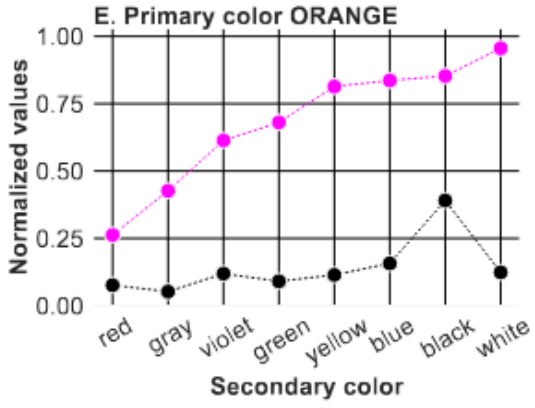
Plot black:
Contrast values

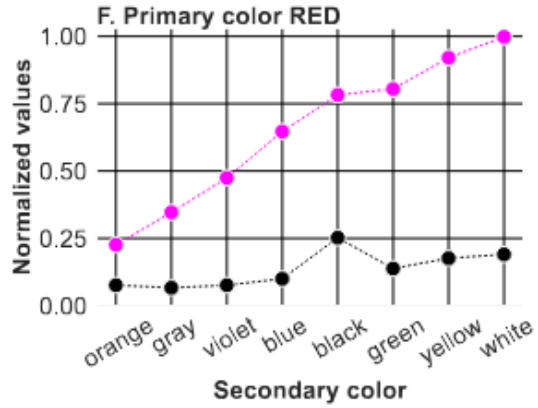


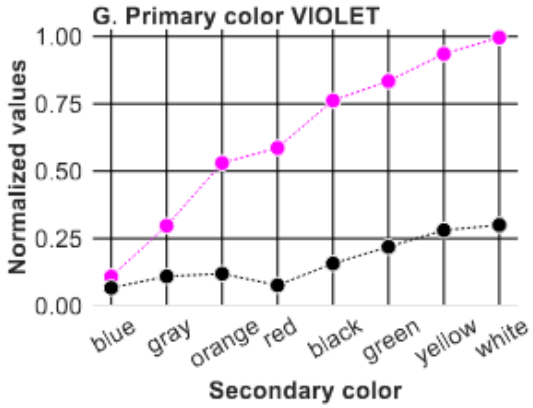


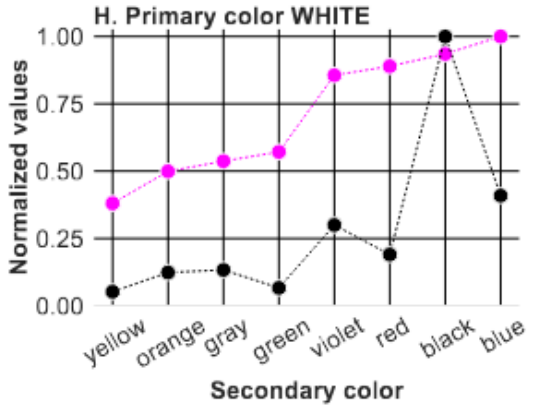


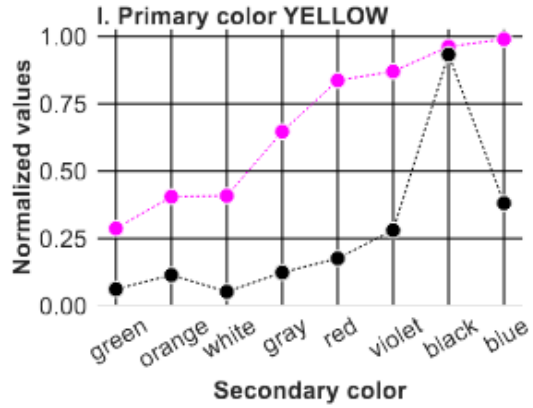












Key findings

Friendliness and visibility	Low-contrast color pairs were often rated as more user-friendly and visibility than those with maximum contrast.
WCAG standard	Users preferred color combinations that did not meet the WCAG AAA level.
Neutral colors	Combinations including white and black performed well. Gray as a secondary color was rated significantly lower.
Foreground/Background	Reversing the role of colors did not significantly affect user ratings.

Step 3: Practical application - ColoUR Picker Tool

Allows selecting color pairs based on:

- Color role (foreground/background).
- User-friendliness and visibility ratings.
- Contrast values (according to WCAG).

https://visual-communication.github.io/ColoUR-Picker

Key use cases

- Interface Constraints

For fixed accent colors (e.g., blue), designers can use this study to select secondary colors that enhance readability.

- Banners and alerts

Red draws attention but may overwhelm. Pairing it with softer colors improves visibility without strain.

- Branding and logos

Test how logo colors (e.g., violet) perform on different backgrounds to ensure accessibility.

- Gamification elements

Balanced color combos in progress bars or feedback systems support engagement and user comfort.

Color Range
Explore different levels of saturation and brightness.

Readability and Comfort
Study text readability and effects of long-term exposure.

Usage Contexts
Include users with color vision deficiencies,
and platforms like mobile apps, AR, and e-learning.

Future works

Thank you

Welcome for cooperation to validate approach in different areas.

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