The influence of background on the visual color difference evaluation of multicolored material

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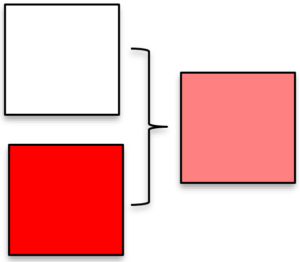
Single-color sample

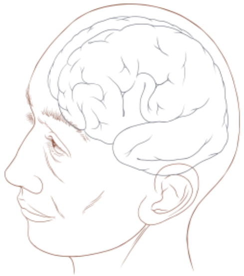
Multicolored sample



Averaging all colors in the aperture.

Measuring a single color at a time and ignoring the influence of other colors with the scene.

Contradictions



Human observer

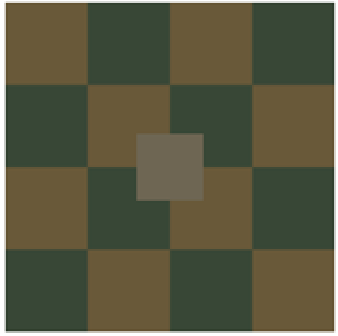
Marine Pattern (MARPAT)

Define a complex background: Pattern shape, size, orientation; contrast between center and background; over all size of central color and background; etc.

Center-background configuration

Simple background:

Complex background:
e.g., checkerboard pattern

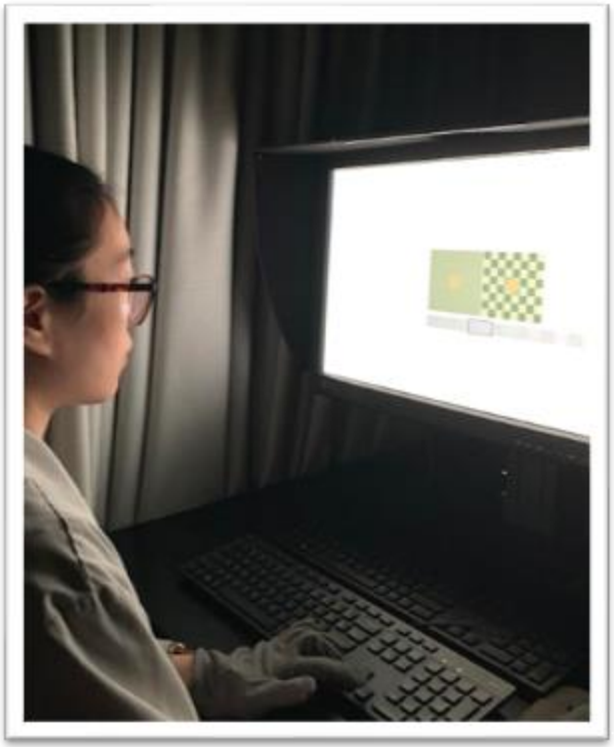


?

Color-averaged background:

For MARPAT colors

➢ Psychophysical experiment



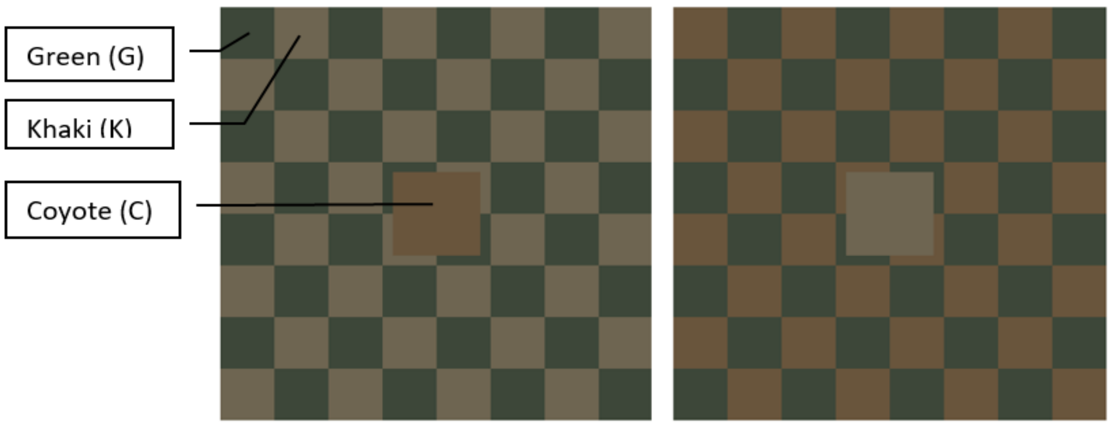


Figure 1. The “GK_C” (left) and “CG_K” (right) color combinations.

Sample pairs

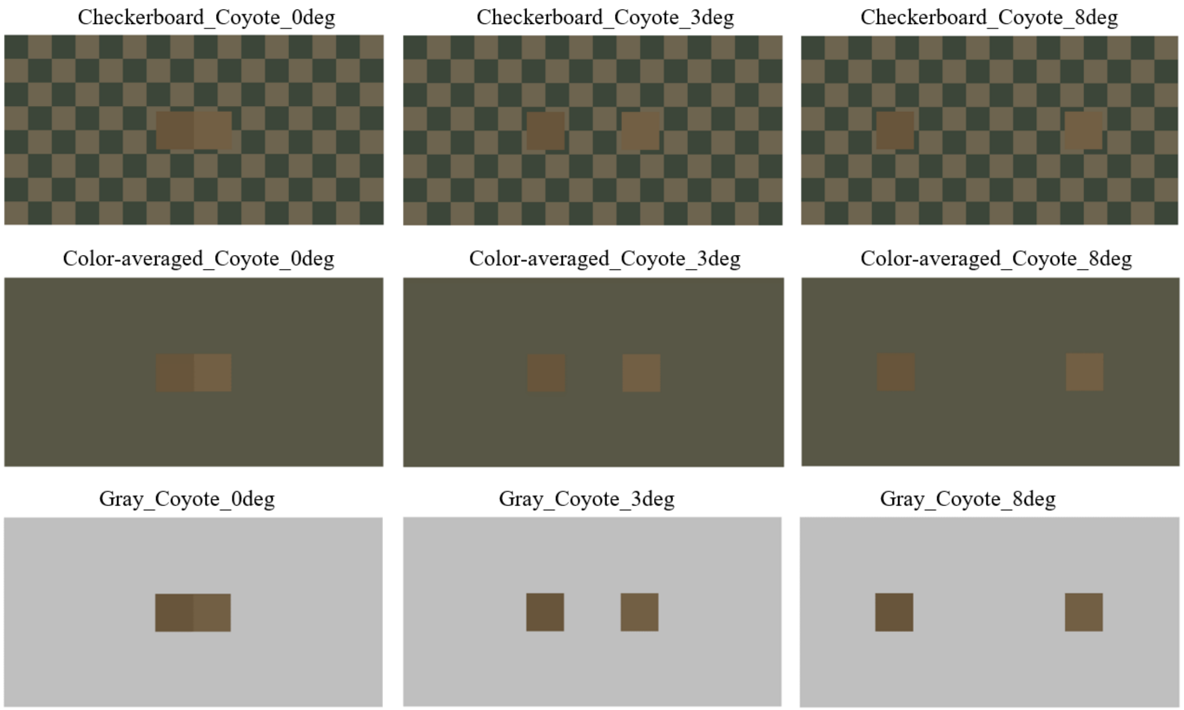
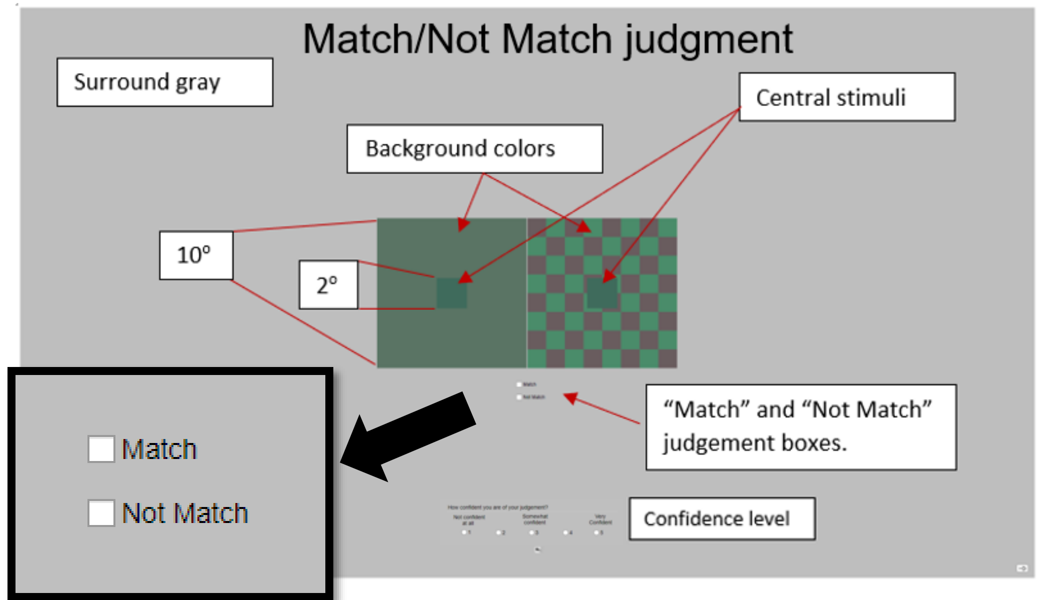
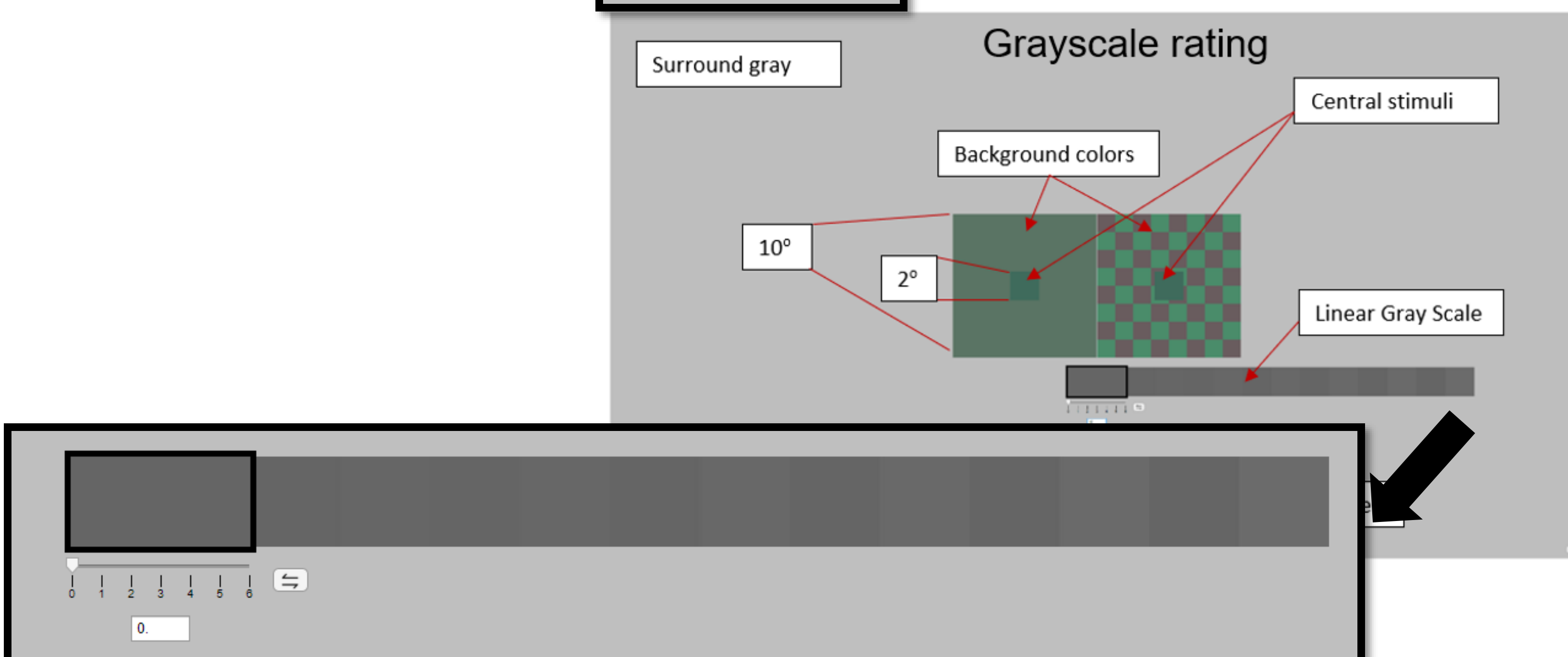


Figure 2. Examples of stimuli with different background and separation distances between central patches for the color combination "8_GK_C".

Color combinations:
GK_C, CG_K
Backgrounds:
Checkerboard, color-averaged, gray
Distances:
0, 3, 8 degrees
Color differences:
-4.0, -3.0, -2.5, -2.0, -1.5, -1.0, 0,
+1, +1.5, +2.0, +2.5, +3.0, +4.0
units ΔL^*

MATLAB graphic user interface





Grayscales

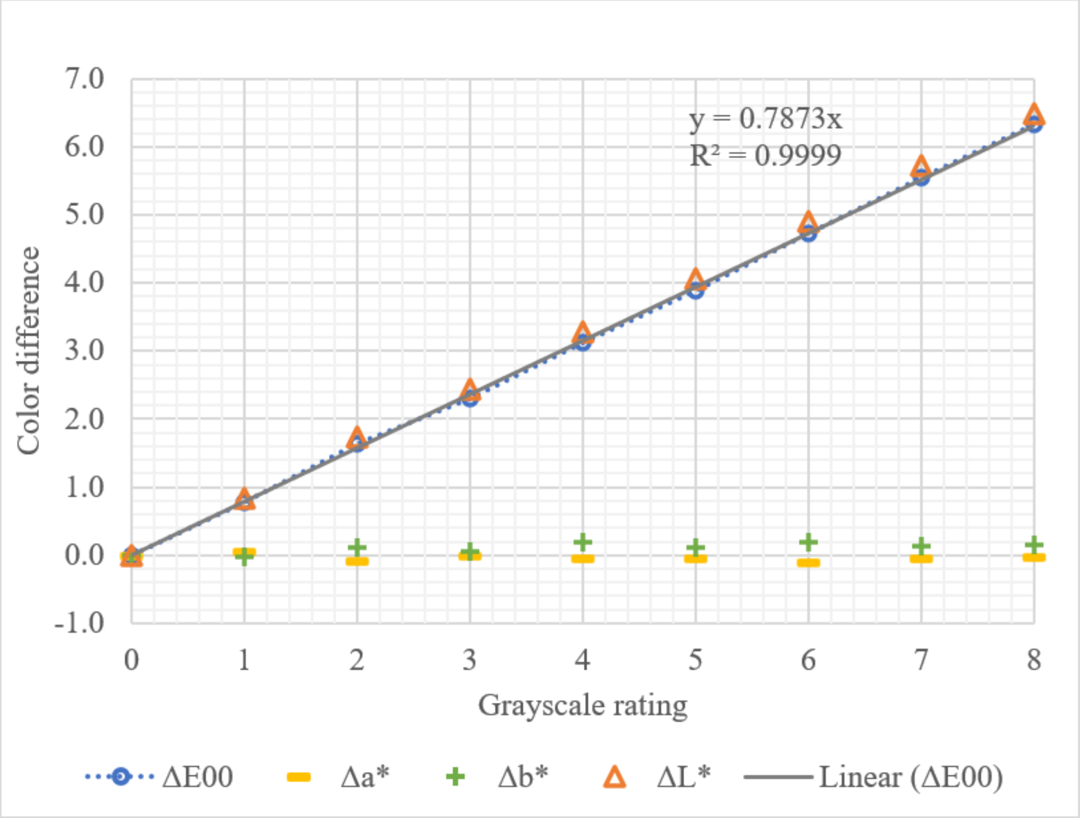


Figure 3. Relationship between gray scale rating and the reproduced CIEDE2000(1:1:1) color difference as well as component color differences for each of the gray pairs.

- Nine achromatic pairs
- Linearly increasing
- Grayscale rating: 0 – 8
- ΔE_{00} range: 0-6.3 units with 0.8 units steps

➢ Observer characteristics

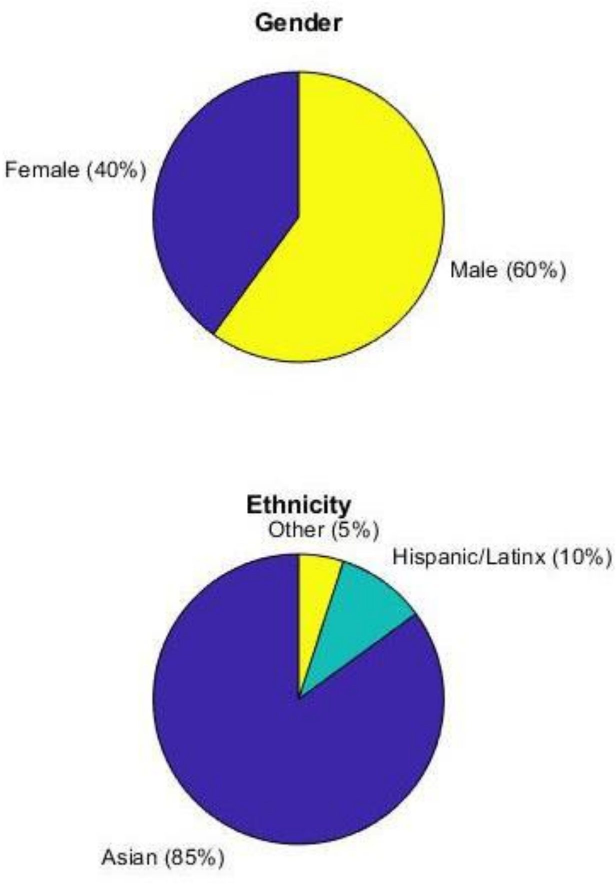


Figure 4. Demographics of the participating observers.

- Twenty observers with normal color vision
- 234 unique pairs, 90 pairs replicated 3 times
- 414 assessments in total in three sessions
- A total of 8280 assessments

➢ Observer visual differences

The influence of separation distance

c_Lc4.0+_0

c — Checkerboard background

Lc4.0+ — Lightness increases of 4 unit compared to reference "Coyote"

0 — 0-degree separation

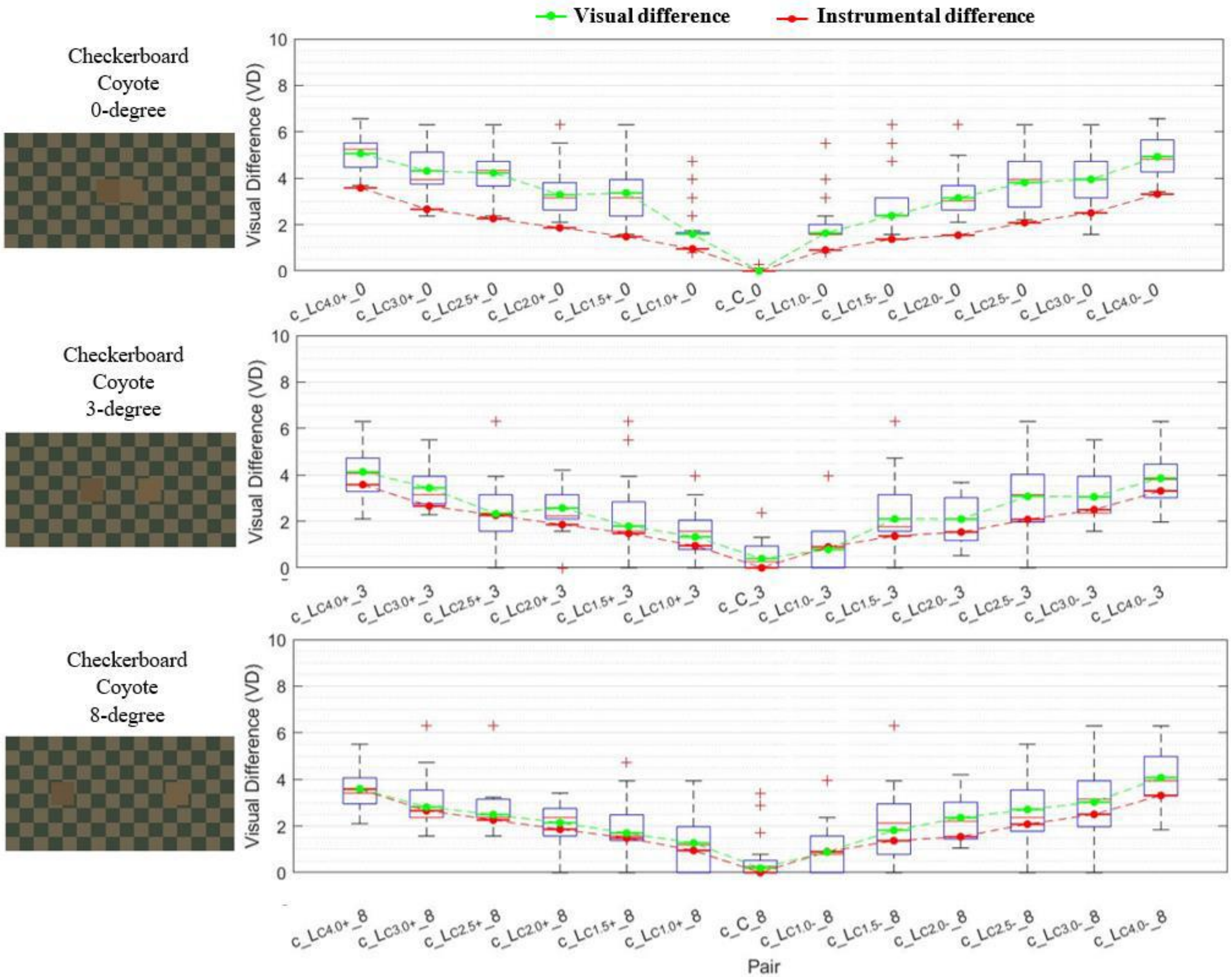
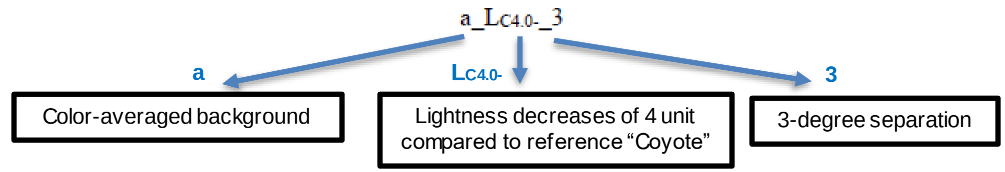
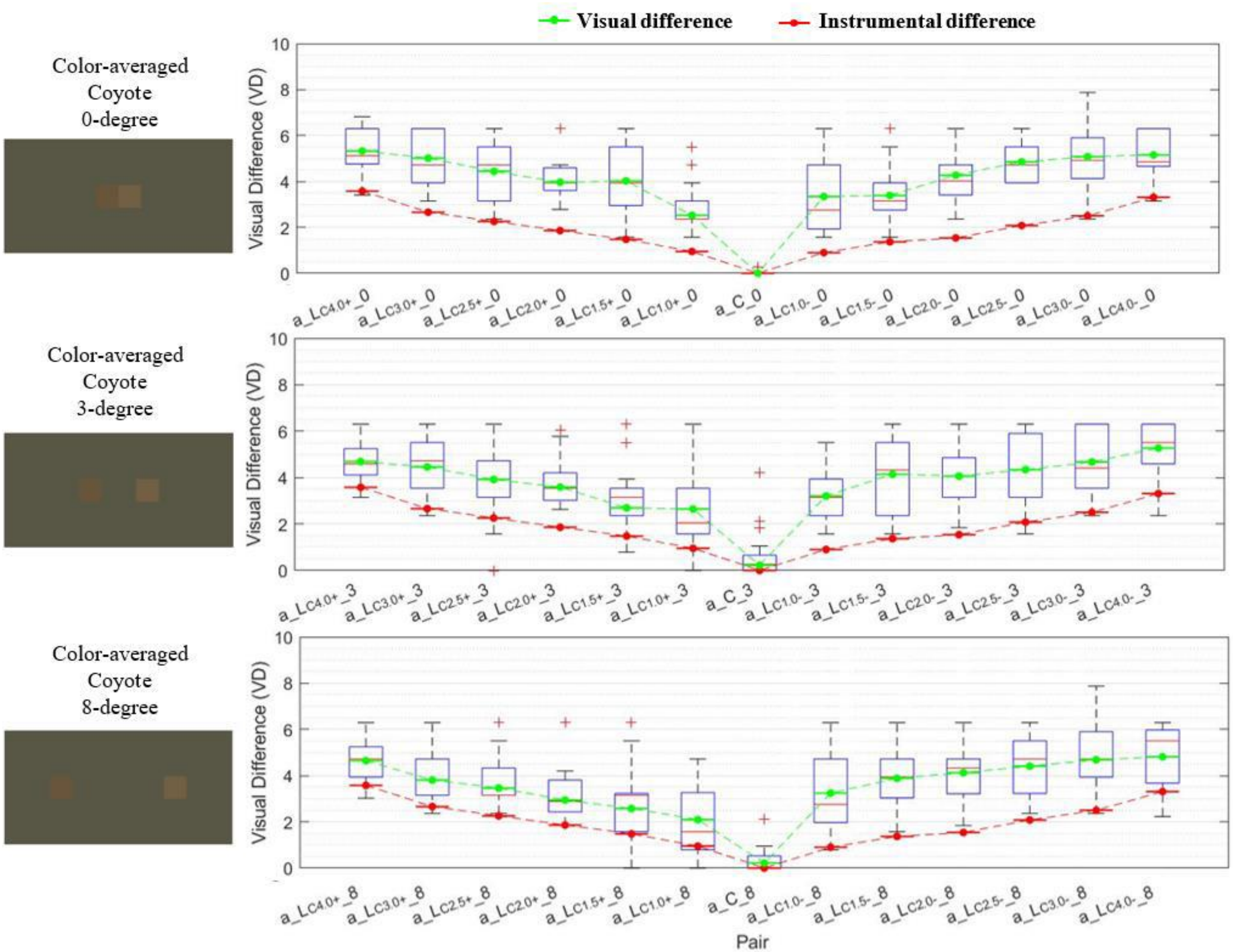


Figure 5. Variability in visual differences (VDs) of sample pairs with a checkerboard background, a central reference color "Coyote", and different separation distances.

- Follow a "V" shape
- Flatter "V" with an increasing distance





- Less influenced by the distance if central reference color is "Coyote"

Figure 6. Variability in visual differences (VDs) of sample pairs with a color-averaged background, a central reference color "Coyote", and different separation distances.

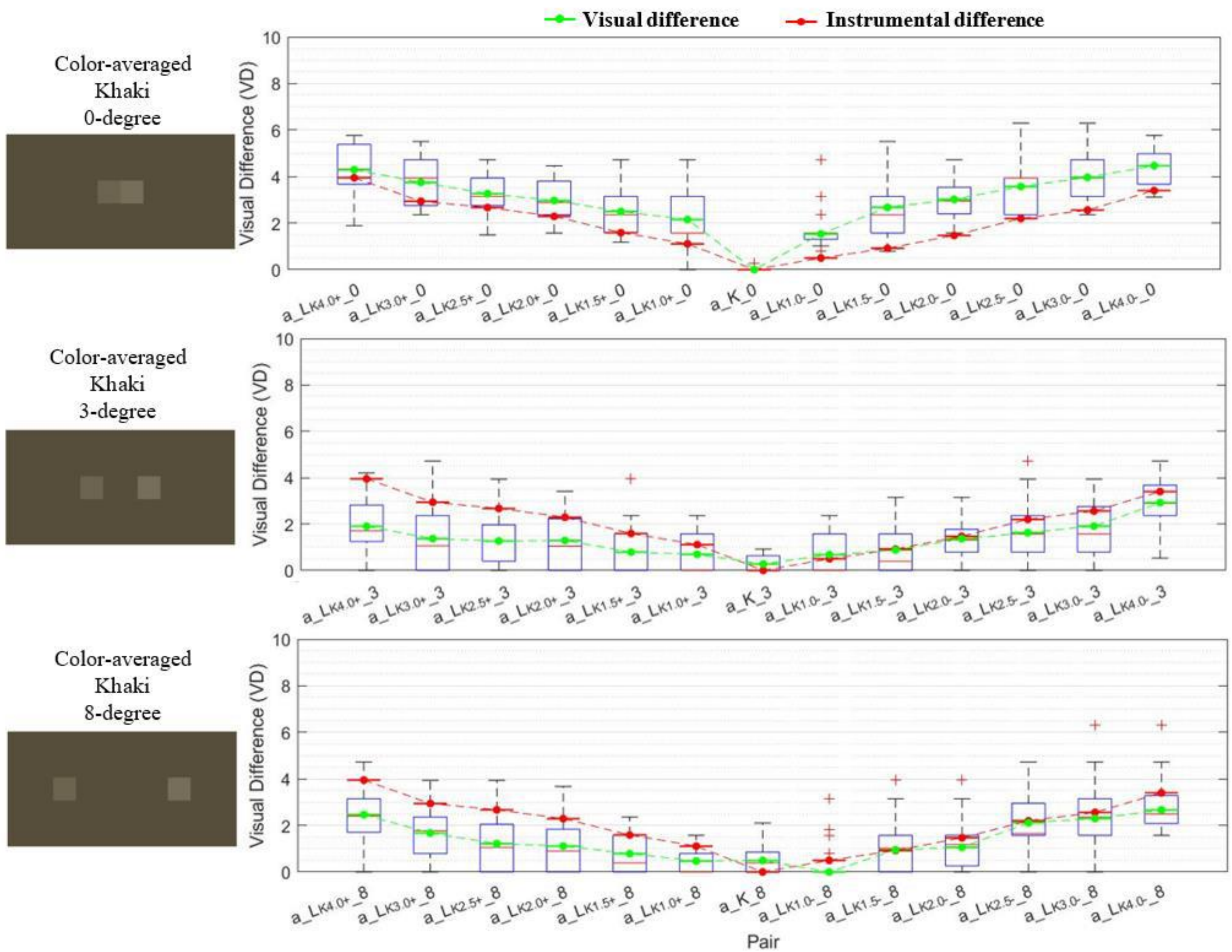


Figure 7. Variability in visual differences (VDs) of sample pairs with a color-averaged background, for the central reference color “Khaki”, and different separation distances.

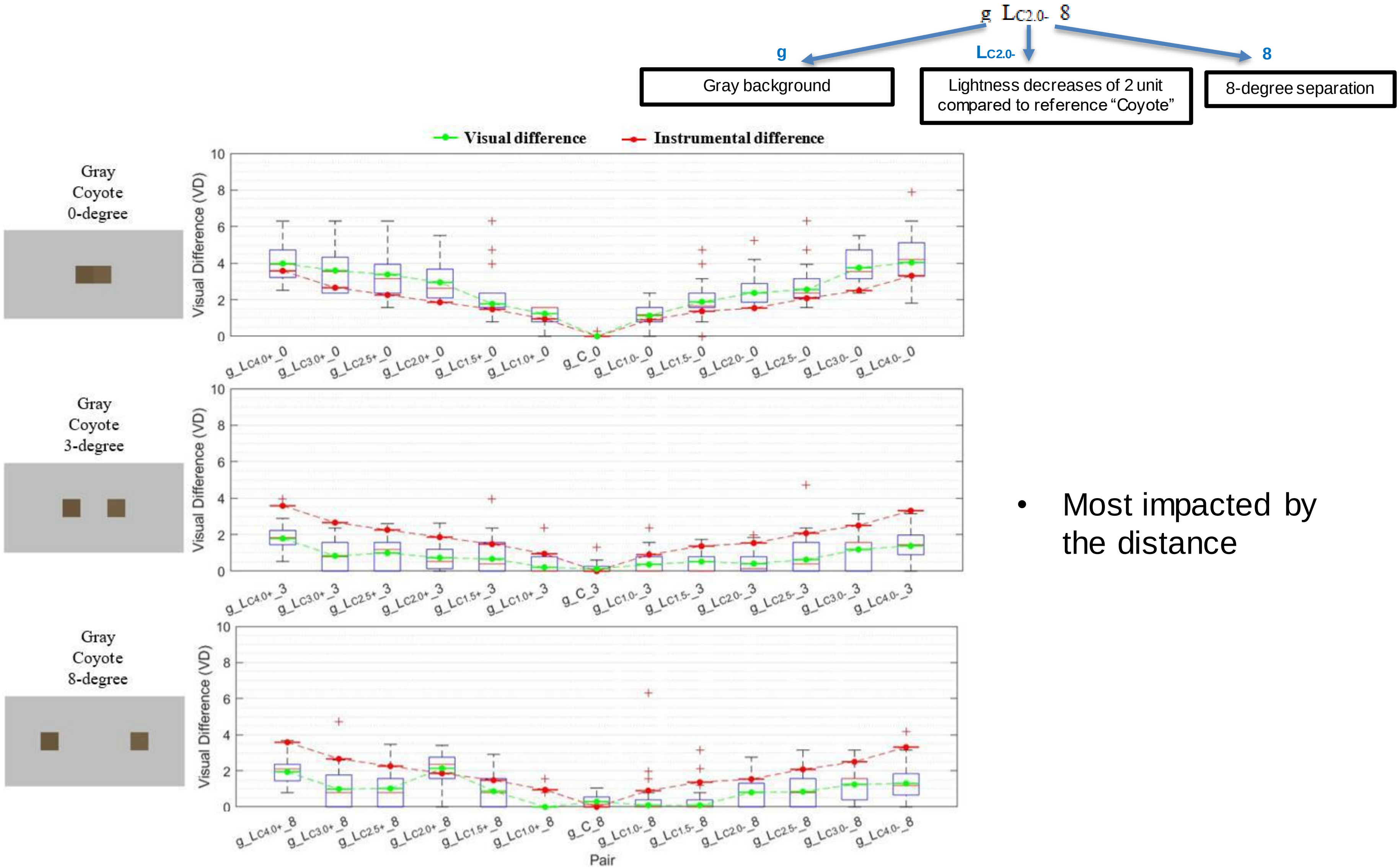


Figure 8. Variability in visual differences (VDs) of sample pairs with a gray background, a central reference color "Coyote", and different separation distances.

- Most impacted by the distance

Statistically significant difference when comparing 0 vs. 3 or 8 degrees.
Insignificant difference when comparing 3 vs.8 degrees

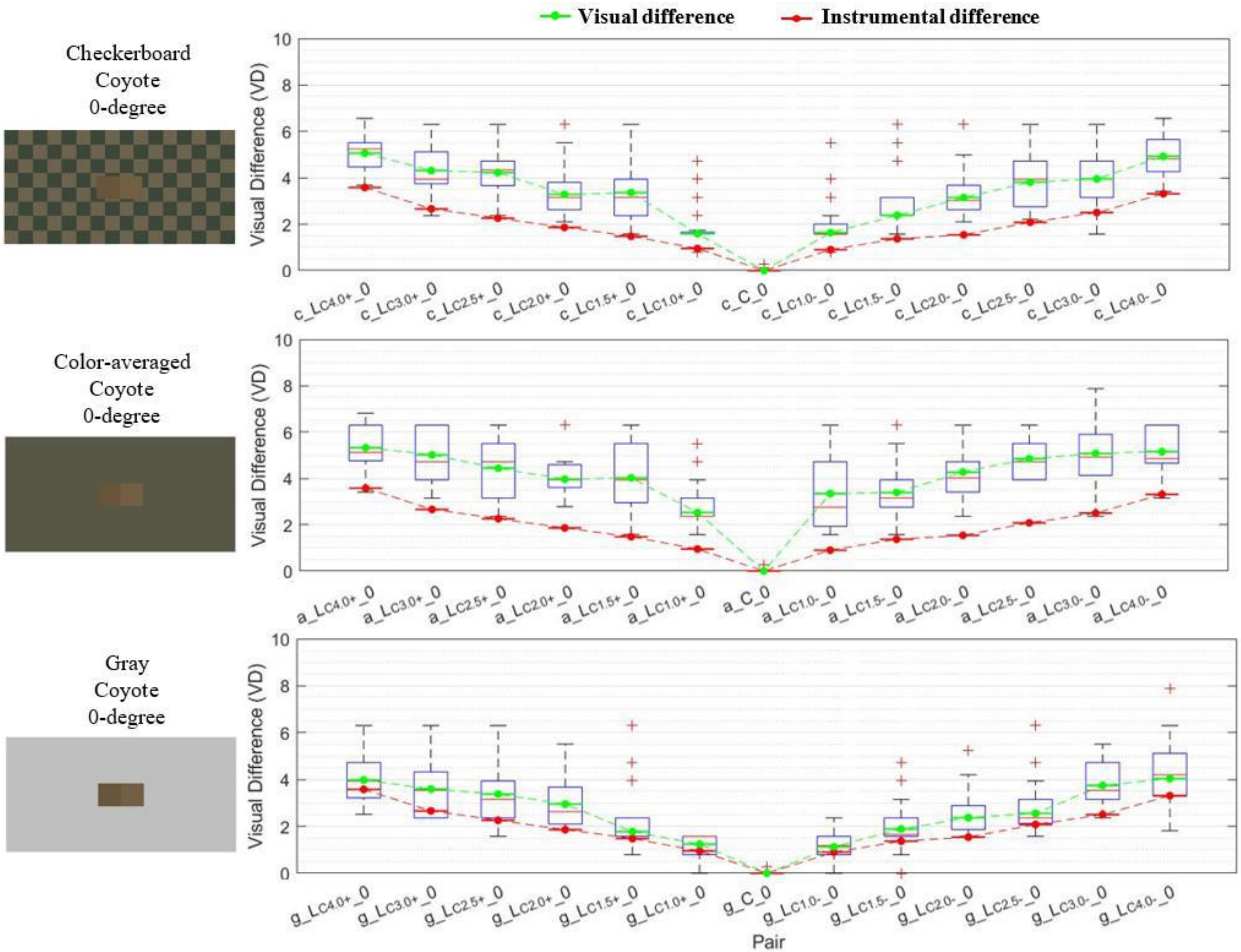
The influence of background

c_LC4.0+_0

c — Checkerboard background

LC4.0+ — Lightness increases of 4 unit compared to reference "Coyote"

0 — 0-degree separation



- Follow a "V" shape
- Flatter "V" with a gray background

Figure 9. Variability in visual differences (VDs) of sample pairs with a 0-degree separation distance, a central reference color "Coyote", and different backgrounds.

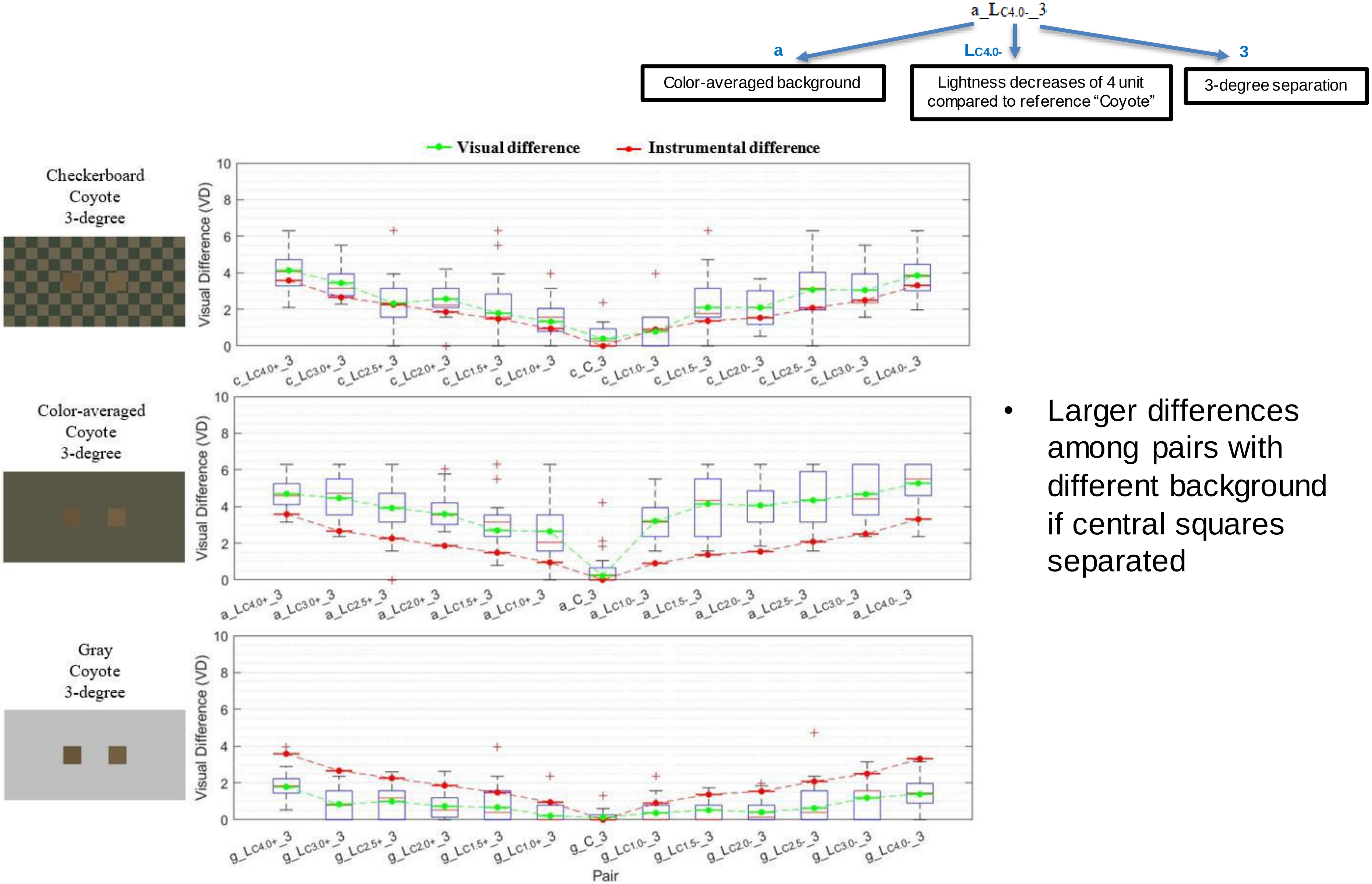


Figure 10. Variability in visual differences (VDs) of sample pairs with a 3-degree separation distance, a central reference color "Coyote", and different backgrounds.

- Larger differences among pairs with different background if central squares separated

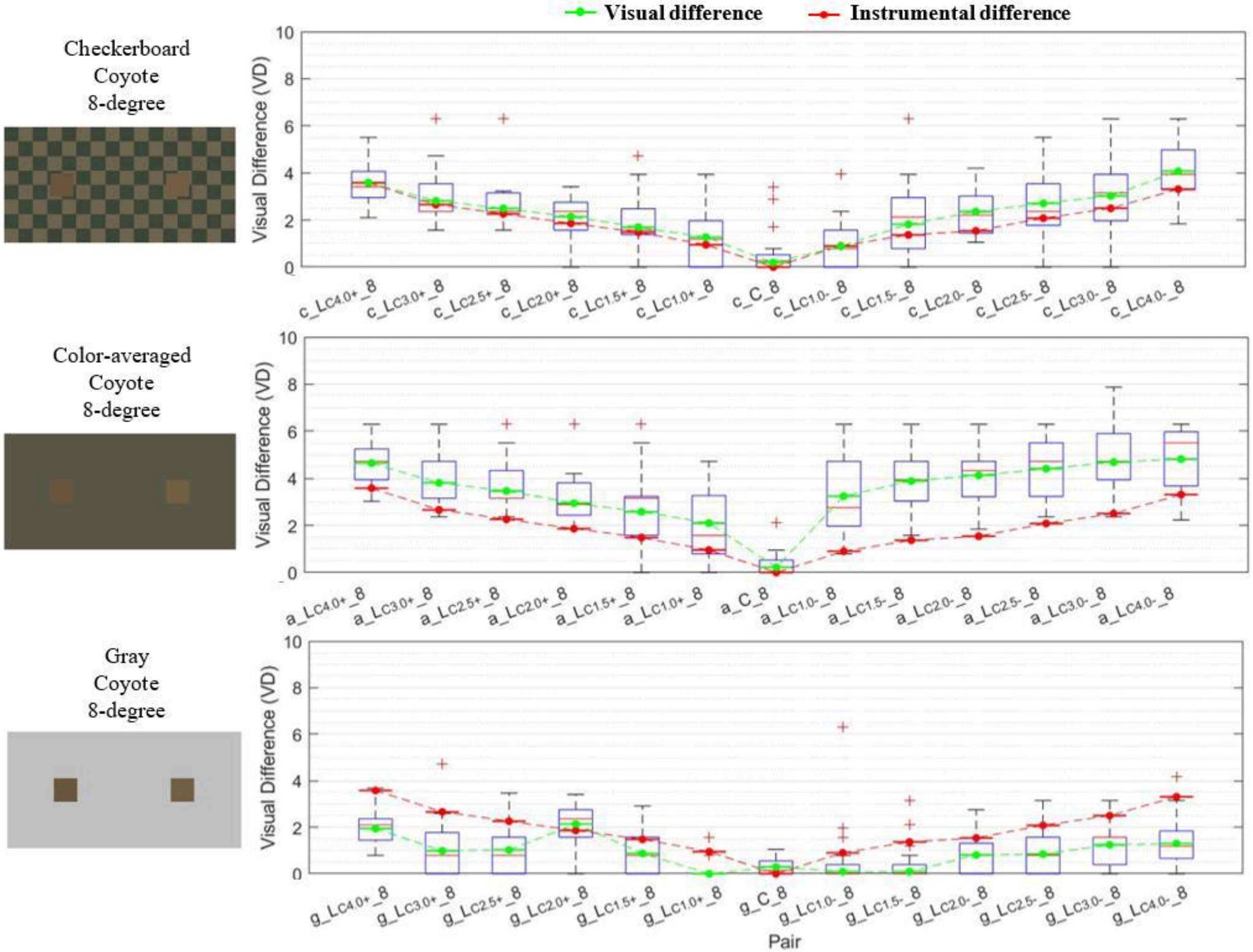


Figure 11. Variability in visual differences (VDs) of sample pairs with an 8-degree separation distance, a central reference color "Coyote", and different backgrounds.

- The choice of background significantly influences observers' perception of color difference

Larger simultaneous contrast effect

Visual differences:

- <u>Central reference color "Coyote"</u>: color-averaged > checkerboard > gray
- <u>Central reference color "Khaki"</u>: checkerboard <= color-averaged > gray

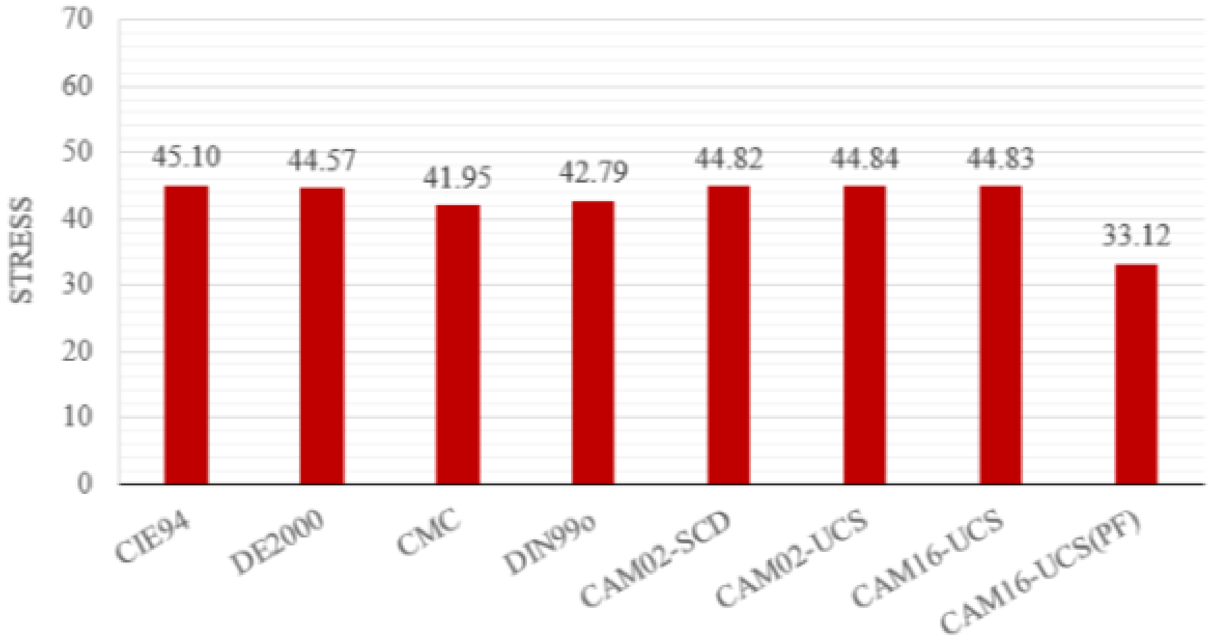
➢ Performance of color difference formulas

Tested models include the CIE94, CIEDE2000(1:1:1), CMC(1:1), DIN99o, CAM02-SCD, CAM02-UCS, CAM16-UCS, and CAM16-UCS with a power function(Huang et al. (2015).

Model-predicted color differences ("DE")

Observed color differences ("VD")

The standardized residual sum of squares (STRESS)



Unsatisfactory performance.

Figure 12. STRESS values calculated using different color difference models and based on responses for all sample pairs.

➢ Conclusions

- Observers consistently perceived smaller visual differences when a gray background was used compared to sample pairs with checkerboard or color-averaged backgrounds.
- Results show significant differences in visual differences between connected and separated central squares.
- The presence of a chromatic background, enhanced the visual difference through simultaneous contrast effects.
- All tested color difference models showed relatively high STRESS values suggesting room for improvement in accurately predicting human visual perception of color differences presented on sample pairs within complex surrounds.