The Effect of Temporal Frequency and Hue on the Perceived Level of Caution Adopted During Driving

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Purpose

This study was undertaken to provide insight into the interaction between hue, hue pairs, and temporal frequency on the level of caution adopted when driving. It is our hope that through this study, traffic warning signals, emergency responders and law enforcement agencies may adopt more informed strategies by which to modulate the sense of caution of drivers, specifically by manipulating hue, hue pairs and temporal frequency.

Methods

All participants (N=15) were adult subjects between the ages of 21 and 27 with driving experience ranging from 6 to 11 years. Each had 20/20 monocular vision, at both distance and near, and scored 14 out of 14 on the Ishihara color plates. All tests described below were performed in a dark room, on a Dell LCD computer monitor.

Measurement of Perceived Caution

- Participants rated their perceived level of caution evoked by a flickering 2-degree circular patch presented on a computer screen with isolated hues of either red (R), green (G), or blue (B) , or as a combination of hues: R/G, B/G, or R/B.
- Flicker was square-wave modulated at temporal frequencies (TF) of 1, 2, 4, 8, 16, and 24Hz. The luminance of isolated hues was modulated in an ON/OFF sequence, while the paired hue conditions (R/G, R/B, G/B) were interleaved consecutively at the respective temporal frequency.
- The flickered stimulus was presented for four seconds, followed immediately by the presentation of a continuous scale (1 = lowest level of caution to 10 = highest level of caution) on the monitor, which was used by the subject to indicate their perceived level of caution. Hue condition and TF were randomly interleaved within a single experimental session.
- The mean of 5 repetitions for each hue and TF condition comprised a completed session.

Determination of Isoluminance

- Hues were rendered approximately isoluminant using the heterochromic flicker method (@ 30 Hz) relative to the reference hue of Blue which was presented at maximal luminance (9.5 cd/m2).
- Subjects adjusted the luminance of R and G hues using the keyboard until the perceived heterochromic flicker was either minimal or imperceptible.
- The isoluminant point was calculated as the mean of five adjustments for both R and G when interleaved with the reference hue B.
- Stimulus was a 2 degrees circular patch.

References

1. Yates, Travis. (2009). How to Safely use Emergency Lights. https://www.policeone.com/police-products/emergency-lights/articles/1858042-How-to-safely-use-emergency-lights/
2. De Lorenzo, Robert; Eilers, Mark. (1991). Lights and Siren: A Review of Emergency Vehicle Warning Systems. https://www.emergencydispatch.org/articles/warningsystems1.htm
3. Jackson, David. (2018) Green lights on snow plows proving effective. https://www.uppermichiganssource.com/content/news/Green-lights-on-snow-plows-proving-effective-468874873.html

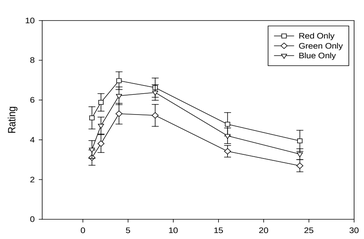
Results

- The perceived level of caution, for each participant, varied significantly with both temporal frequency and hue condition ($p < 0.001$)*.
- The Red hue was associated with the highest perceived level of caution, followed by Blue and Green ($p < 0.001$)* hues when presented in isolation.
- Paired hues (R/G and G/B) in general produced levels of caution approximating the average of the respective isolated hue condition. However, perceived caution for the R/B paired hue condition exceeded levels of caution for the respective isolated hue conditions ($p < 0.001$) and the other paired hue conditions(G/B, R/G - $p < 0.001$)* (, i.e. a faciliatory effect.
- Results from a pilot study also revealed that a reduction in peak stimulus luminance by 1 log unit decreased the mean peak level of caution for each stimulus size.

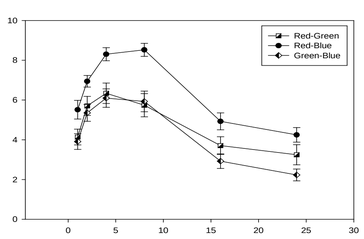
* Two-way (Hue x TF) RM ANOVA

	Red Only	Green Only	Blue Only	Red/Green	Red/Blue	Green/Blue
Mean Peak Temporal Frequency	6.0911 (+/- 3.629)	5.3279 (+/-2.295)	6.3865 (+/-1.766)	6.4807 (+/- 4.418)	5.1815 (+/-2.043)	5.8891 (+/-2.469)
Mean Peak Level of Caution	7.0001 (+/- 2.486)	5.5540 (+/-2.433)	6.6655 (+/-2.235)	6.6387 (+/- 2.468)	8.3452 (+/-2.690)	6.7231 (+/-2.157)

Table 1 compares the mean peak level of caution and the correlating mean peak level of caution for each stimulus hue and hue combination

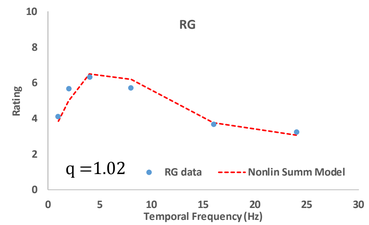


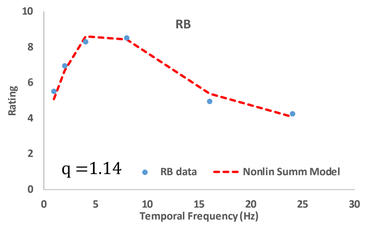
Graph 1 shows the comparison of mean level of caution over each temporal frequency for R, G and B only stimuli.

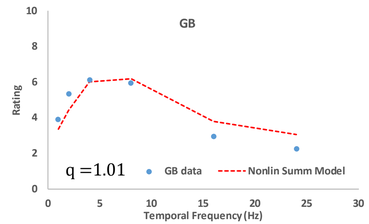


Graph 2 shows the comparison of mean level of caution over each temporal frequency for R/G, R/B and G/B stimuli.

Modelling







$$P_C = (W_1 * P_1 + W_2 * P_2)^q$$

$$W_1 = \sigma_1^{-2}/(\sigma_1^{-2} + \sigma_2^{-2})$$

$$W_2 = \sigma_2^{-2}/(\sigma_1^{-2} + \sigma_2^{-2})$$

Pc = Perceived rating for combined hues
W_1 = Weighting for Hue 1
W_2 = Weighting for Hue 2
q = non-linear perceptual scaling factor

Conclusions/Discussion

- Perceived level of caution (in the context of driving) can be modulated by varying the hue and temporal frequency of flashing lights.
- Temporal frequencies in the range of 6-8Hz produces maximal levels of caution, regardless of hue or hue pair.
- Level of caution is maximal with Red and Blue hues in isolation or when presented consecutively.
- The reduction of caution with higher temporal frequencies could be ascribed to a confluence of at least two effects:
  - Decreasing perceived brightness
  - Decreasing salience of flicker as the TF approaches the color fusion frequency (~15-20Hz).
- The faciliatory effect noted with Red and Blue (especially in combination) may reflect the influence of a conditioned response, i.e. red is usually associated with hazards or danger and blue generally associated with law enforcement.