Evaluation of Colour Appearance Models using Transmissive Media

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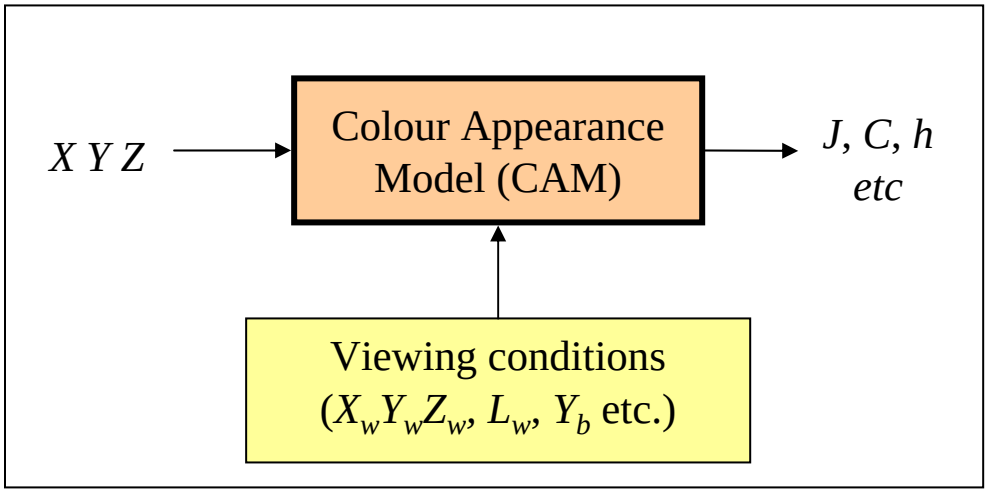
Colour Appearance Models

- To predict colour appearance under a variety of viewing conditions like different luminance levels, backgrounds, light sources and surrounds

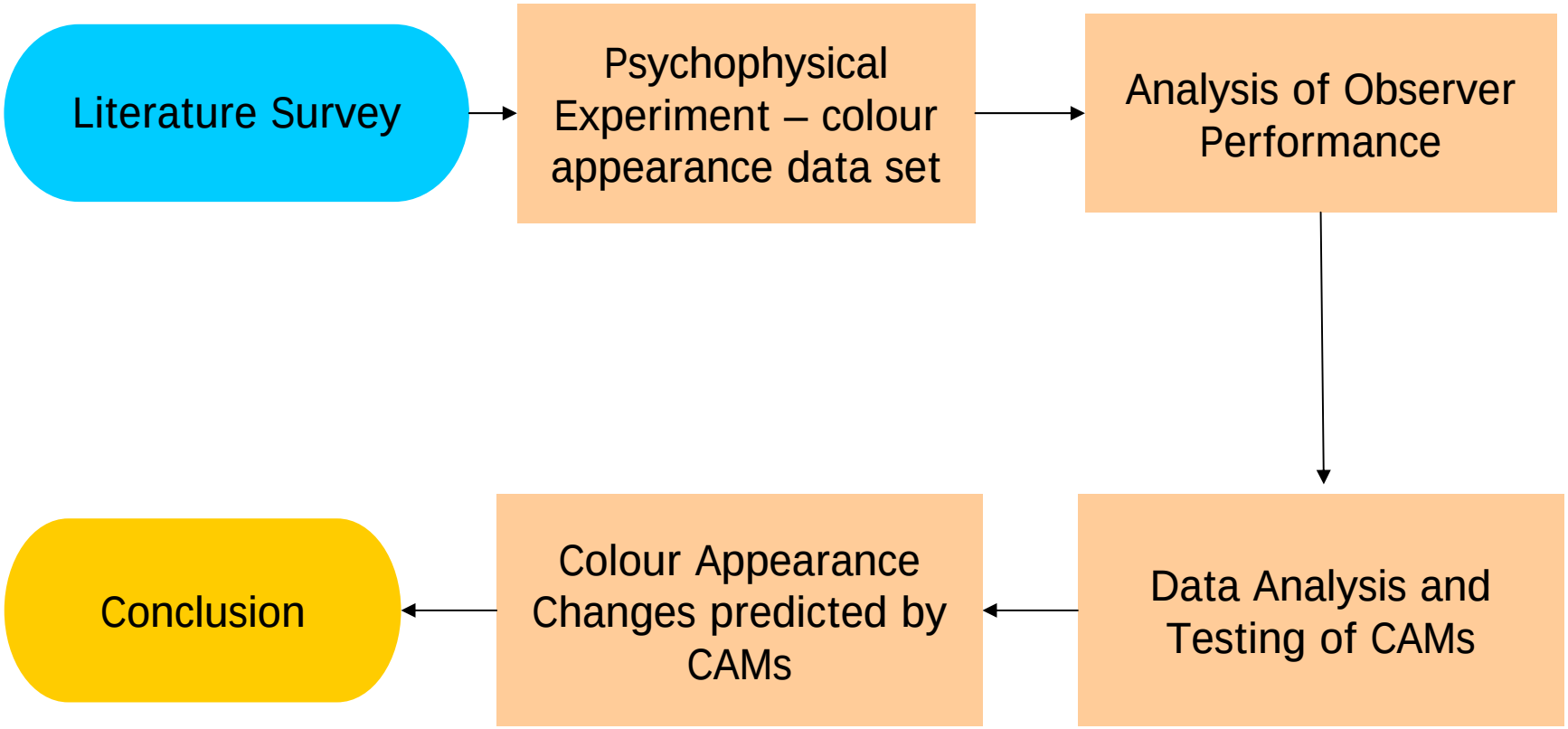


- Used for achieving successful cross-media image reproduction
- No. of models are developed by researchers e.g. Hunt94, CIECAM97s, CIECAM02 etc.
- Relatively few experiments have been performed for testing these models

Project objectives

- To collect new colour appearance data set for transmissive media under high luminance levels
- To evaluate the performances of a number of existing colour appearance models by using the collected colour appearance data set
- To test the ability of different colour appearance models to predict the colour appearance changes in varying luminance levels and background luminance factors

Project Workflow



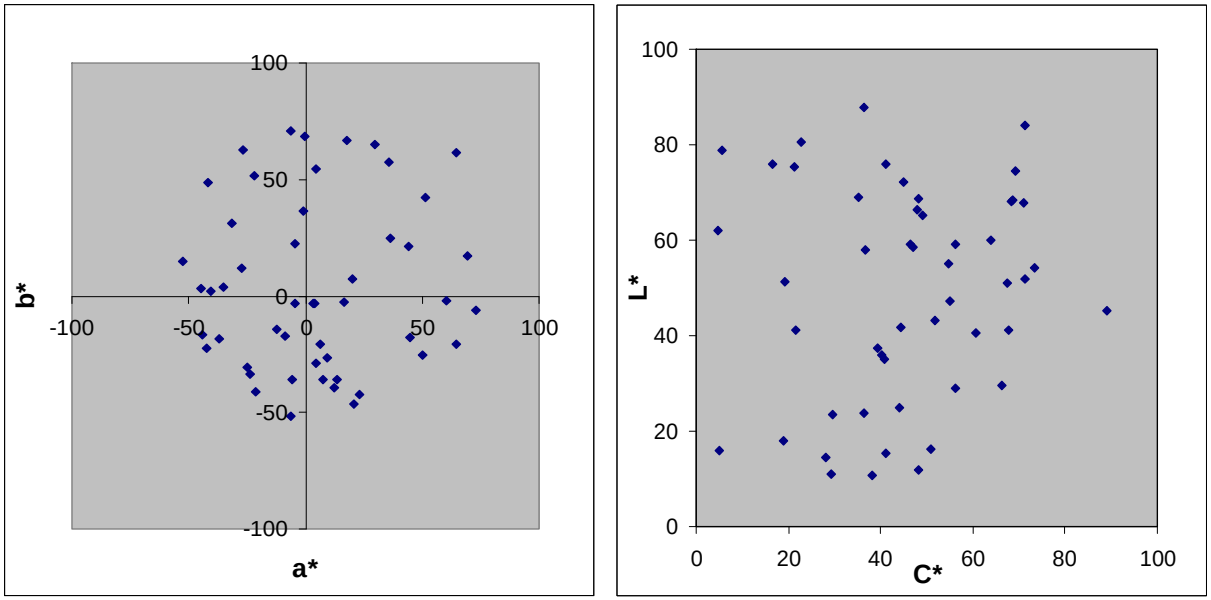
Psychophysical Experiment

- Magnitude estimation technique – lightness, colourfulness and hue of 50 test colours were assessed by the observers
- The experiment was divided into 5 phases according to different luminance levels and background luminance factors

Phase	Luminance	Luminance of reference white (cd/m2)	Background	Background luminance factor Yb
Black Background	High	3320	Black	0.53
White Background	High	3650	White	100
Grey Background/ High Luminance	High	3480	Grey	52.2
Medium Luminance	Medium	298	Grey	53.52
Low Luminance	Low	27.4	Grey	50.06

Psychophysical Experiment

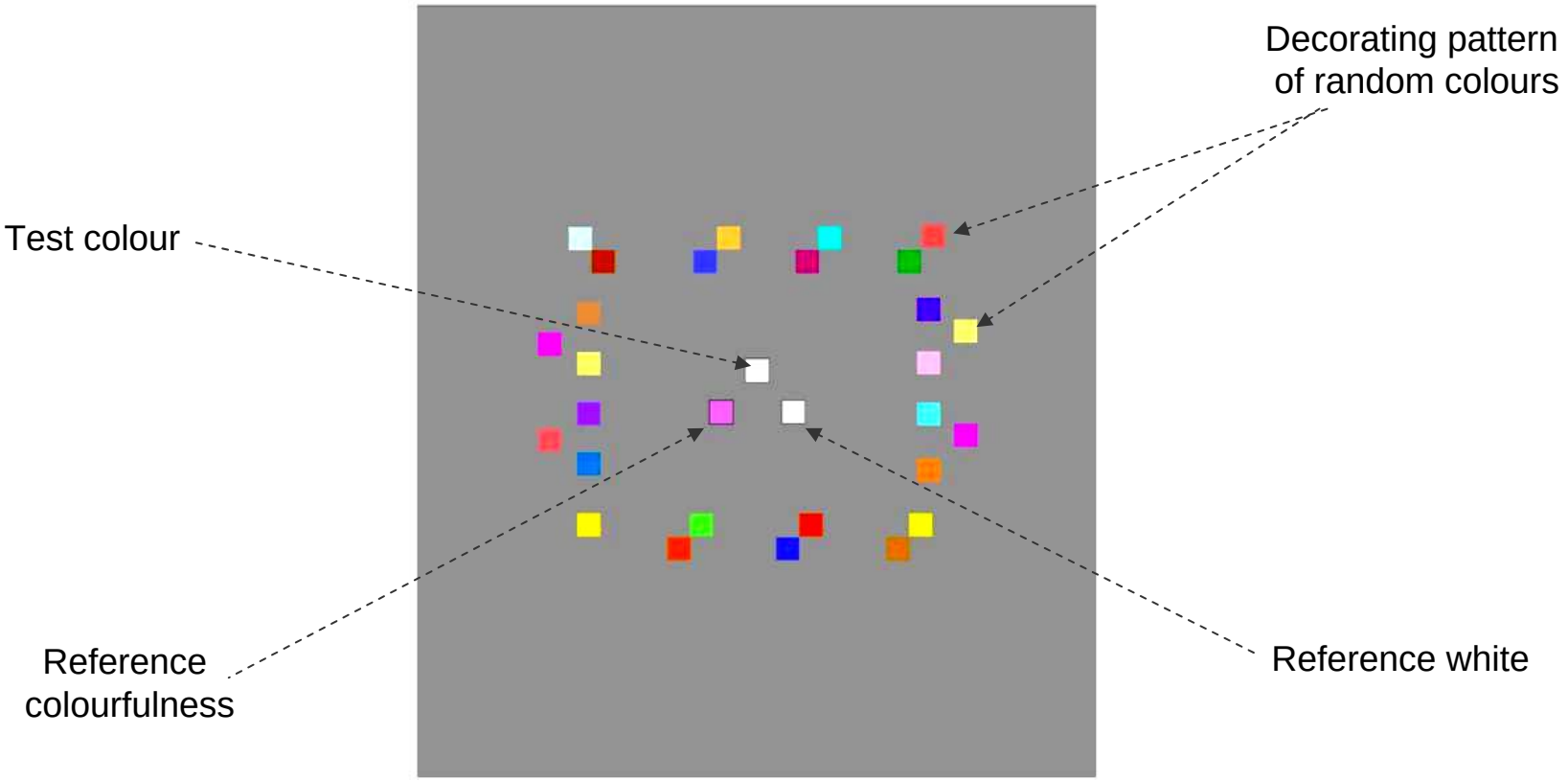
- Sixteen observers participated in the experiment to give a total of 10,500 estimations
- Selection of test colours – wide colour gamut and range of lightness values
- Test colours measured by Telespectroradiometer (TSR)
- Printed on transparent media using wide-format inkjet printer



Distribution of test colours in a* - b* plane and L* - C* plane (black background)

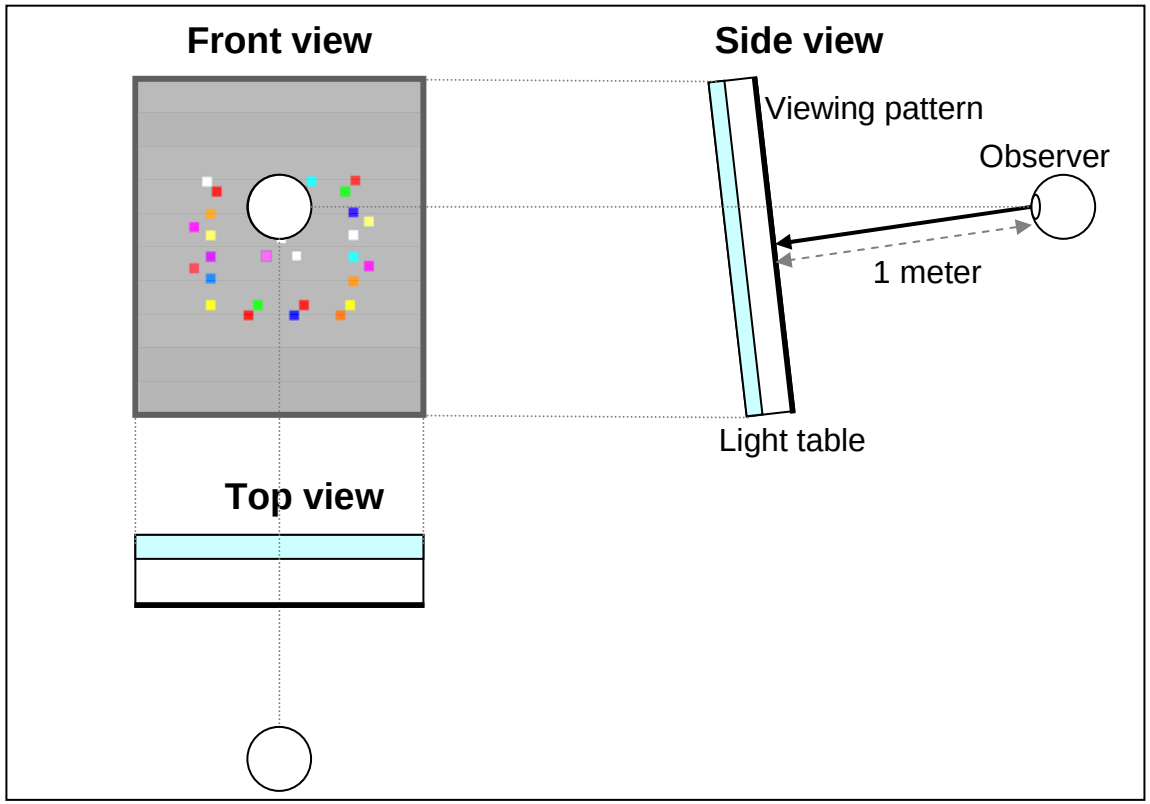
Psychophysical Experiment

- Viewing pattern – 115×104 cm
- Designed for three different backgrounds
- Simulates a complex image and renders the test colours as related colours



Psychophysical Experiment

- A large light table was used for viewing test colours – light intensity control
- High-intensity light source inside the table for back-illuminating viewing pattern
- All phases carried out under dark surround conditions



Experimental setup

Psychophysical Experiment

- Each observer was asked to assign the values for lightness, colourfulness and hue of each test colour
- Size of colour patch – 3.5 × 3.5 cm (subtending angle of 2 degree)
- Adaptation time was given to adapt the surround conditions
- Training was given to get familiar with the colour attributes
- Time duration for a typical observer session of one phase – 1 hour

Observer Performance

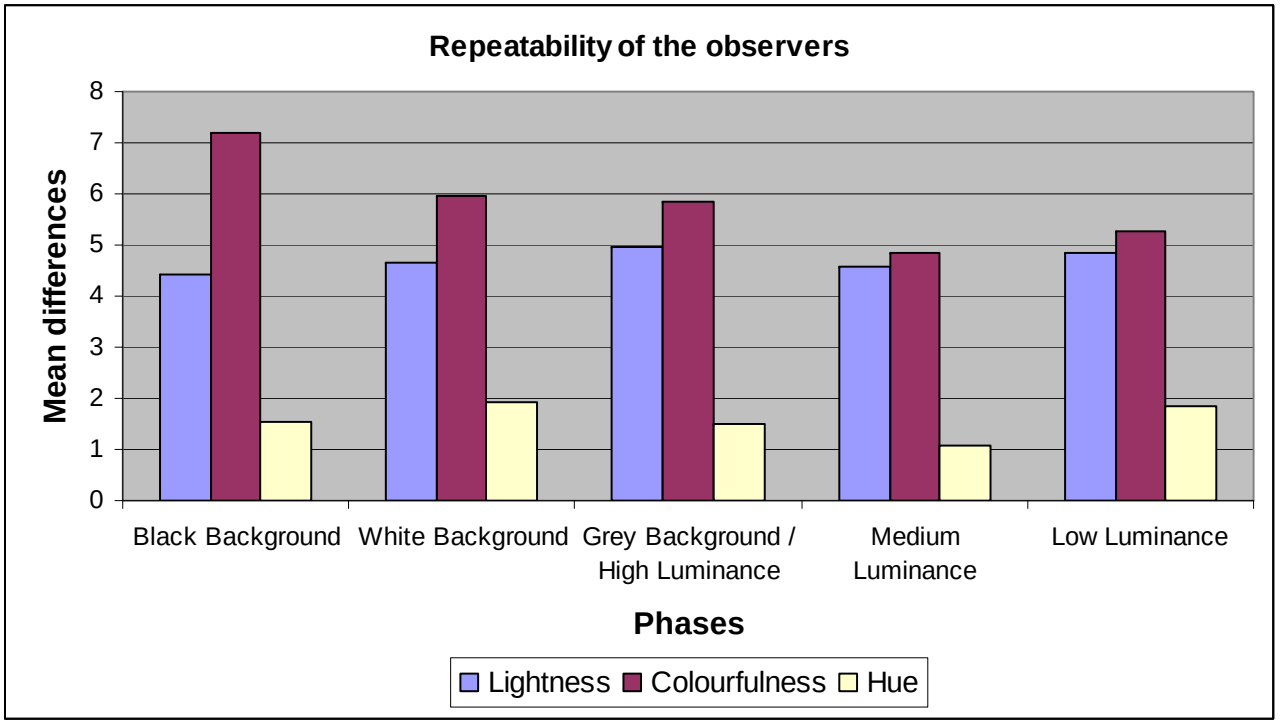
Repeatability of the observers

- In each phase, 3 test colours were repeated randomly for each observer
- The difference between two judgements was calculated
- Average difference values for all the observers are

Lightness – 4.70

Colourfulness – 5.83

Hue – 1.57



Observer Performance

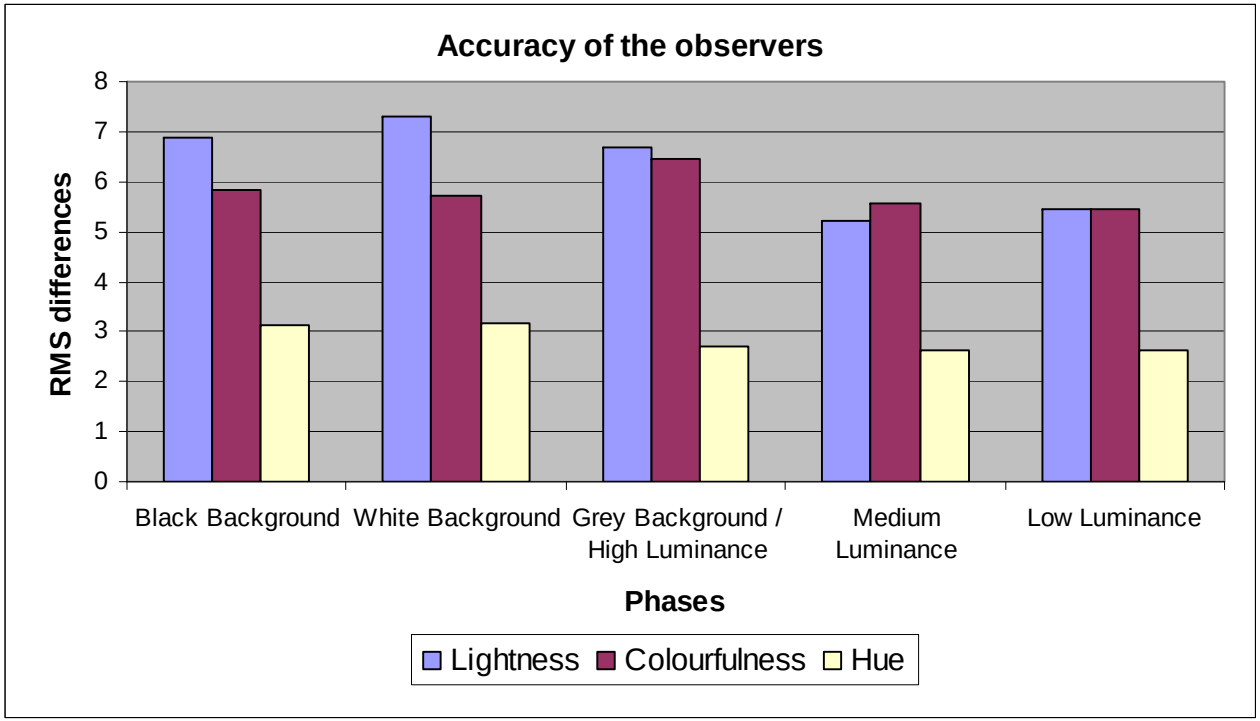
Accuracy of the observers

- Closeness of observer's estimates to the mean visual results
- Deviation between individual's and mean visual results was evaluated
- Average difference values for all the observers are

Lightness – 6.31

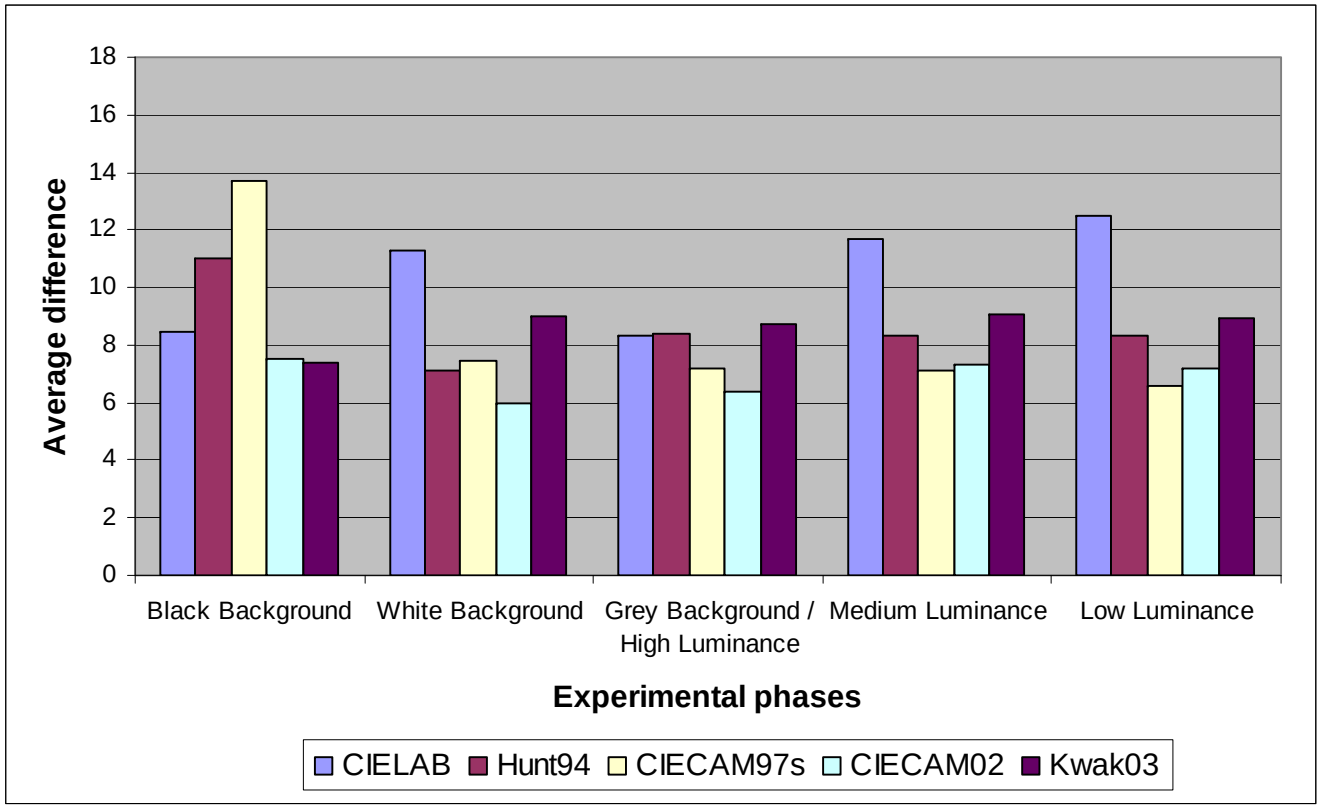
Colourfulness – 5.79

Hue – 2.86



Testing Colour Appearance Models

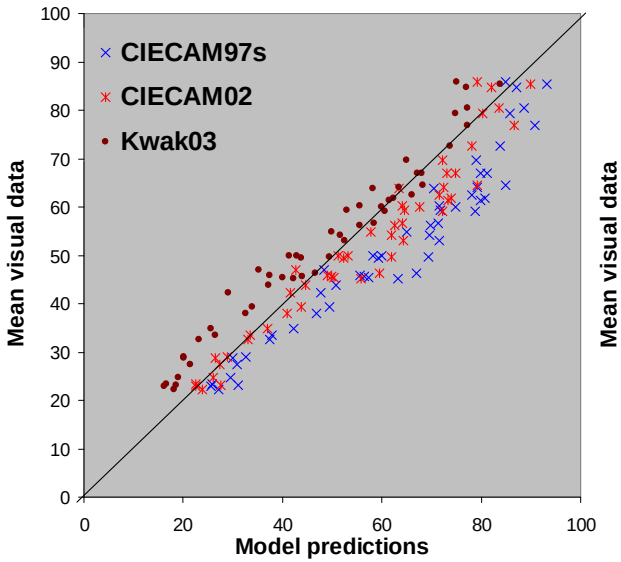
- Ability of the model to predict the mean visual results
- Models: CIELAB, Hunt94, CIECAM97s, CIECAM02, Kwak03
- RMS differences calculated from average differences of lightness, colourfulness and hue
- Absolute difference between mean visual data and model-predicted data was calculated



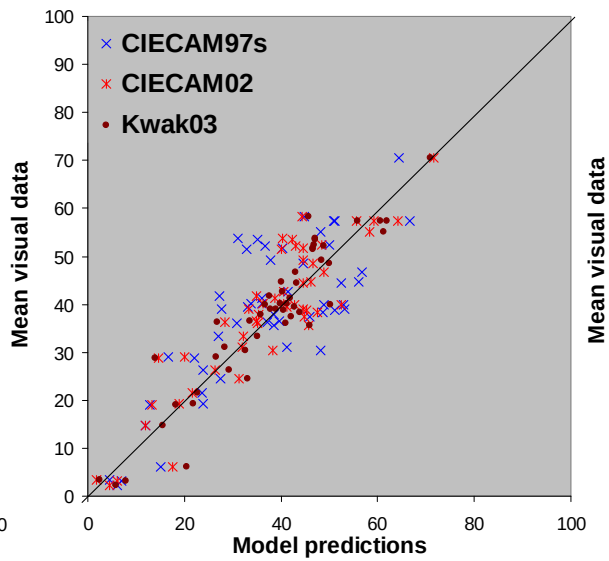
Testing Colour Appearance Models

- Qualitative performances of the models
- Scatter diagram – mean visual data vs. model predictions

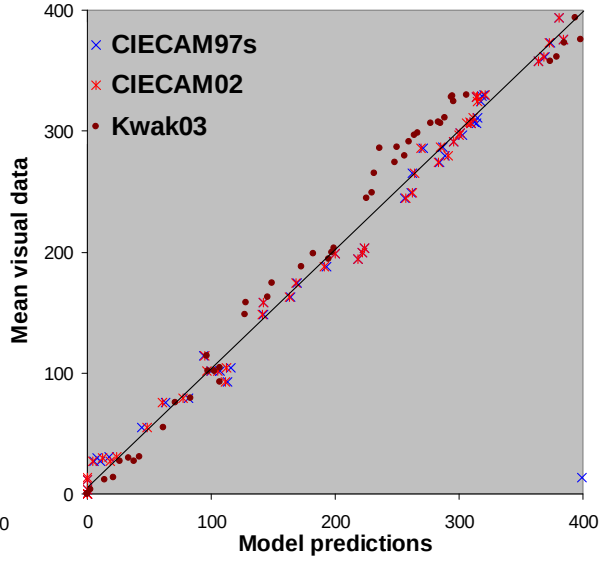
Qualitative performances of three models for Black Background phase



Lightness predictor



Chroma predictor

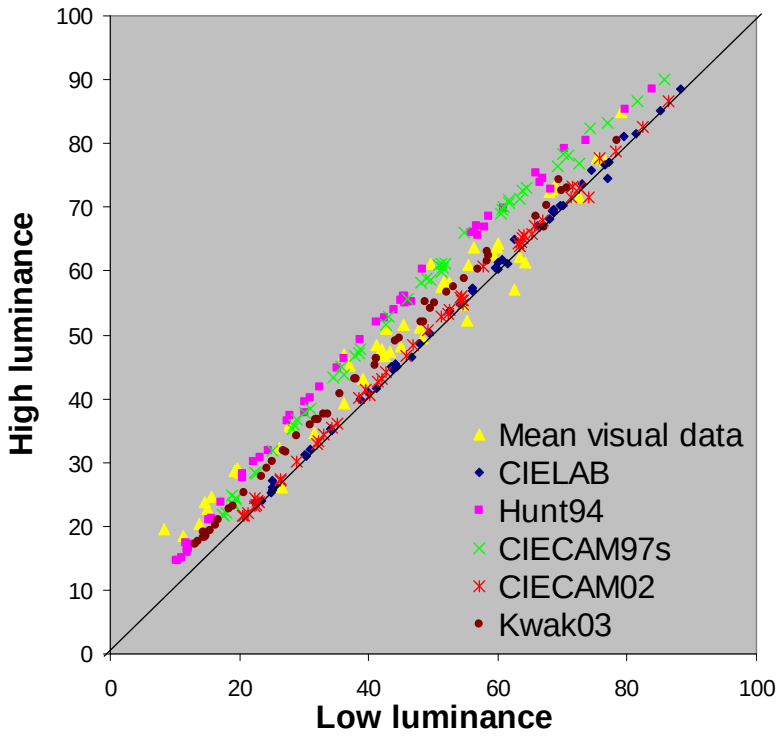


Hue predictor

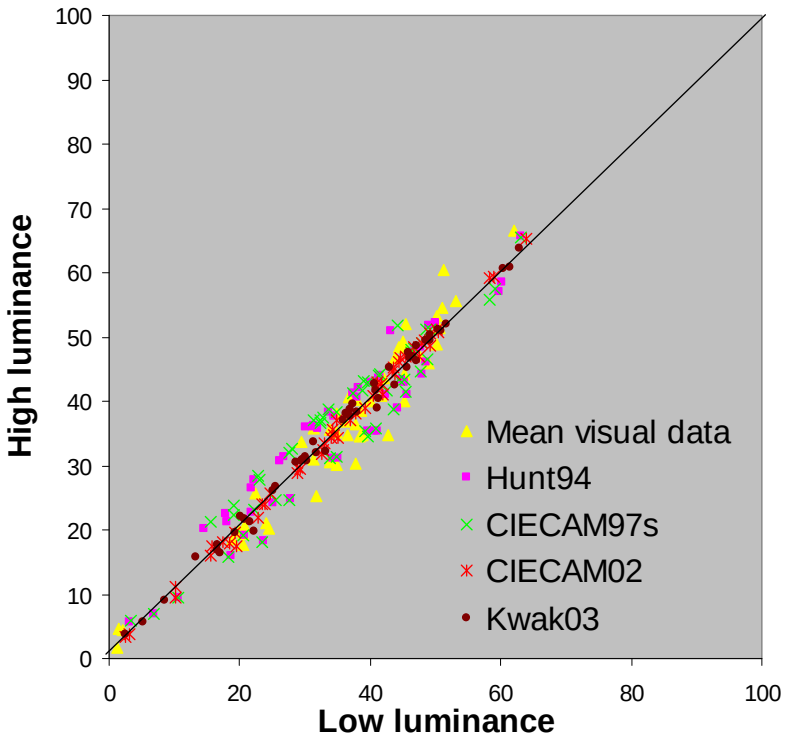
Effect of Luminance Level

- Comparison - model predictions of the effect of luminance levels with those found in the visual data

Prediction of lightness change



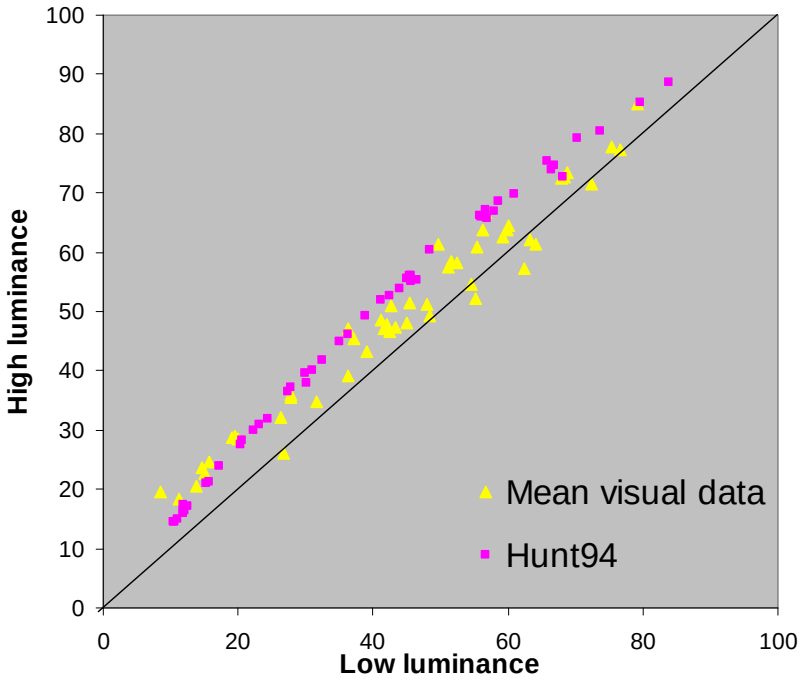
Prediction of colourfulness change



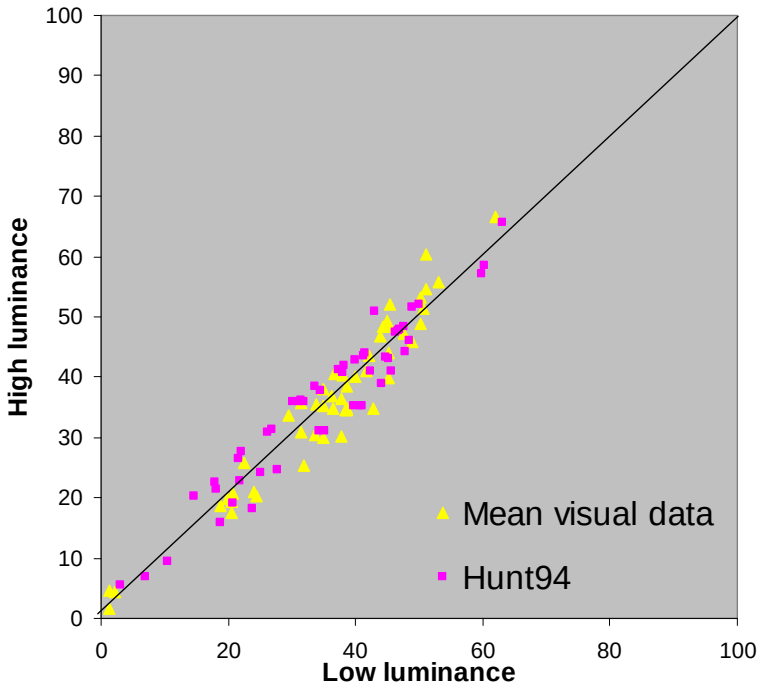
Effect of Luminance Level

- Comparison - model predictions of the effect of luminance levels with those found in the visual data
- Dark colours are judged lighter at high luminance level

Prediction of lightness change



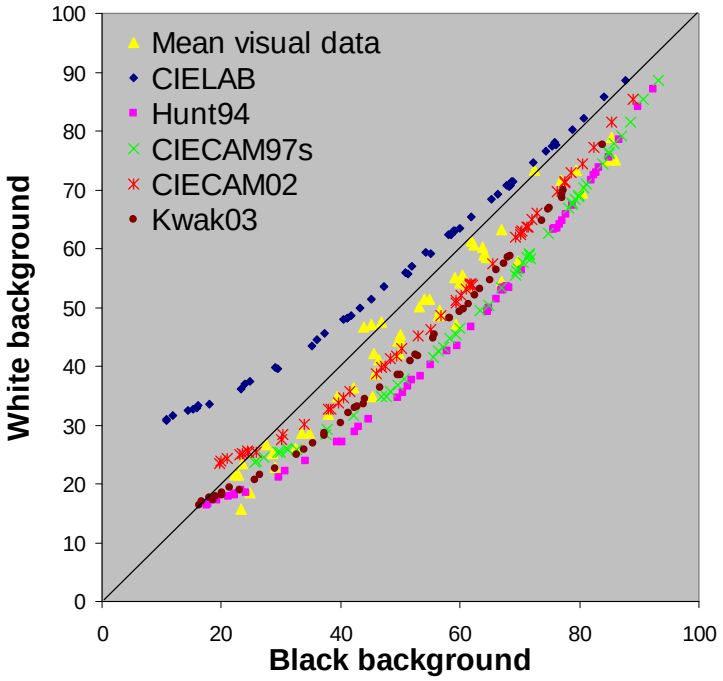
Prediction of colourfulness change



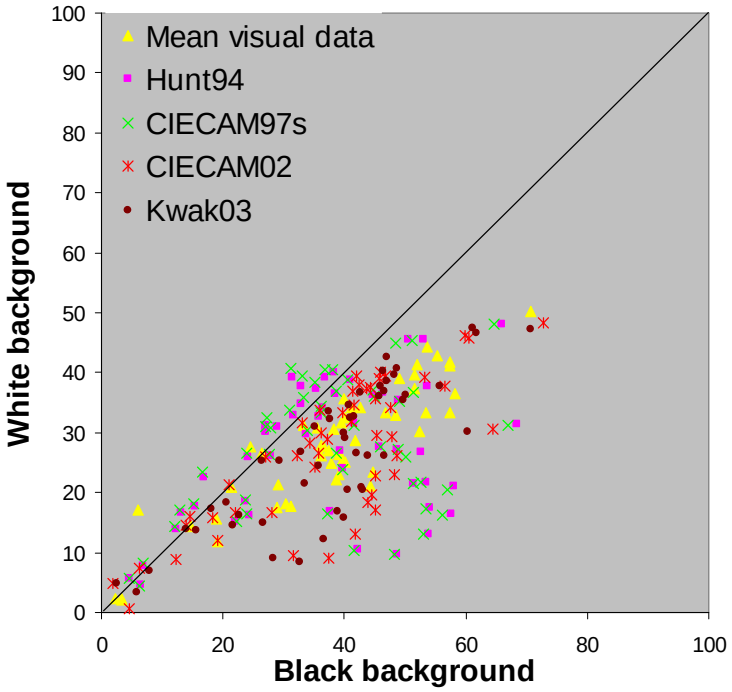
Effect of Background Luminance Factor

- Comparison - model predictions of the effect of background luminance factor with those found in the visual data
- Lightness decreases with increasing background luminance factor

Prediction of lightness change



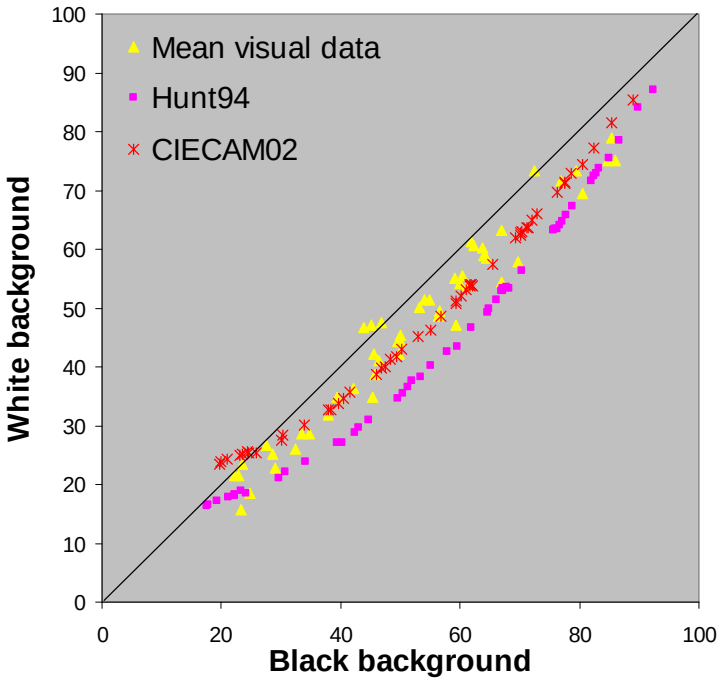
Prediction of colourfulness change



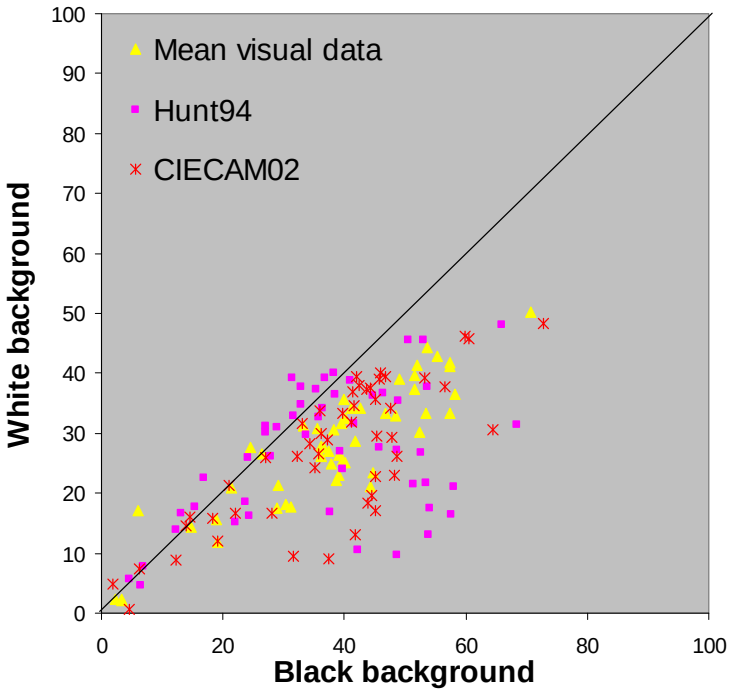
Effect of Background Luminance Factor

- Comparison - model predictions of the effect of background luminance factor with those found in the visual data
- Increase in colourfulness with darker background – with more scatter

Prediction of lightness change



Prediction of colourfulness change



Conclusion

Observer Performance

- Repeatability and accuracy of observers were satisfactory – the data set was found to be reliable
- Difficulty in judging the colour appearance under **high luminance level**
- Longer time to judge **lightness** than to judge colourfulness and hue
- The most consistent attribute - **Hue**

Evaluation of Colour Appearance Models

- Good performances of all models - except CIELAB
- **CIECAM02** has shown the best performance for all the phases, followed by Kwak03
- **Hue** predictors of all models performed the best among all colour attributes
- **Black background phase** – worse performance by all models

Conclusion

Effect of Luminance Level

- Luminance level did not have a strong effect on the visual data
- Dark colours were judged lighter at high luminance than at low luminance
- **Kwak03** model gave the best prediction of the effect of luminance level

Effect of Background Luminance Factor

- Decrease in lightness with increasing background luminance factor
- **CIECAM02** fitted the visual data best
- **Hunt94** and **CIECAM97s**: over-prediction of lightness and colourfulness changes

Future Work

- Modification of present colour appearance model to give better performance under high luminance levels
- The guidelines for applying these models on a real complex image required to be developed
- Issues like image quality, spatial influence on colour appearance need to be included in future models
- The collected data set will be helpful in the future for testing the colour appearance models and to develop more comprehensive new models

Thank you!