Perceived Brightness in Entertainment Lighting Can we quantify it?

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What is Brightness?

LUMINANCE is what is measured by a light meter – it's an objective measurement.

BRIGHTNESS however is a completely subjective attribute of light to which humans assign a label between very dim and very bright.

Brightness is perceived, not measured.

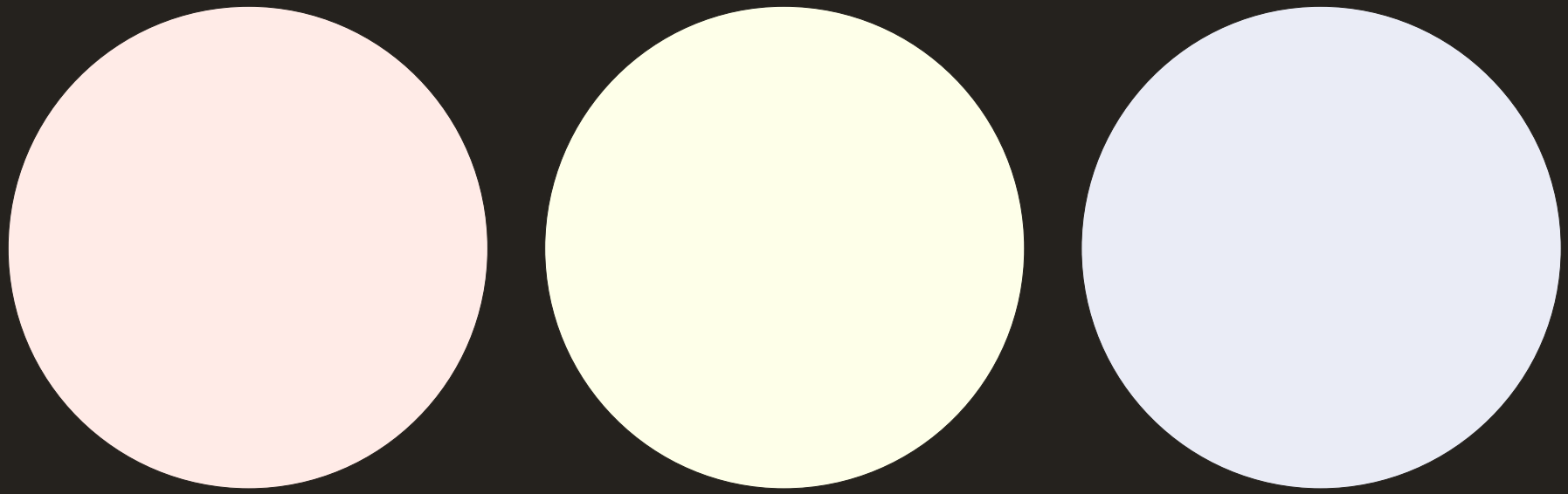
Factors that affect Perceived Brightness

- Color Temperature
- Field Flatness
- ‘Red Ring’
- Relative contrast
- Dazzle or Raw Power
- Time – adaptation of the eye

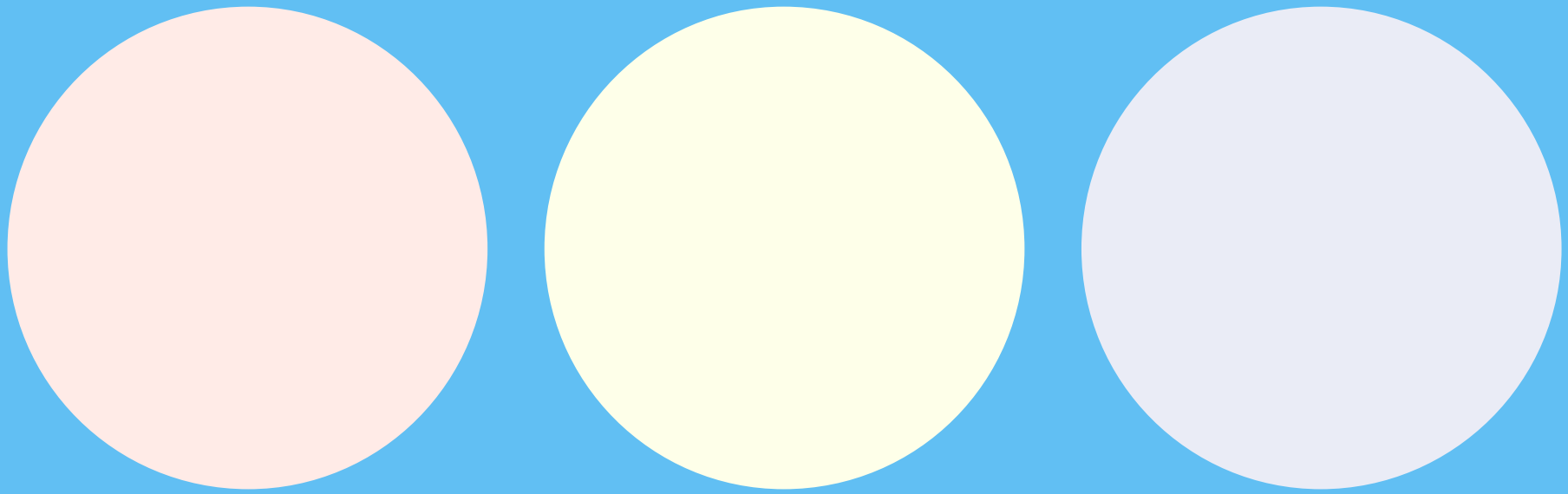
Color Temperature

- Within reasonable limits Blue (cool) light appears brighter than Red (warm)
- Color of the background amplifies the effect

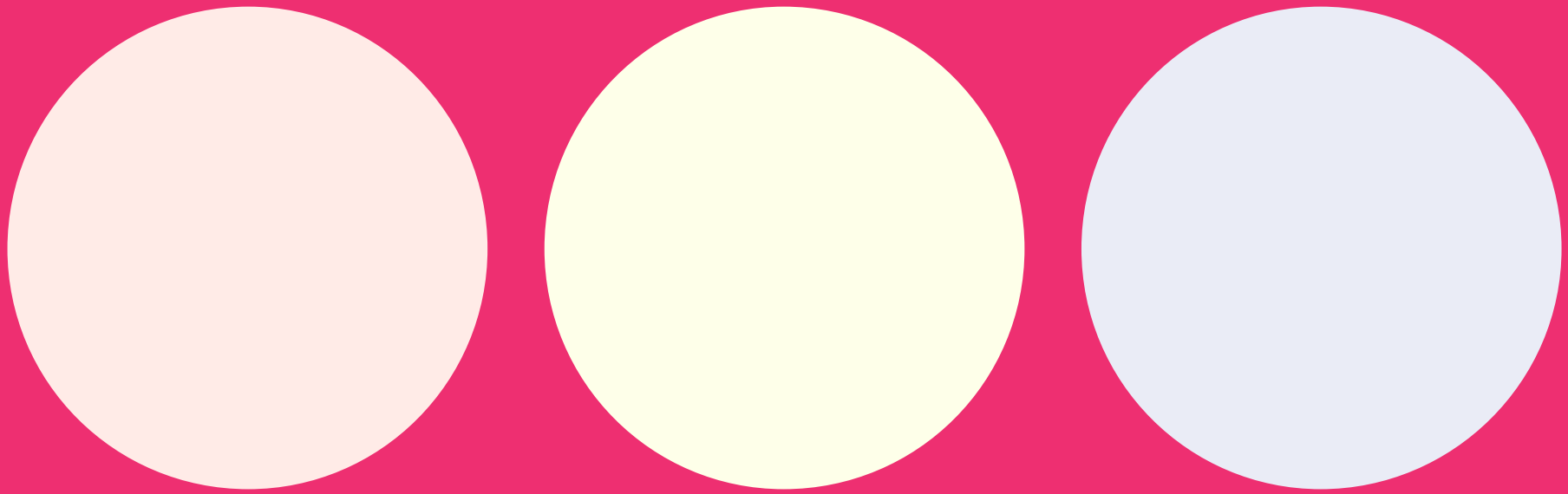
Color Temperature



Color Temperature



Color Temperature



Field Flatness

- A Center Hot Spot may help blending but it doesn't help the brightness
- Again the color of the background amplifies the effect

Field Flatness

Field Flatness

Field Flatness

Red Ring

- A very common combination of the last two – color temperature and flatness

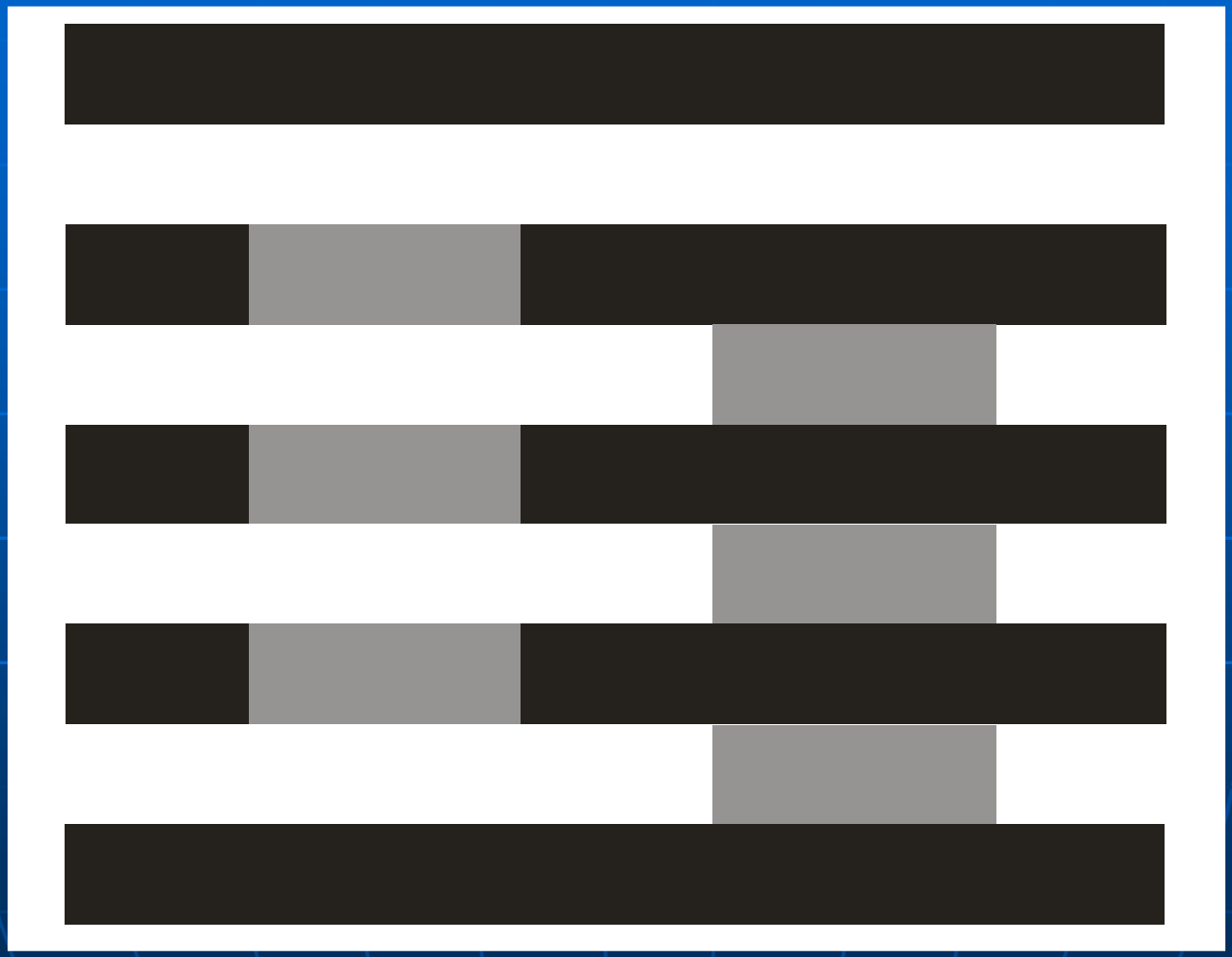
Red Ring

Contrast

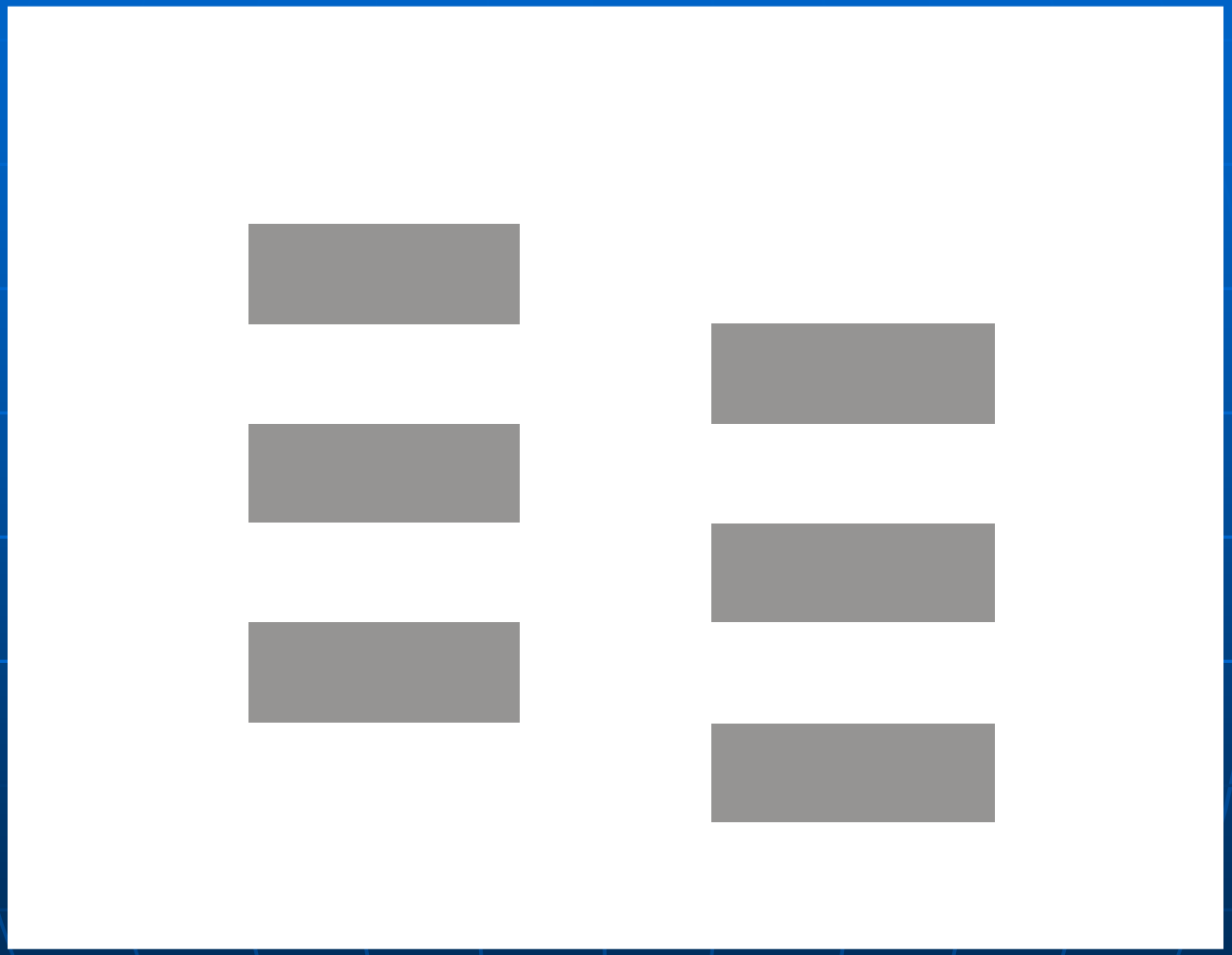
- Area where there is most potential for fooling the eye and brain
- Many illusions use these effects

Contrast

Simultaneous Contrast



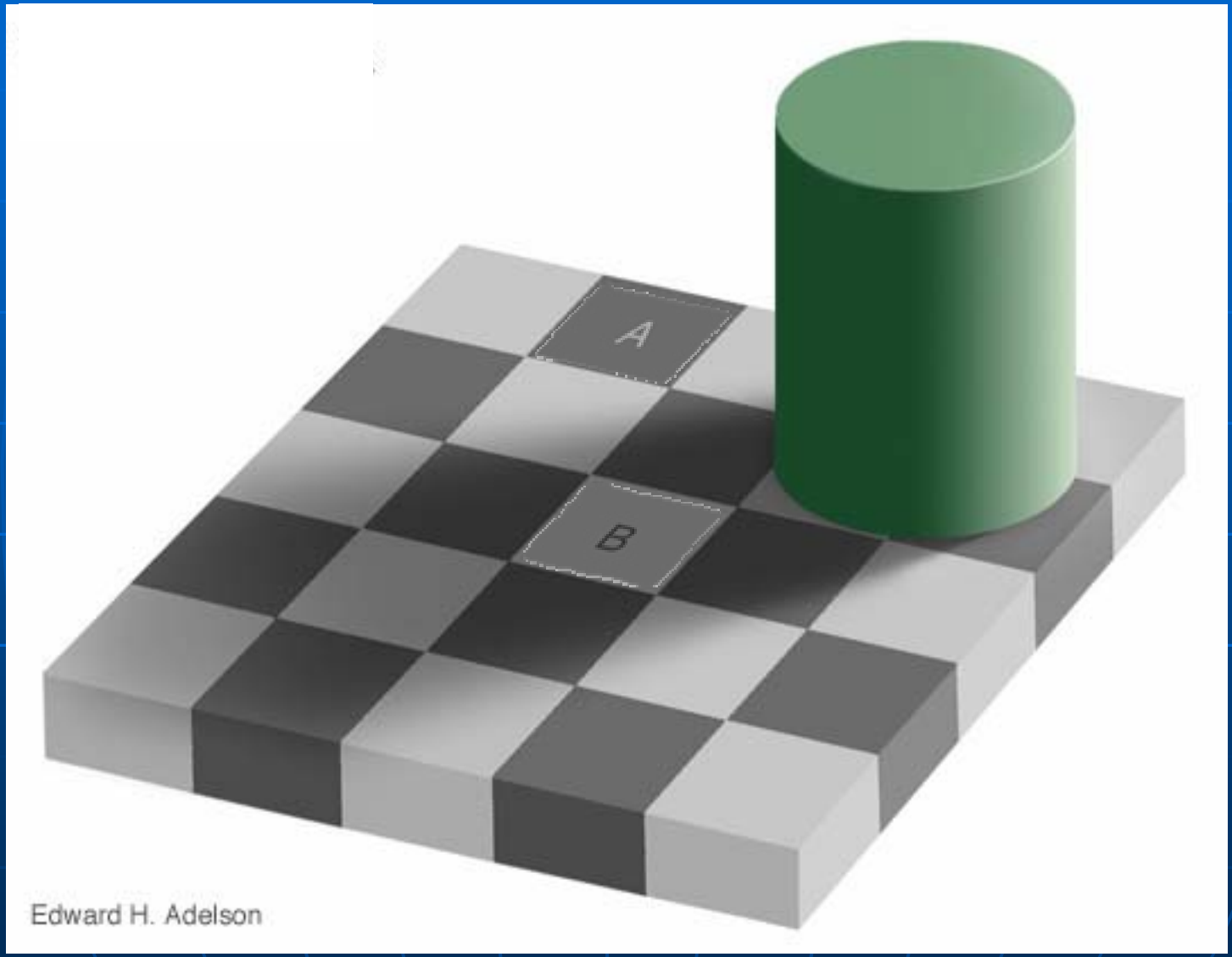
Simultaneous Contrast



Effects of Shadow

- Shadows also affect our perception of contrast
- We are used to shadows in the real world and we ‘know’ that anything in a shadow is really brighter than it appears, so we compensate.
- This happens all the time on stage, but most of the time we are not aware that we are making this unconscious compensation

Shadow and Contrast



Dazzle

- Difficult to demonstrate in a Powerpoint slide
- The higher the luminance the less sensitive the eye becomes
- Overload
- Do colored strobes ever really look anything other than white?

Can we quantify these effects?

- By definition this is a qualitative procedure – attempting to apply empirical values to a perception.
- Would be useful to be able to establish some repeatable quantitative figures to predict what the eye will see.

Simple Formula

- Start by assuming that the perceived brightness can be represented by a simple set of factors applied to the luminance value.
- For simplicity begin with just two variables – Color Temperature and Field Flatness

Simple Formula

$$\text{Brightness} = \text{Lumens} \times (\text{Flatness Ratio})^{\alpha} \times (\text{Color}/5600)^{\beta}$$

Where α and β are power indices derived empirically from observation by multiple observers

Flatness Ratio is the Edge luminance divided by the Center luminance

Color is arbitrarily referred back to 5600K. This value was chosen because the human eye is optimized for daylight. Other values such as 3200K could also be used.

Real Data – Example 1

Fixture	Field Lumens	Edge / Center	Color Temp	Perceived	%
		α = 0.1	β = 1.4		
Studio Spot 250	4159 lm	0.33	8500K	6669	100%
Studio Spot 400sa	8503 lm	0.42	5600K	7804	117%

This matches reality well – the 400W fixture 'looked' 20% brighter than the 250W, not 100% brighter

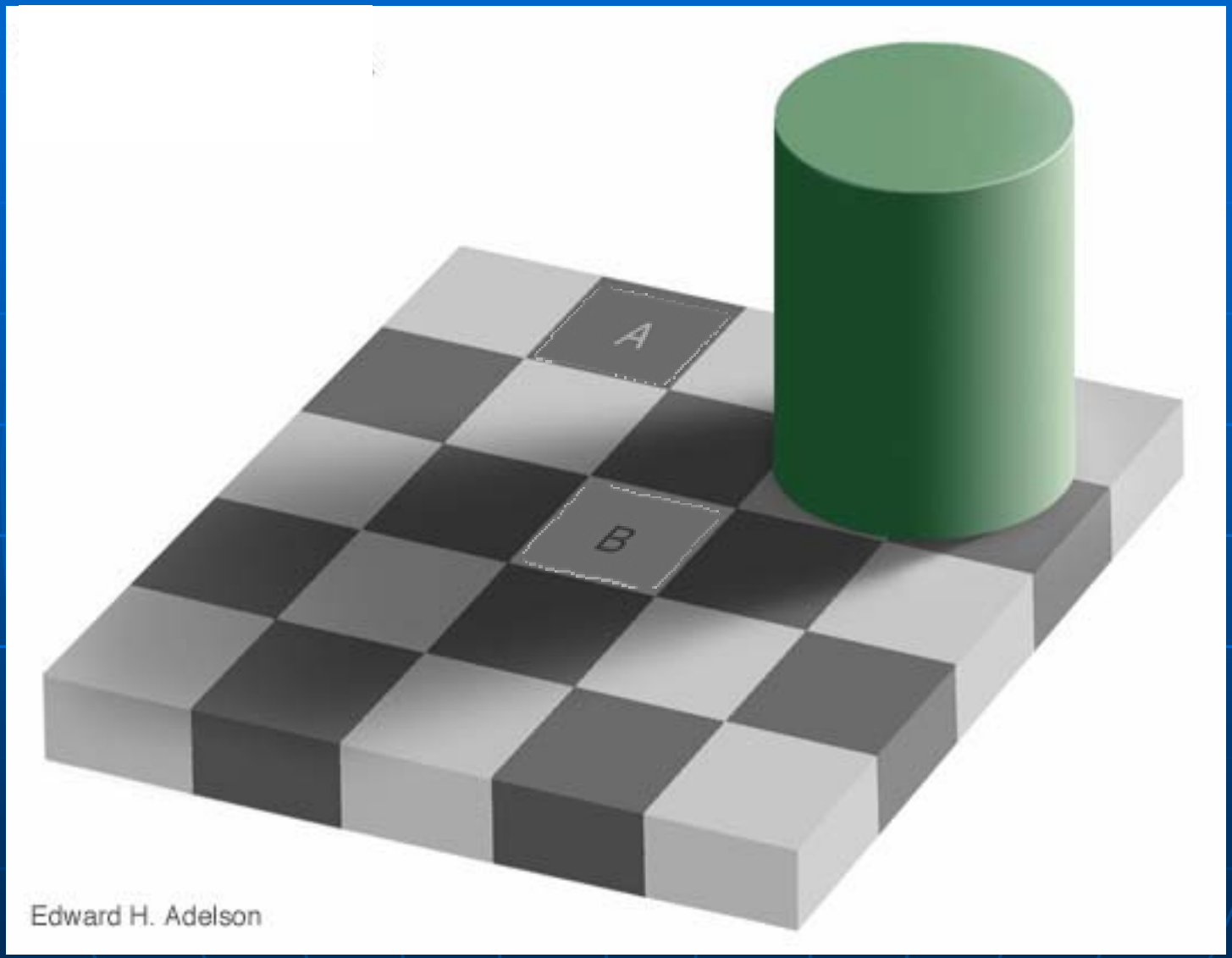
Real Data – Example 2

Fixture	Field Lumens	Edge / Center	Color Temp	Perceived	%
		α = 0.1	β = 1.4		
Studio Spot 575	8165 lm	0.15	5600K	6772	100%
Studio Spot 575 / 2	8165 lm	0.15	7200K	9628	142%

Nothing changes here except Color Temp – prediction of 42% brighter! Again, this matches reality very well.

Where do we go from here?

- To make this data meaningful and repeatable would need a much larger statistical study to check that all observers see the same results.
- If this is done it would be possible to predict how ‘Bright’ a fixture would actually look in practice.
- Caveat – the above simple formula didn’t allow for Contrast or Time effects. Contrast in particular is very significant and would need to be controlled if comparisons are to be useful.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Edward H. Adelson