A color inference approach to interpreting colors in information visualization

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People can extract complex messages from visual features

A storm is coming

Ripe and ready to eat

Cherries are less popular than grapes

Whole milk is in here

These are all forms of **visual reasoning**

Forming conceptual inferences from visual information
But, color inference is complicated...

There is no one-to-one correspondence between colors and entities
(Elliot & Maier, 2012; Humphrey, 1976; Lin et al., 2013; Schloss, et al., submitted; Setlur & Stone, 2016).

One-to-many conflict

Many-to-one conflict

How do people interpret the meanings of colors in visual communication?
Rely on legends and labels to interpret colors?

There is a processing cost if labels do match people’s predictions. (Lin, Fortuna, Kulkarni, Stone, & Heer, 2013; Silverman, Gramazio, & Schloss, VSS-2016; Parker, Silverman, Wang, & Schloss, VSS-2017)

But, what are people’s predictions?
Based on color-entity associations alone? Or, more complex inferences?
Visual reasoning about color

Color inference framework

A functional system of how people make **conceptual inferences** from **color information**…

…which influence the way people **evaluate** and **interpret** the world.

How much do you like this color?
Visual reasoning about color

Color inference framework

A functional system of how people make **conceptual inferences** from **color information**...

...which influence the way people **evaluate** and **interpret** the world.

Which bin is for paper? For trash?

0
1
Color inference framework

Input

- Color-entity associations
- Contextual cues

Functions

- Color inference processes

Output

- Judgments about the world

Association strength between colors and entities, stored in the mind. Continually updated by experiences.

Perceptual color space

Color-association spaces

- BANANA
- OCEAN
- TROPICAL BIRD
Color inference framework

Input
- Color-entity associations
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Association strength between colors and entities, stored in the mind. Continually updated by experiences.

Color-association network in the mind
Color inference framework

Input
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Association strength between colors and entities, stored in the mind. Continually updated by experiences.

Color-association network in the mind
Color inference framework

Association strength between colors and entities, stored in the mind. Continually updated by experiences.
Color inference framework

**Input**
- Color-entity associations
- Contextual cues

**Functions**
- color inference processes

**Output**
- Judgments about the world

**Perceptual context**
- Colors, shapes, textures, sounds, odors
- 

**Conceptual context**
- Concepts depicted in the design (*paper, trash, glass*)
- Concepts activated in the mind for other reasons
Color inference framework

Input
- Color-entity associations
- Contextual cues

Functions
- color inference processes

Output
- Judgments about the world

Evaluations
- How much do you like this color?

Interpretations
- Which bin for paper?
- For trash?
1. **Pooling**: inferences about colors
1. Pooling: inferences about colors

Color inference framework

Input
Color-entity associations
Contextual cues

Functions
color inference processes

Output
Judgments about the world

Ecological Valence Theory
Color inference framework

1. Pooling

2. Transmitting: inferences about entities
Color inference framework

Input
Color-entity associations
Contextual cues

Functions
color inference processes

Output
Judgments about the world

3. Assigning: inferences about color-entities mappings

1. Pooling

2. Transmitting
Color inference framework

Input
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Contextual cues

Functions
color inference processes

Output
Judgments about the world

Pooling

Transmitting

Assigning

Evaluations
Interpretations
Color inference framework

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- color inference processes

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- Judgments about the world

Pooling

Transmitting

Assigning

Evaluations

Interpretations
Color-coding in recycling

Do people make inferences about which colored bins code for which entities?

If so, how do they make those inferences?

Schloss, Lessard, Walmsley, & Foley (under review)
Assessing color inference in a recycling task

All pairwise combinations
(Colors selected from pilot study)

Schloss, Lessard, Walmsley, & Foley (under review)
Hypotheses

Isolated association hypothesis:
Choose the color that is most strongly associated with paper or trash

Assignment hypothesis:
Choose the color that maximizes associations strength across all color-entity pairs, even if it means assigning colors to weak associates

Analogous to assignment problems in optimization

Schloss, Lessard, Walmsley, & Foley (under review)
Results support assignment hypothesis

Both hypotheses make same prediction

Schloss, Lessard, Walmsley, & Foley (under review)
Results support assignment hypothesis

Supports assignment hypothesis

Assignment hypothesis

Isolated association hypothesis

Target strong

Target weak

Supports assignment hypothesis

Assignment hypothesis

Isolated association hypothesis
Results support assignment hypothesis
Results support assignment hypothesis

People make inferences about mappings between colors that are analogous to solving an assignment problem.

Interpretations of colors change from moment to moment depending on contextual colors.
Summary and conclusion

**Color inference framework**
People make conceptual inferences from color information, which influence the way people evaluate and interpret the world.

Multiple inference processes operate on the same color-association network.

Anticipating people’s color inferences will make visual communication more effective, efficient, and enjoyable.
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