Implicit Shape-Color Associations in Synesthesia

David Brang
Northwestern University
david.brang@northwestern.edu
Stimulation of one sense causes activation in a second modality

Can theoretically bind any two senses

- Grapheme-Color Synesthesia
- Sound-Color Synesthesia
- Time-Space Synesthesia
Phenomenology

- Involuntary, automatic, laden with affect
- Approximately 4% of the population
- Thought to be genetic

Brang and Ramachandran (2011) *PLoS Biology*
Cross-Activation Theory

Ramachandran & Hubbard (2001)

Increased anatomical connections link neighboring regions in synesthetes
Cross-Activation Theory

FMRI and PET studies show co-activation of grapheme and color regions.

Cross-Activation Theory

Diffusion tensor imaging (DTI) studies show increased connectivity in the fusiform gyrus.

Ramachandran & Hubbard (2001)

Rouw & Scholte (2007)
Grapheme-Color Synesthesia

- Consistent
- Idiosyncratic
- What rules (if any) dictate these associations?
- Do pre-linguistic children experience synesthesia?

Brang and Ramachandran (2011) *PLoS Biology*
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

- Semantic and linguistic commonalities (Simner et al., 2005)
- Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
- Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Experience in Synesthesia

• Semantic and linguistic commonalities (Simner et al., 2005)
• Higher frequency letters and numbers pair with brighter colors (Beeli et al., 2007; Smilek et al., 2007)
• Small role of memory imprinting from childhood (Witthoft & Winawer, 2013)
Role of Grapheme Shape in Synesthesia

- Similarly shaped letters evoke similar colors in synesthesia.
- 52 grapheme-color synesthetes.
- Within-subject comparison of color similarity and letter similarity.
- Shape-color bias is independent of experience-based determinants (Watson et al., 2012).

Brang et al., (2011) Neuropsychologia
• What do synesthetes experience before they can read?
• Do adult synesthetes experience latent shape-color associations?
Early Activation of V4 in Synesthesia

Activation of color areas in synesthesia early in the grapheme-processing hierarchy as seen with MEG

Ramachandran & Hubbard (2001)

Brang et al., (2010)
• Most synesthetes do not experience conscious shape-color associations
• Synesthetic colors will emerge over time
• Novel grapheme-color associations based on shape-similarity (Jürgens & Nikolić, 2012)
Training Novel Synesthetic Associations

• Enforce grapheme-color associations for shapes that do not elicit conscious colors

• Any implicit shape-color associations present in a synesthete should interfere with learning novel pairings

Brang et al., (2013) Frontiers in Human Neuroscience
Training Novel Synesthetic Associations

- 15 grapheme-color synesthetes and 15 controls
- 6 shapes chosen from 12 possible
- No familiarity with symbols or synesthetic colors

Brang et al., (2013) *Frontiers in Human Neuroscience*
Training Novel Synesthetic Associations

Performance throughout Training

Brang et al., (2013) Frontiers in Human Neuroscience
Training Novel Synesthetic Associations

Performance throughout Training

Accuracy after Achieving Criterion

Brang et al., (2013) *Frontiers in Human Neuroscience*
Discussion

• Experiential factors influence synesthetic associations
  – Color names
  – More common letters are brighter colors
• The shape of the letter biases its color
  – Similarly shaped letters are similar colors
  – Synesthetes take longer to learn novel grapheme-color associations and make more residual errors
• Shape-color associations may predate grapheme-color associations during development through the linking of form and color regions in the temporal lobe
Acknowledgements

**Northwestern**  
Satoru Suzuki, Marcia Grabowecky

**UC San Diego**  
VS Ramachandran, Seana Coulson, Michael Ghiam

**U Amsterdam**  
Romke Rouw

NINDS 2T32NS047987, R01 EY021184

Thank you. Questions?  
david.brang@northwestern.edu
Timing of Activity in Synesthetes

Brang, Hubbard, Coulson, Huang, Ramachandran (2010) *NeuroImage*
Cross-Activation Theory

FMRI and PET studies show co-activation of grapheme and color regions

Hubbard et al. (2005)

Rouw & Scholte (2007)

Increased connectivity in the fusiform gyrus
Grapheme ROI

Brang, Hubbard, Coulson, Huang, Ramachandran (2010) *NeuroImage*
V4 ROI

Grapheme task

Brang, Hubbard, Coulson, Huang, Ramachandran (2010) *NeuroImage*
Training Novel Synesthetic Associations

Brang et al., (2013) *Frontiers in Human Neuroscience*
Predicting Latent Associations: EA

| ← ㅂ → u   ← ㅃ → u   | 4 errors |
| ← ㅗ → m   ← apia → m   | 4 errors |
| ← ㅏ → n   ← apia → n   | 4 errors |
| ← ㅐ → 5   ← apia → 5   | 8 errors |
| ← ㅔ → g   ← apia → g   | 9 errors |
| ← ㅚ → w   ← apia → w   | 5 errors |

Brang et al., (2013) *Frontiers in Human Neuroscience*

\[ r = .96 \]
Predicting Latent Associations: KE

Brang et al., (2013) *Frontiers in Human Neuroscience*

![Diagram showing correlations and error counts between characters and their respective mappings]

\[ r = .34 \]
### Predicting Latent Associations: KL

<table>
<thead>
<tr>
<th>Symbol 1</th>
<th>Symbol 2</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>14 errors</td>
</tr>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>15 errors</td>
</tr>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>7 errors</td>
</tr>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>10 errors</td>
</tr>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>5 errors</td>
</tr>
<tr>
<td>ㅏ ㅏ ㅏ ㅏ ㅏ</td>
<td>ㅗ ㅗ ㅗ ㅗ ㅗ</td>
<td>10 errors</td>
</tr>
</tbody>
</table>

$r = .43$

---

Brang et al., (2013) *Frontiers in Human Neuroscience*
Study 4 Summary

- Similar shapes elicit similar colors in synesthesia, particularly in projectors
- Other factors important for the generation of a particular grapheme-color association
- Training novel symbol-color associations supports the notion that synesthesia is active during the form processing stage of perception
- Important to understanding how synesthesia arises through development
• Novel grapheme-color associations also follow shape similarity conventions
• Notion of shape similarity is critical since may give a developmental account of synesthetic associations
  – Before a synesthete knows what an A or a B is, do they have any synesthetic associations?
  – One possibility is that pre-linguistic synesthetes experience shape-color associations
  – Wagner and Dobkins have shown X month old infants but not Y month old infants show reliable shape-color associations
  – And as we know that synesthetic concurrents change with experience, it is plausible that shape-color associations are refined into letter-color associations
• We wanted to show causal influence of shape-similarity on learning new color associations with complex shapes that did not evoke conscious synesthetic concurrents
• Training study
• Then put in framework of cross-activation theory and Cascaded Cross-tuning Model

Brang et al., XX (XXXX)