

Implicit Shape-Color Associations in Synesthesia

David Brang
Northwestern University
david.brang@northwestern.edu

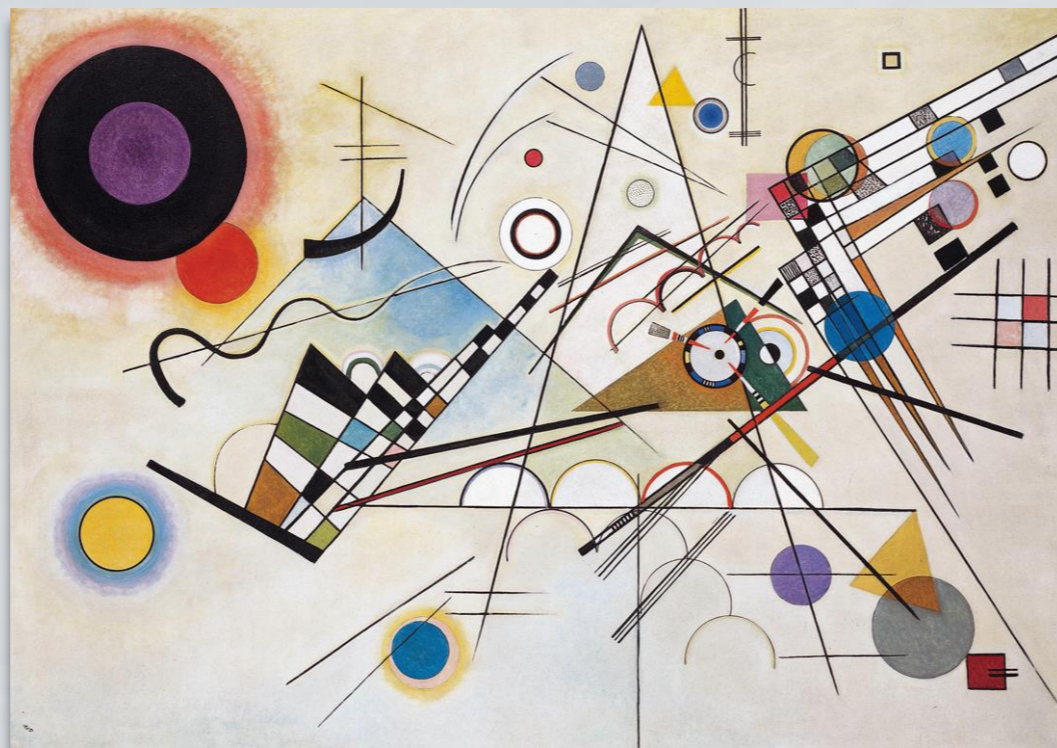
Synesthesia

- Stimulation of one sense causes activation in a second modality
- Can theoretically bind any two senses

Grapheme-Color
Synesthesia



Sound-Color
Synesthesia

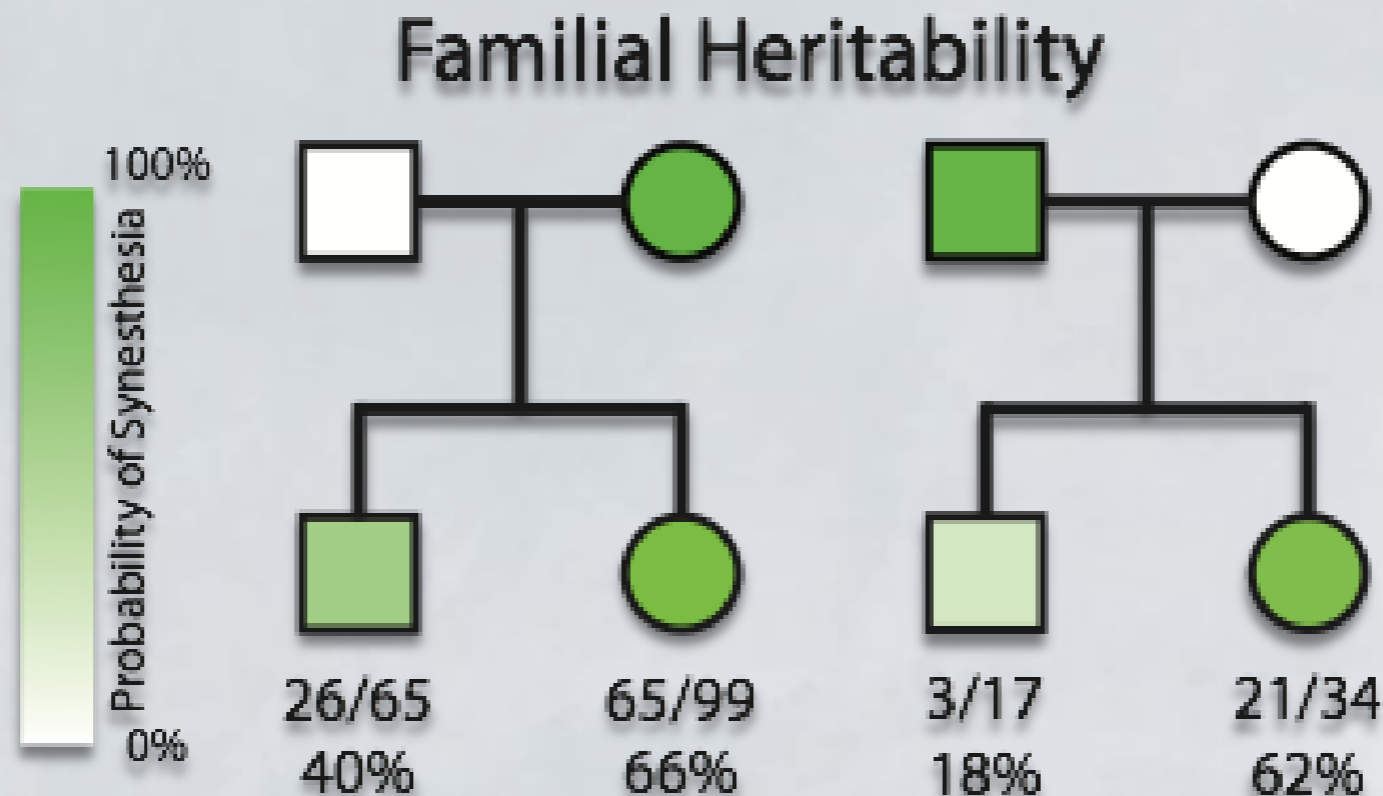


Time-Space
Synesthesia



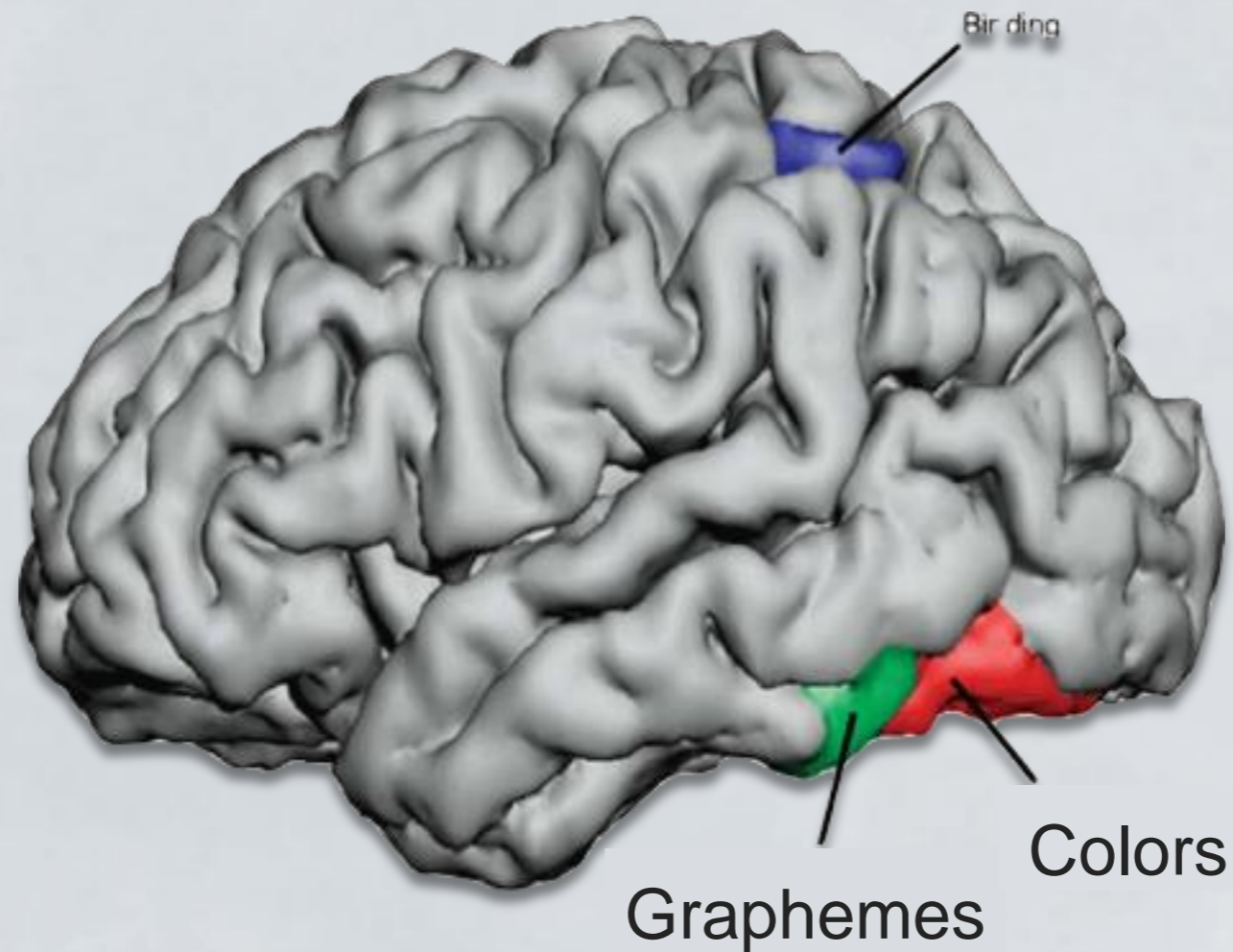
Phenomenology

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



Brang and Ramachandran (2011) *PLoS Biology*

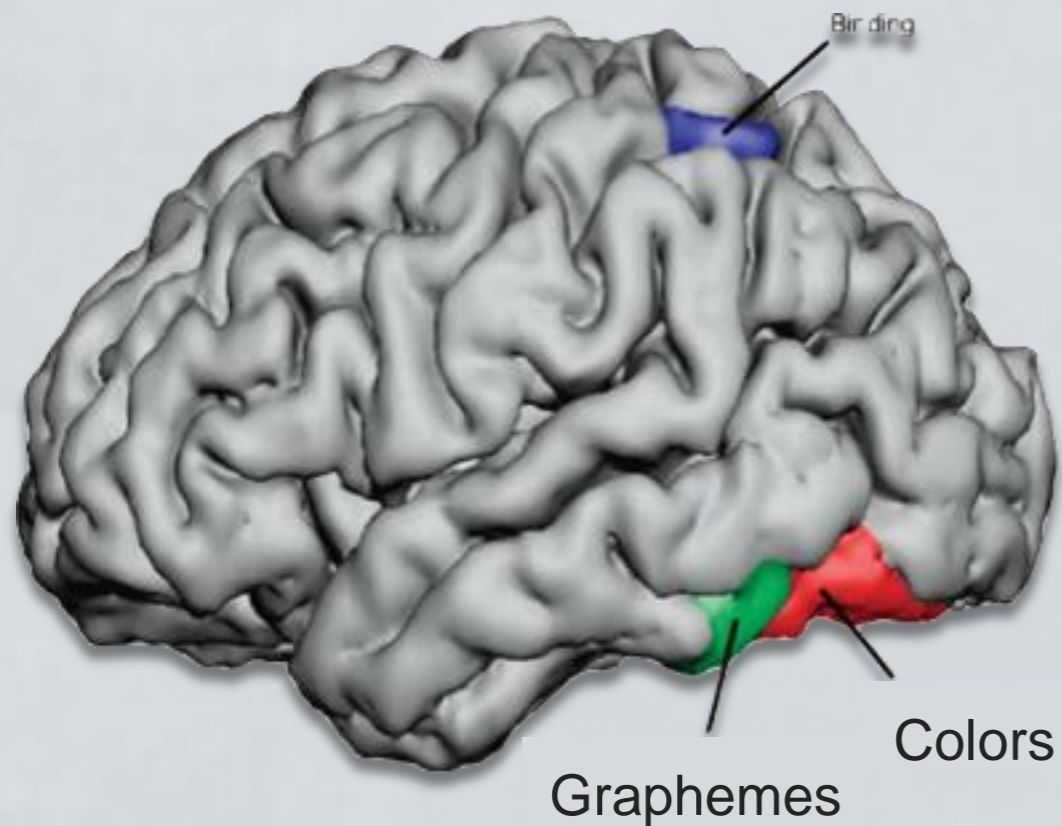
Cross-Activation Theory



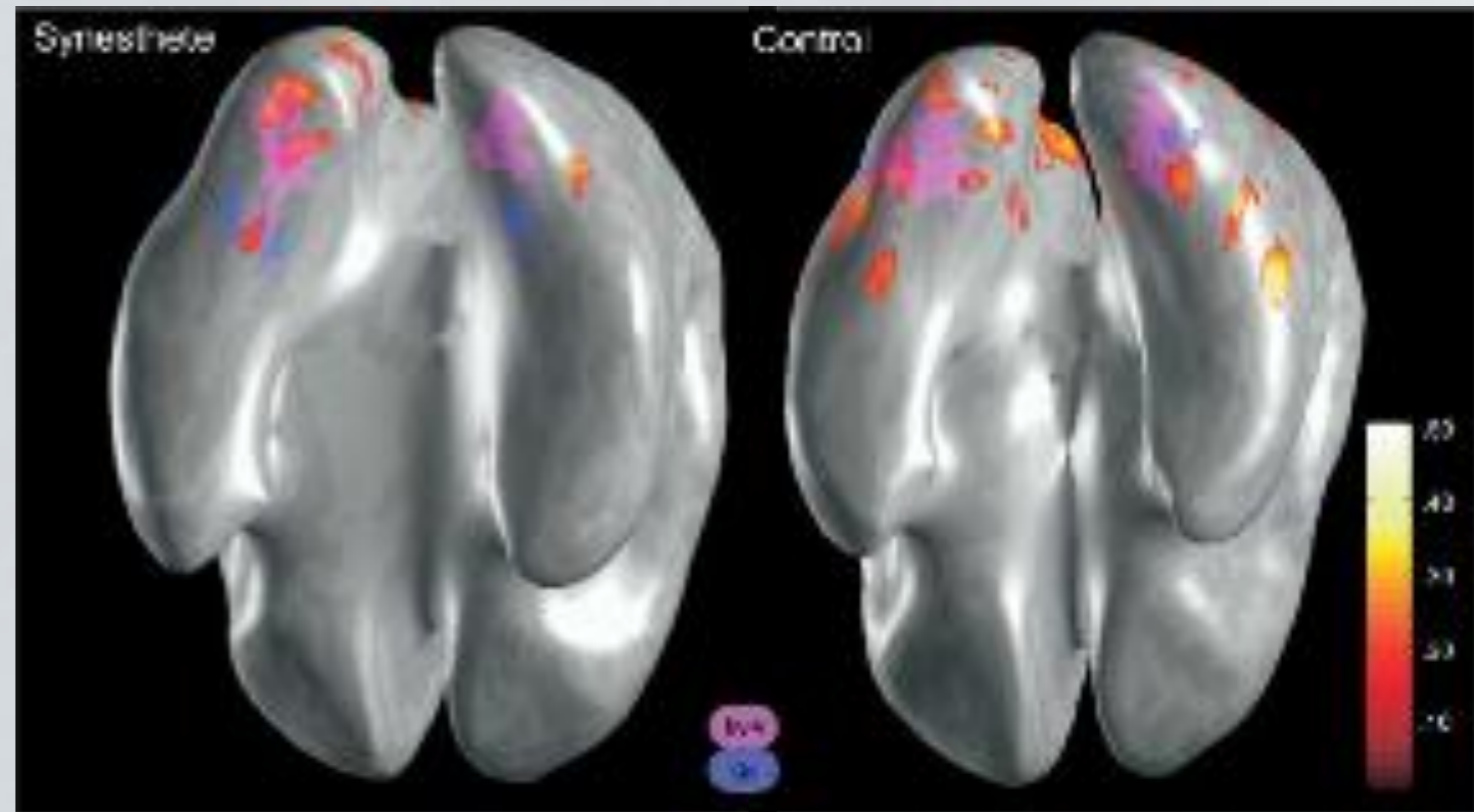
Ramachandran & Hubbard (2001)

Increased anatomical connections link neighboring regions in synesthetes

Cross-Activation Theory



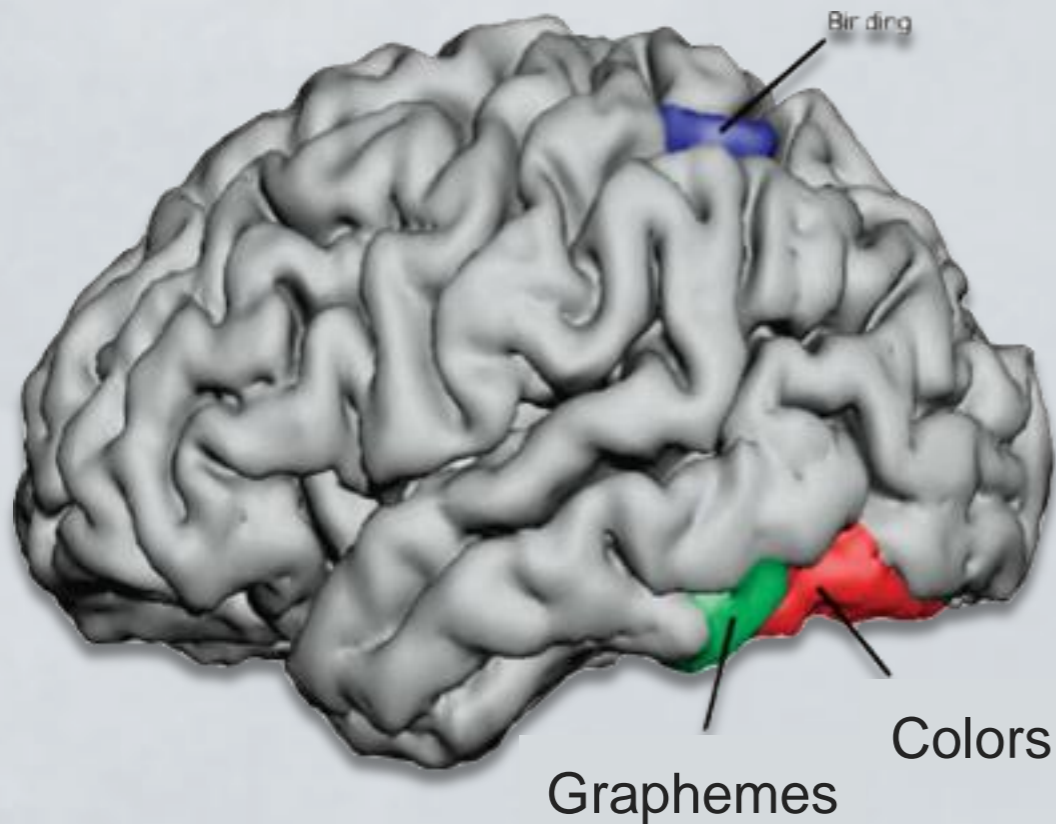
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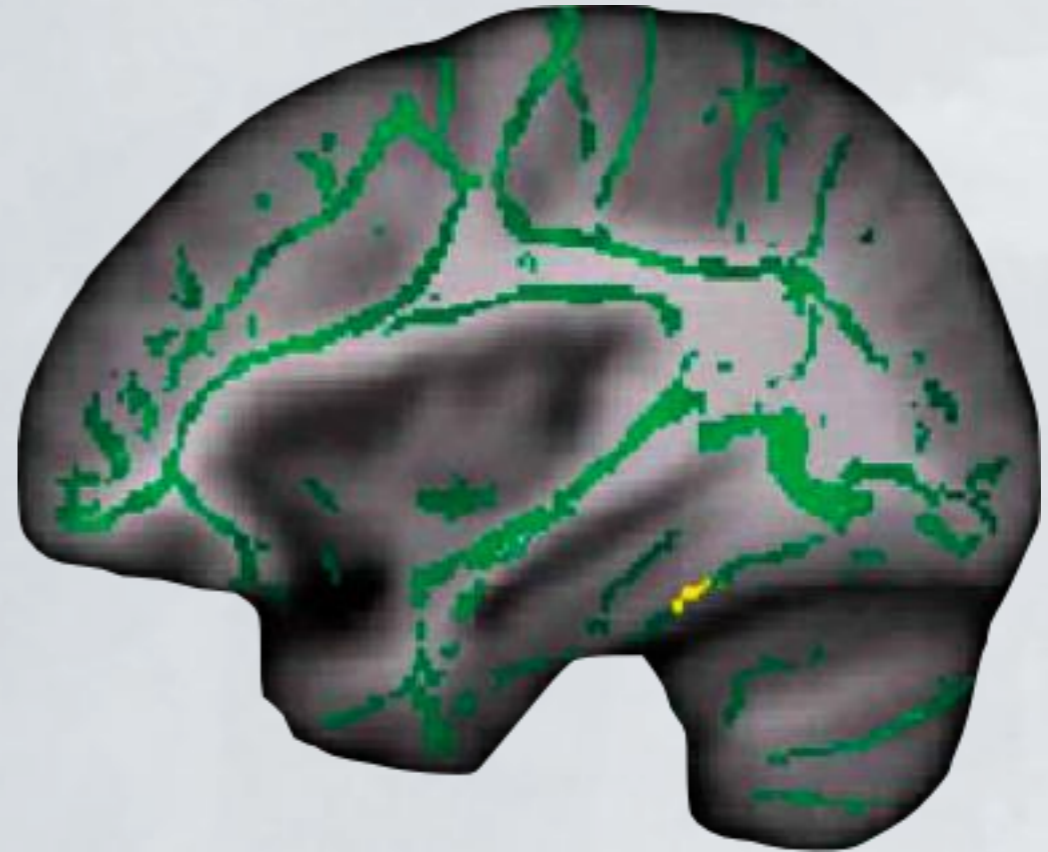
Hubbard et al. (2005)

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

Cross-Activation Theory



Ramachandran & Hubbard (2001)

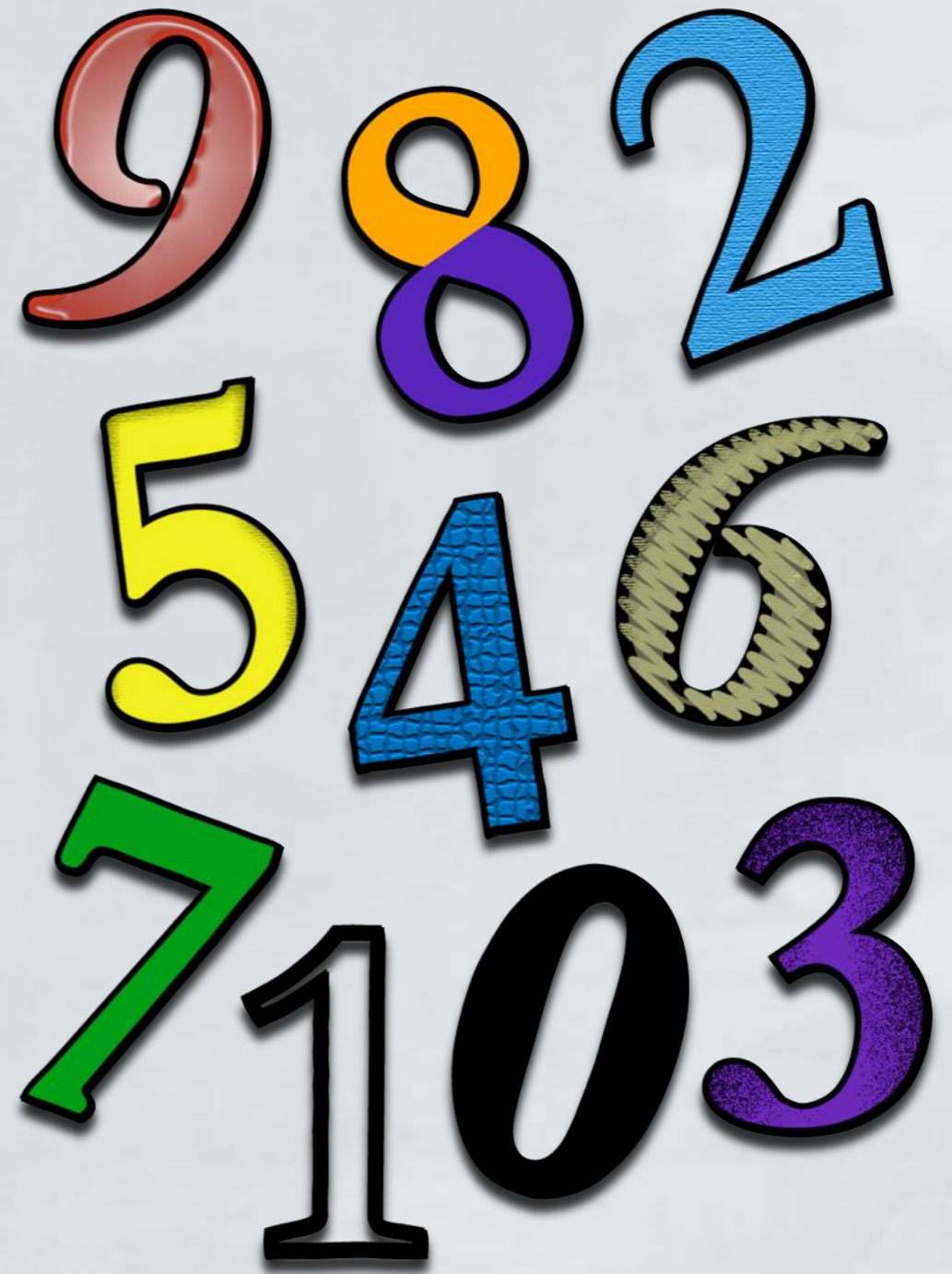


Rouw & Scholte (2007)

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

Grapheme-Color Synesthesia

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



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)

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P
Q	R	S	T
U	V	W	X
Y	Z		

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set	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
A	A	A	A	A	A	A	A	A	A	A	A
B	B	B	B	B	B	B	B	B	B	B	B
C	C	C	C	C	C	C	C	C	C	C	C
D	D	D	D	D	D	D	D	D	D	D	D
E	E	E	E	E	E	E	E	E	E	E	E
F	F	F	F	F	F	F	F	F	F	F	F
G	G	G	G	G	G	G	G	G	G	G	G
H	H	H	H	H	H	H	H	H	H	H	H
I	I	I	I	I	I	I	I	I	I	I	I
J	J	J	J	J	J	J	J	J	J	J	J
K	K	K	K	K	K	K	K	K	K	K	K
L	L	L	L	L	L	L	L	L	L	L	L
M	M	M	M	M	M	M	M	M	M	M	M
N	N	N	N	N	N	N	N	N	N	N	N
O	O	O	O	O	O	O	O	O	O	O	O
P	P	P	P	P	P	P	P	P	P	P	P
Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
R	R	R	R	R	R	R	R	R	R	R	R
S	S	S	S	S	S	S	S	S	S	S	S
T	T	T	T	T	T	T	T	T	T	T	T
U	U	U	U	U	U	U	U	U	U	U	U
V	V	V	V	V	V	V	V	V	V	V	V
W	W	W	W	W	W	W	W	W	W	W	W
X	X	X	X	X	X	X	X	X	X	X	X
Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z



Role of Grapheme Shape in Synesthesia

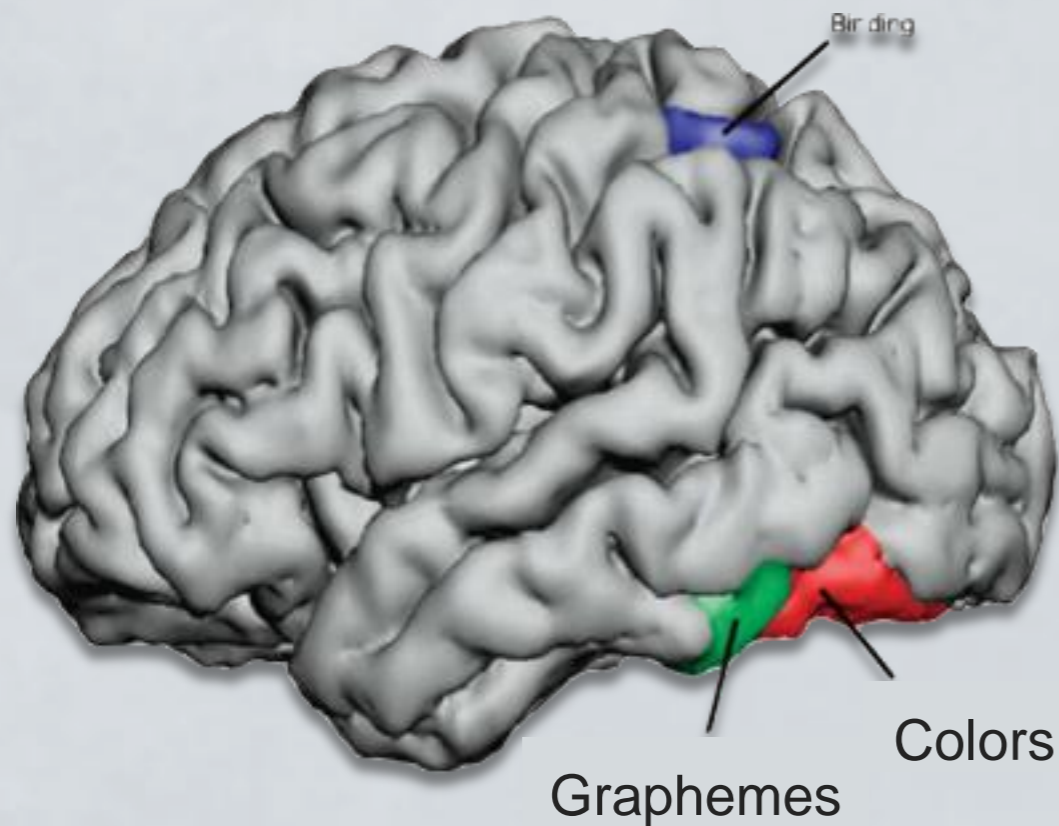
- Similarly shaped letters evoke similar colors in synesthesia
- 52 grapheme-color synesthetes
- Within-subject comparison of color similarity and letter similarity
- Shape-color bias is independent of experience-based determinants (Watson et al., 2012)

3	E	F
3	E	F
3	E	F
3	E	F
B	P	8
B	P	8
B	P	8
B	P	8
M	N	W
M	N	W
M	N	W
M	N	W

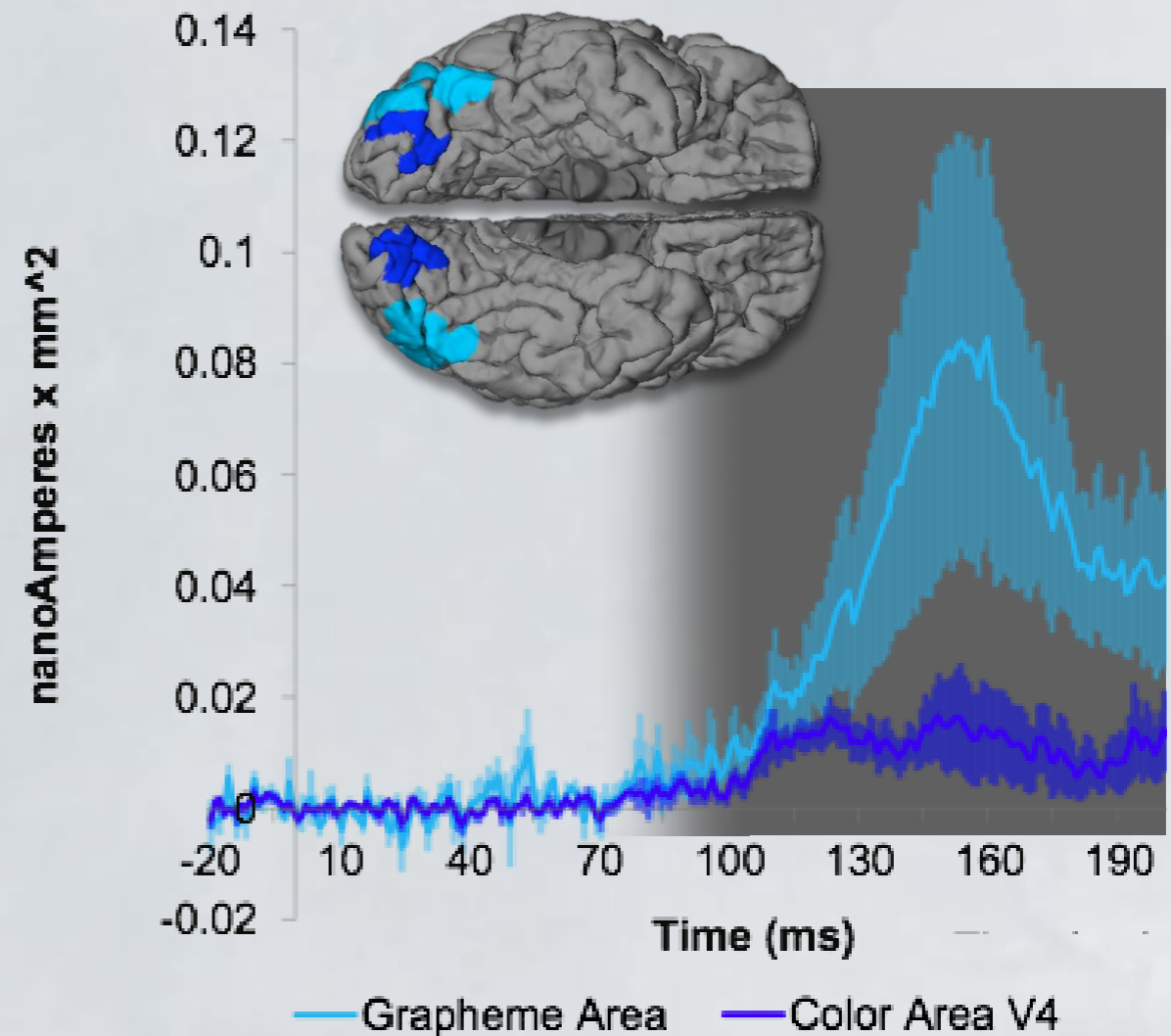
Role of Grapheme Shape in Synesthesia

- What do synesthetes experience before they can read?
- Do adult synesthetes experience latent shape-color associations?

Early Activation of V4 in Synesthesia



Ramachandran & Hubbard (2001)

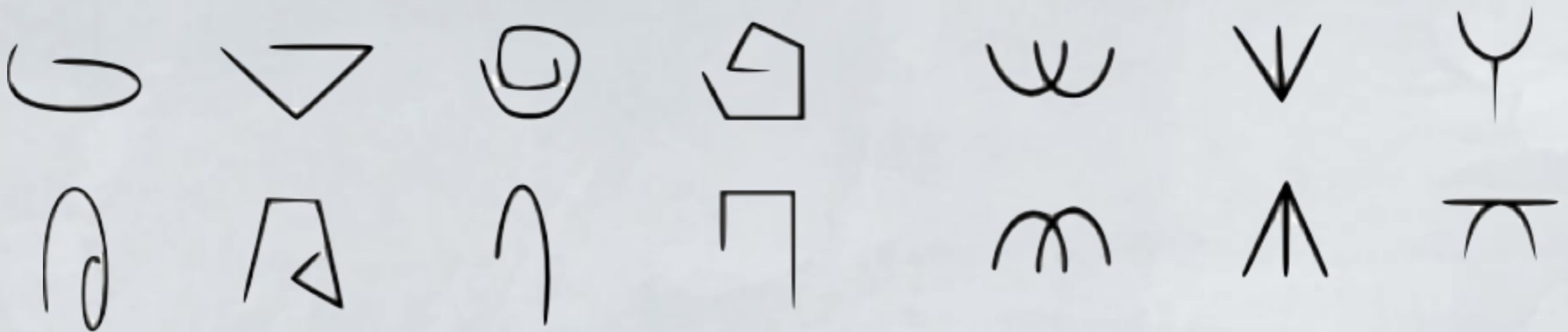


Brang et al., (2010)

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

Role of Grapheme Shape in Synesthesia

- 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

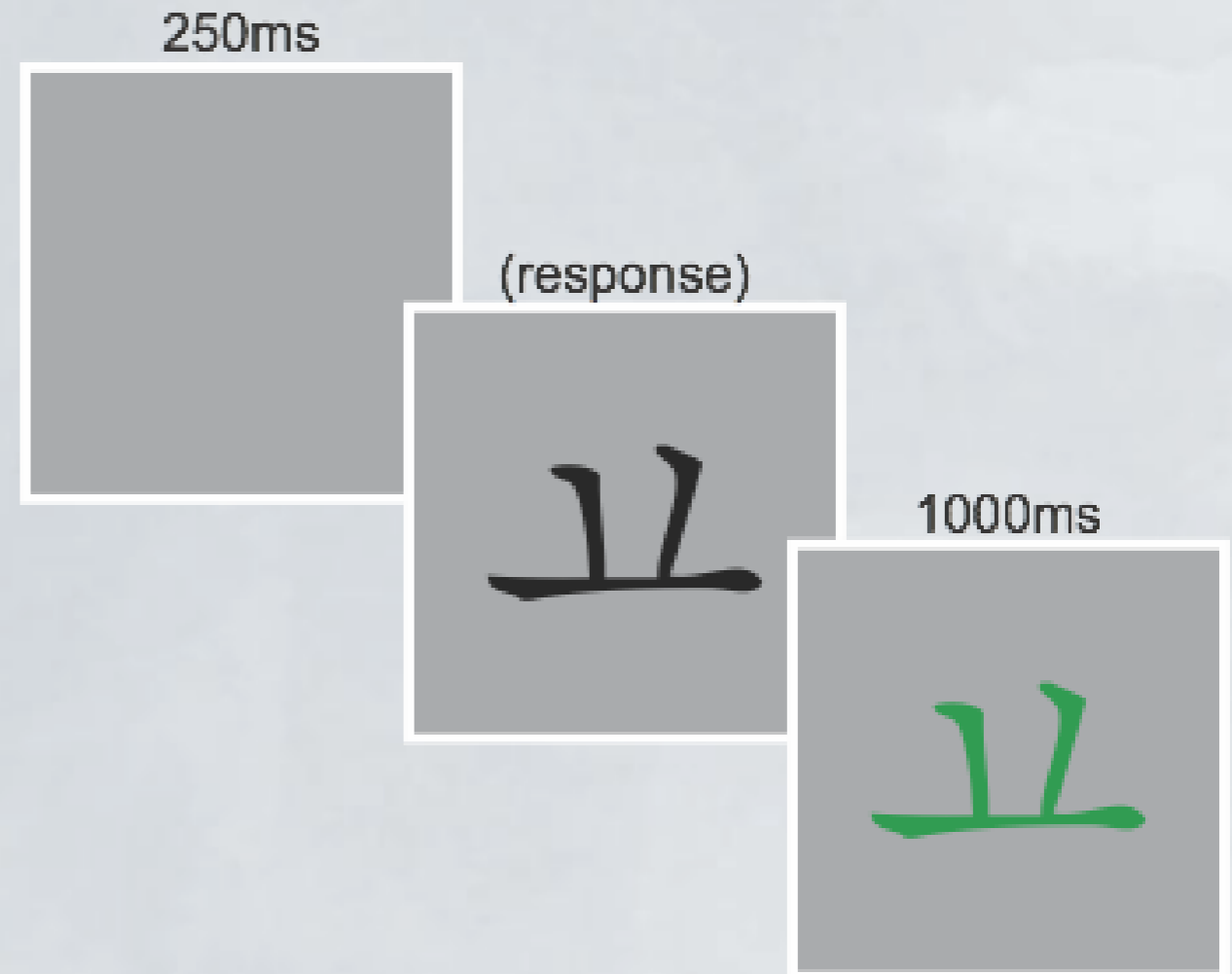
- Enforce grapheme-color associations for shapes that do not elicit conscious colors

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

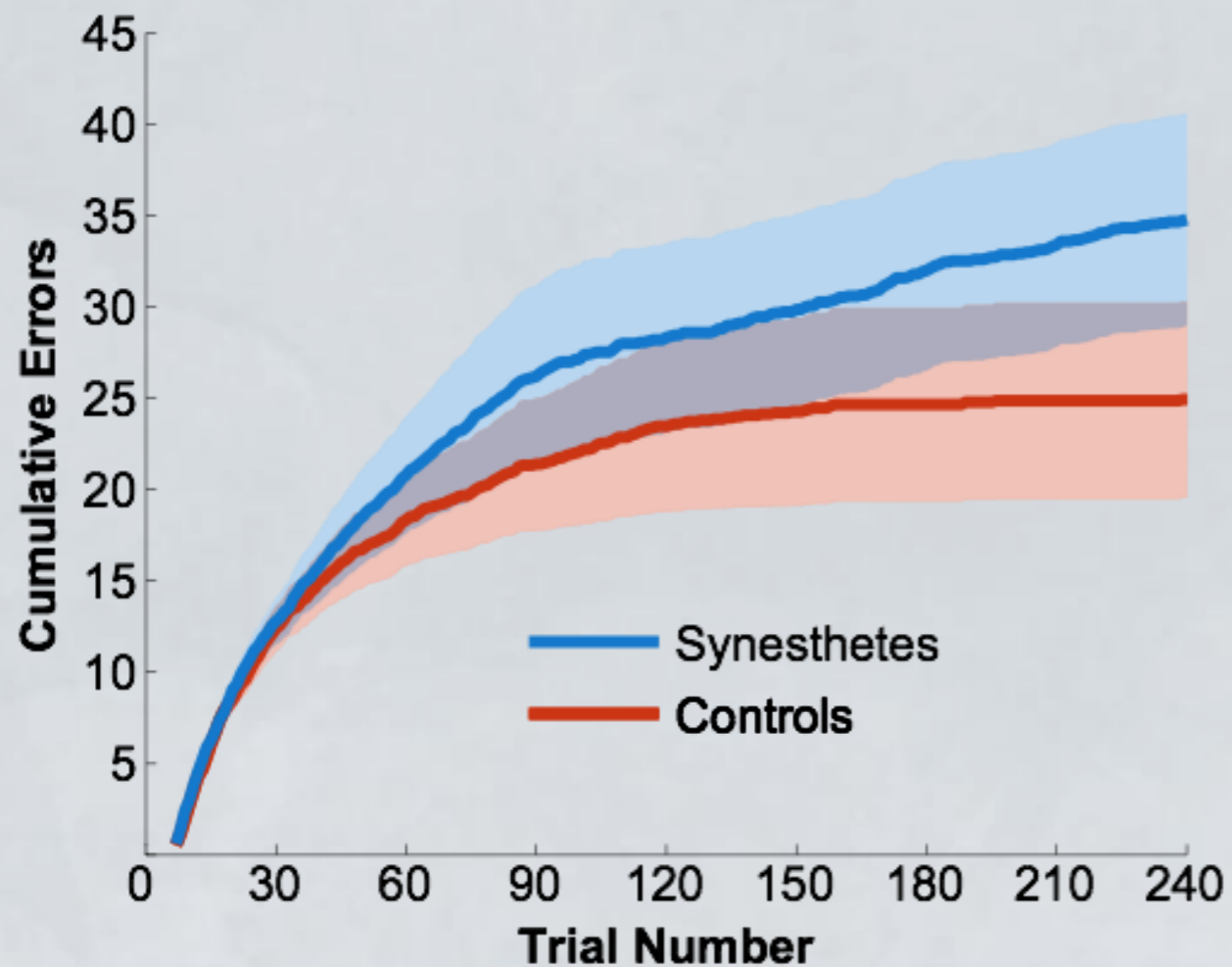
Training Novel Synesthetic Associations

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



Training Novel Synesthetic Associations

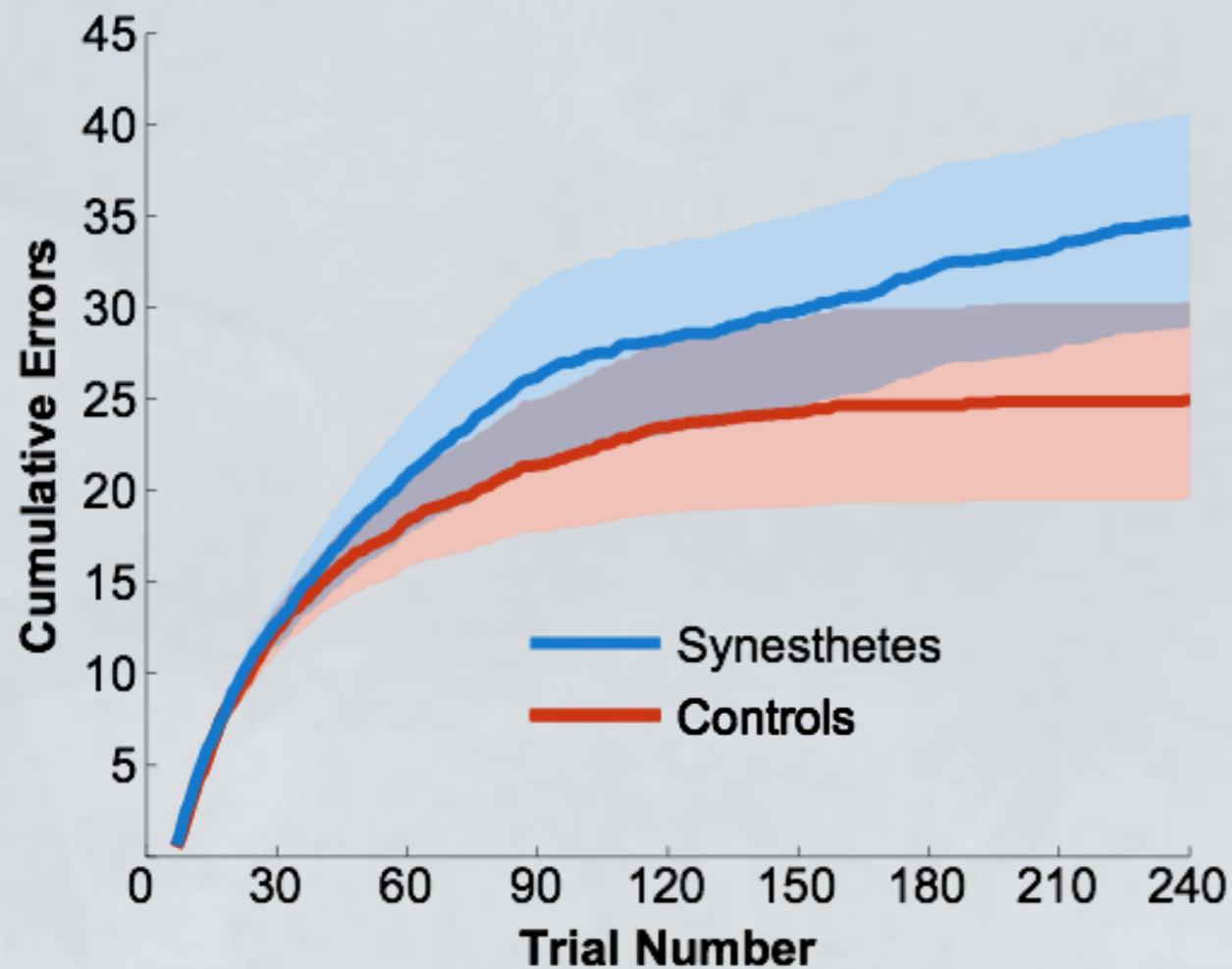
Performance throughout Training



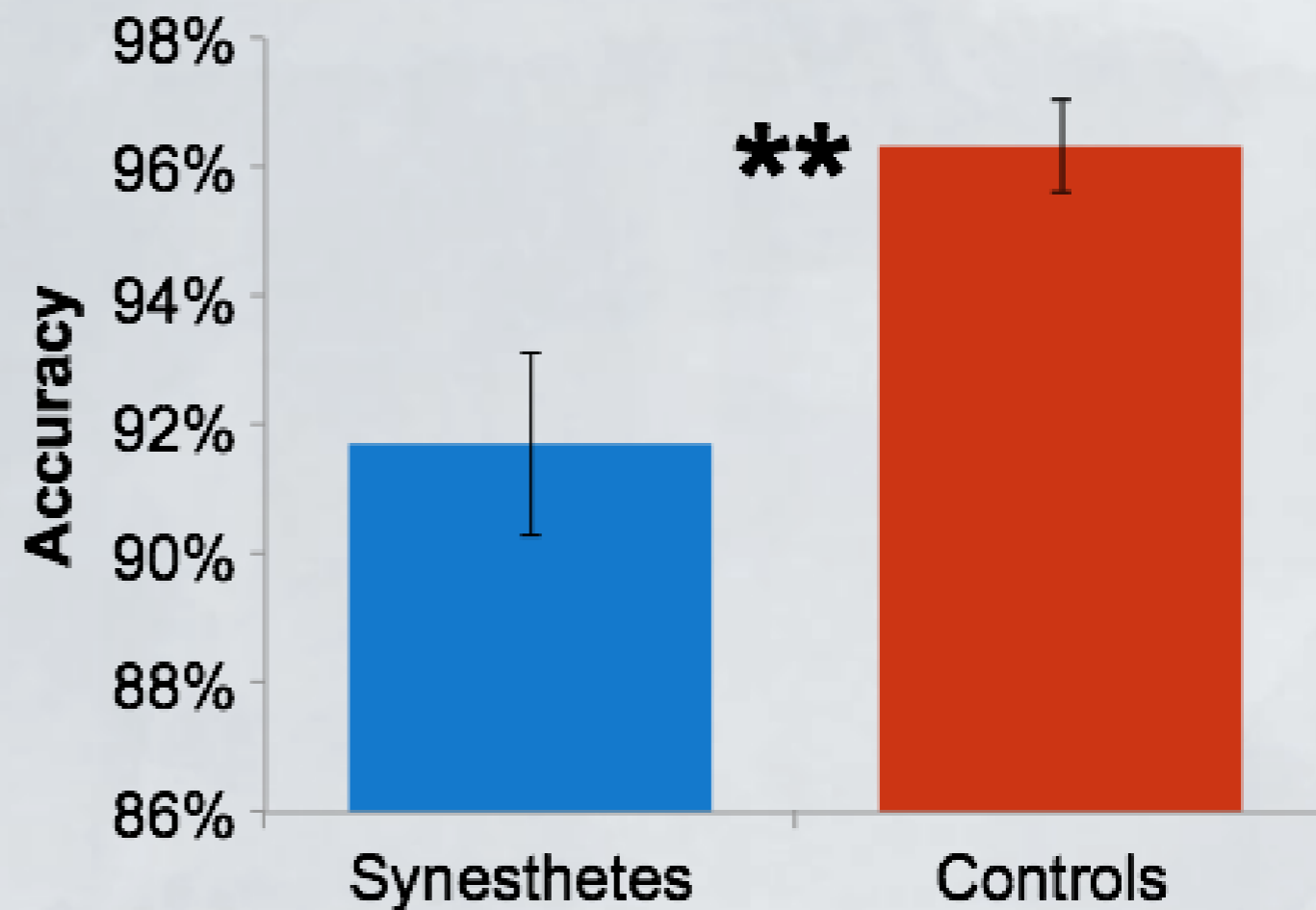
Brang et al., (2013) *Frontiers in Human Neuroscience*

Training Novel Synesthetic Associations

Performance throughout Training



Accuracy after Achieving Criterion



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 Grabowecy

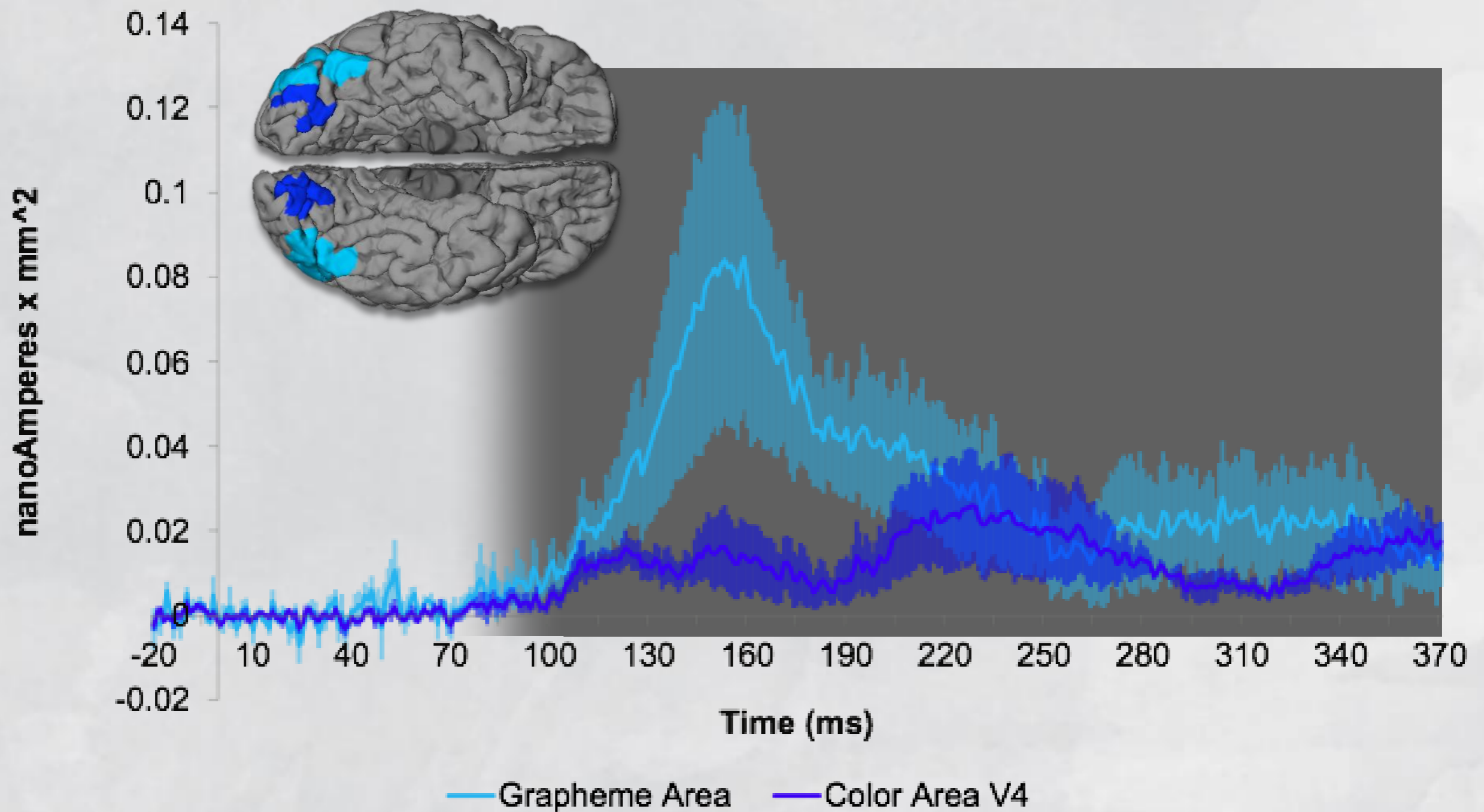
UC San Diego VS Ramachandran, Seana Coulson,
Michael Ghiam

U Amsterdam Romke Rouw

NINDS 2T32NS047987, R01 EY021184

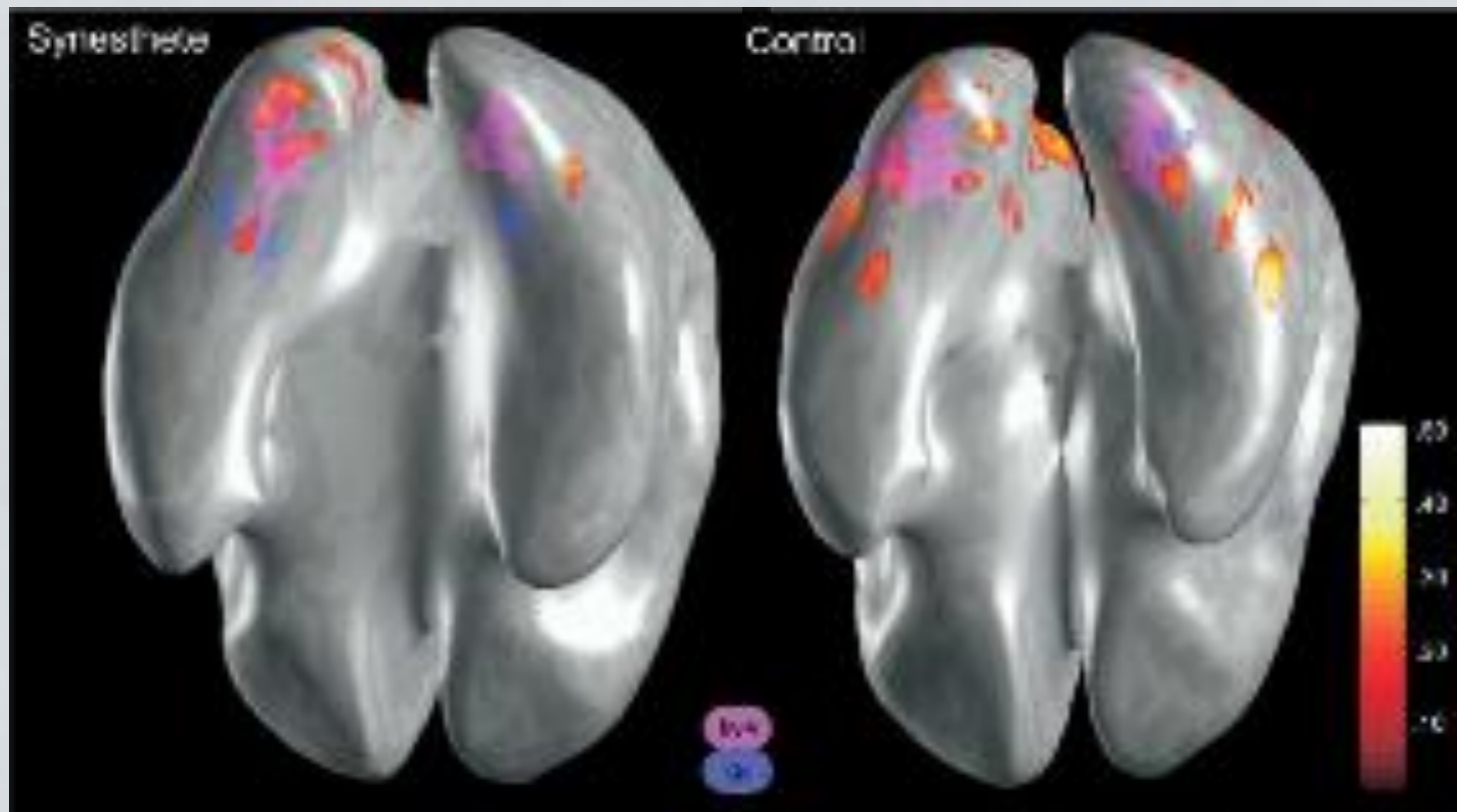
Thank you. Questions?
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Timing of Activity in Synesthetes



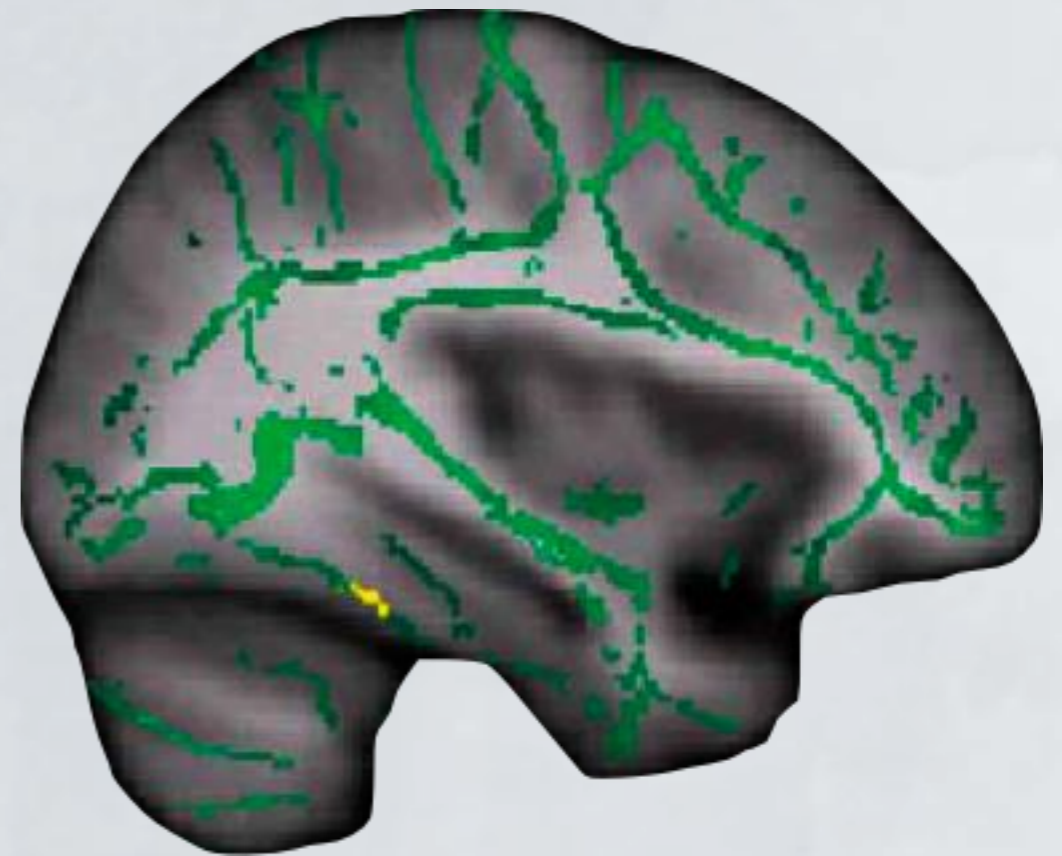
Brang, Hubbard, Coulson, Huang, Ramachandran (2010) *NeuroImage*

Cross-Activation Theory



Hubbard et al. (2005)

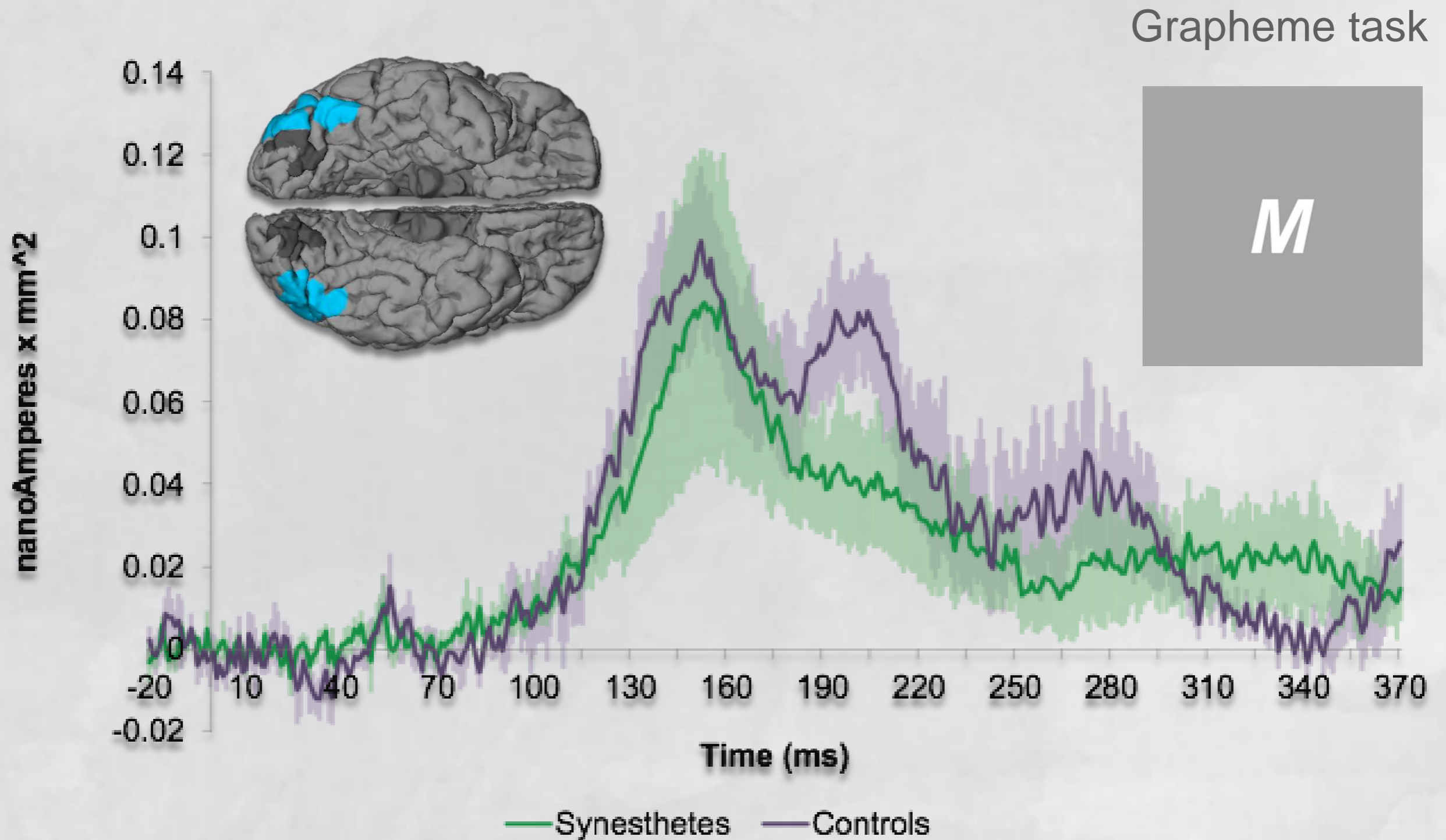
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Rouw & Scholte (2007)

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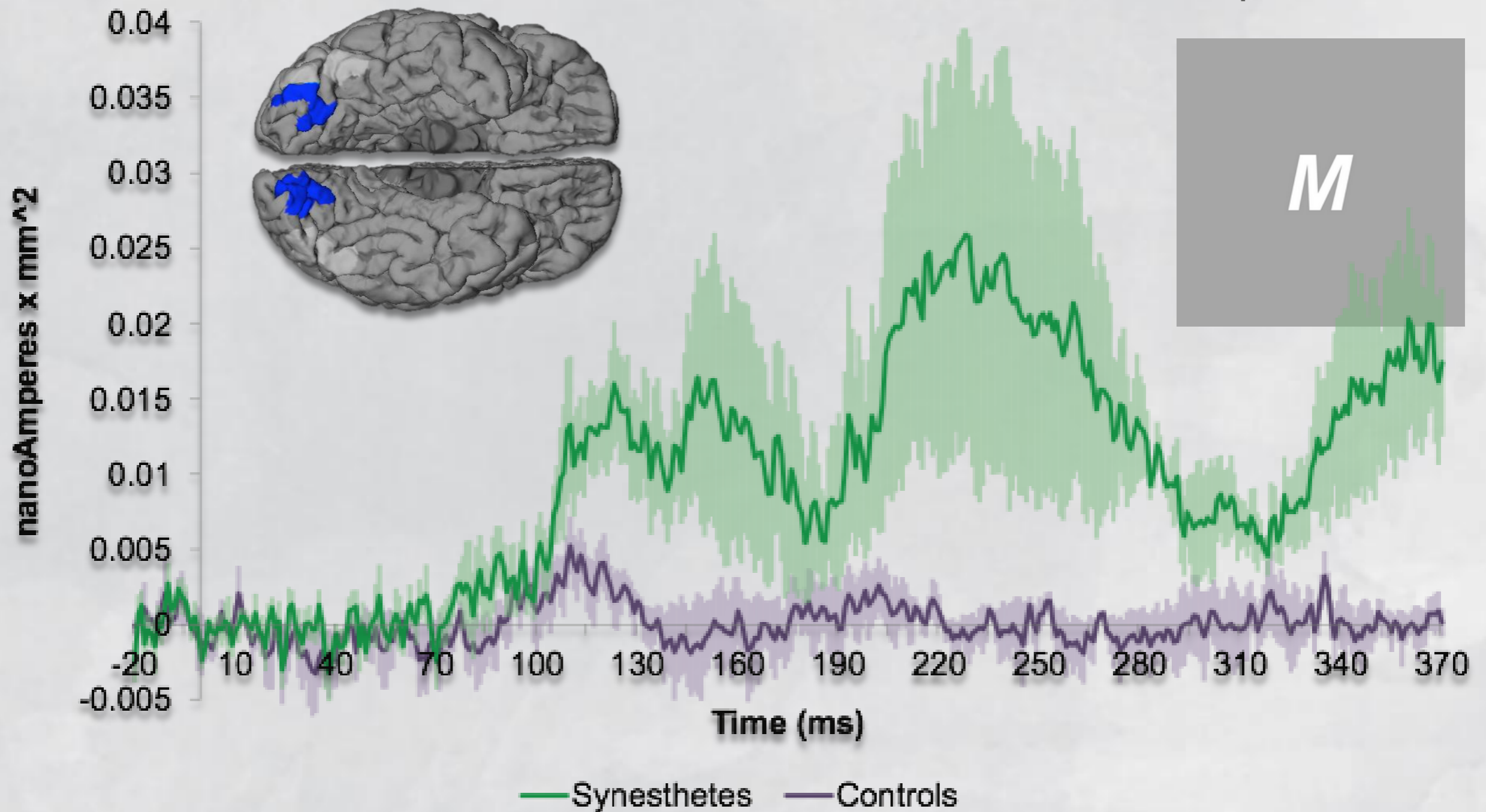
Grapheme ROI



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

V4 ROI

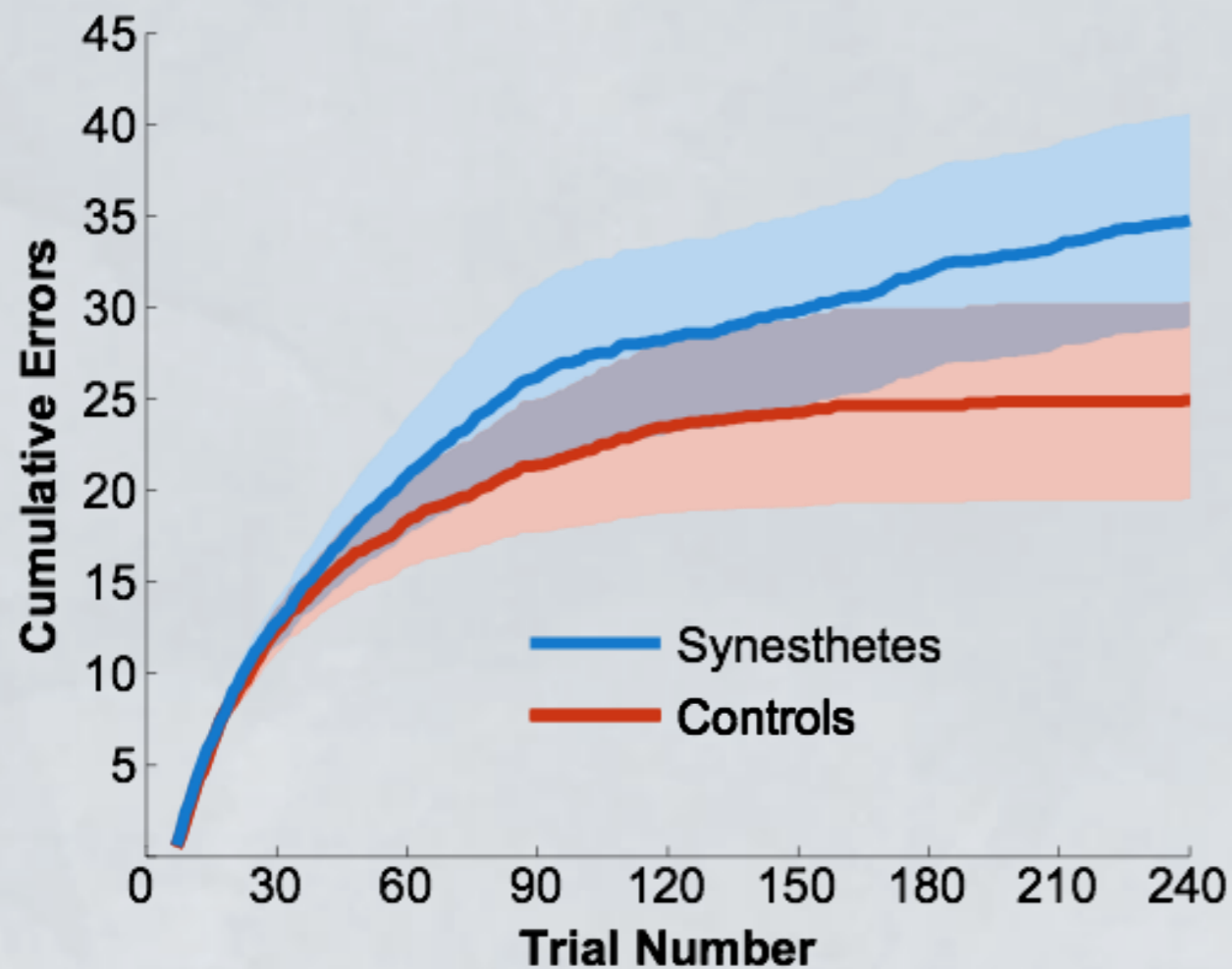
Grapheme task



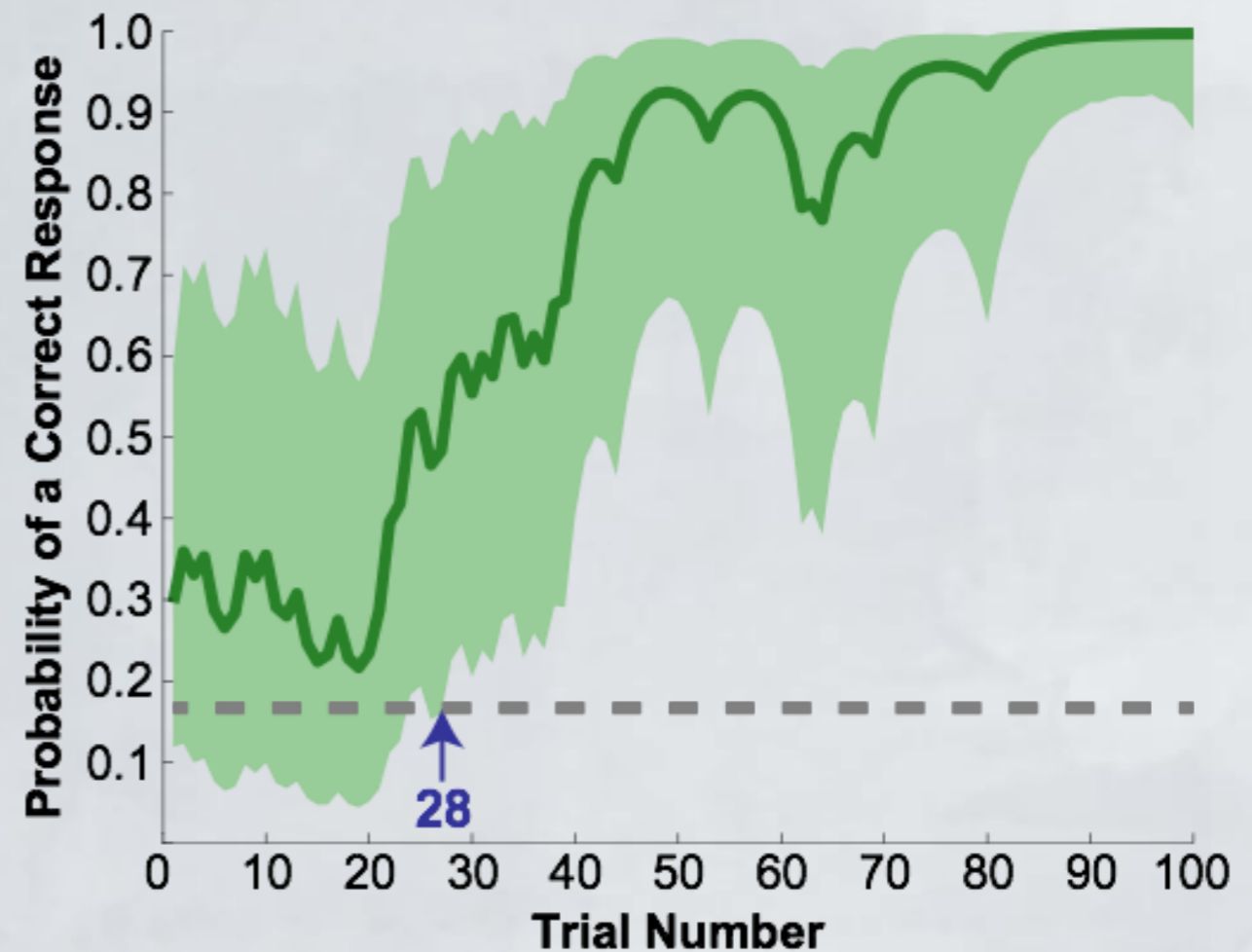
Brang, Hubbard, Coulson, Huang, Ramachandran (2010) *NeuroImage*

Training Novel Synesthetic Associations

Performance throughout Training



Learning Curve and Criterion Threshold



Predicting Latent Associations: EA

ㄣ	→	u	ㄣ	→	u	4 errors
ㄇ	→	m	ㄇ	→	m	4 errors
ㄋ	→	n	ㄋ	→	n	4 errors
ㄆ	→	5	ㄆ	→	5	8 errors
ㄍ	→	g	ㄍ	→	g	9 errors
ㄘ	→	w	ㄘ	→	w	5 errors

Predicting Latent Associations: KE

ㄣ	→	u	ㄣ	→	u	0 errors
ㄣ	→	m	ㄣ	→	m	12 errors
ㄣ	→	n	ㄣ	→	n	3 errors
ㄣ	→	5	ㄣ	→	5	27 errors
ㄣ	→	g	ㄣ	→	g	11 errors
ㄣ	→	h	ㄣ	→	h	15 errors

Predicting Latent Associations: KL

ㄣ	→	u	ㄣ	→	u	14 errors
ㄣ	→	m	ㄣ	→	m	15 errors
ㄣ	→	n	ㄣ	→	n	7 errors
ㄣ	→	5	ㄣ	→	5	10 errors
ㄣ	→	g	ㄣ	→	g	5 errors
ㄣ	→	n	ㄣ	→	n	10 errors

$*r = .43$

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

Title Text

- 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)