Meta-Analysis of Functional Neuroimaging Studies of Dyslexics and Normal Readers

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INTRODUCTION

Neuroimaging studies addressing the pathophysiology of developmental dyslexia in alphabetic languages have focused primarily on reading and phonological processing. To date, there has been no objective assessment of the consistency of these findings. Accordingly, we submitted spatial coordinates from nine papers (14 experiments) to two Activation Likelihood Estimate (ALE) meta-analyses [Ref 1], to identify regions most likely exhibiting more brain activation in controls compared to dyslexics, and vice versa.

METHODS

Criteria for Inclusion in ALE Meta-Analysis

- Paradigms involved processing of visually presented words, pseudowords or letters in the subjects' native, alphabetic language.
- Participants were post-pubertal teens and adults.
- Stereotactic Talairach/MNI coordinates of local maxima from a direct comparison between normal readers and dyslexics were reported.

Nine Papers Met Criteria [Refs 3-11]

1	Paulesu	1996	decision (rhyme)
2	Grünling	2004	decision (rhyme)
3a	Rumsey	1997	decision (phonological/orthographic)
3b			explicit (phonological/orthographic)
4a	Brunswick	1999	decision (ascender)
4b			explicit (reading)
5	Paulesu	2001	explicit/decision
6	Georgiewa	1999	explicit/transformation
7	Ingvar	2002	explicit reading
8	McCrory	2005	explicit reading
9	Flowers	under review	explicit reading

Controls > Dyslexics
96 foci from 9 publications (14 experiments).

Dyslexics > Controls
75 foci from 6 of the 9 publications (10 experiments).

Activation Likelihood Estimate Parameters:

- 10,000 Randomizations to estimate null distribution
- Spatial smoothing = 14.1 mm FWHM
- ALE Threshold = 0.00485, FDR = 0.0001 [Ref 2]

RESULTS

Controls > Dyslexics

ALE maps identified consistent hypoactivation in dyslexia in the left hemisphere in two extrastriate areas within BA 37, superior temporal sulcus, inferior parietal cortex, inferior frontal gyrus, precuneus and thalamus. Consistent right hemisphere hypoactivation was found in the fusiform and superior temporal gyri.

Table 1: Nine clusters of suprathreshold voxels for Controls > Dyslexics, MNI coordinates of each local maximum, ALE values of each maximum, and the % influence each contrast contributed to a given ALE value. Values in parentheses are below a cutoff of 7% (1/14).

Cluster Size in voxels	Estimated Localization of Local Maximum	MNI coordinates of Local Maximum			ALE Local Maximum Within Cluster (*10e-3)	% Influence from Studies														Papers/ Exp.
		X	Y	Z		1	2	3a		4a	5	3b		4b	6		7	8	9	
32	Left Precuneus (BA 31)	-4	-76	28	5.55			34%				47%	19%							1/3
843	Left Inferior Temporal Gyrus (BA 37)	-48	-58	-10	7.52			(1%)		18%	32%		(4%)	34%				11%		3/4
	Left Fusiform Gyrus (BA 37)	-48	-42	-22	7.01			32%	36%	19%		(1%)		(5%)				(5%)	(1%)	2/3
42	Left Inferior Parietal Lobule (BA 40)	-46	-44	26	5.82			36%	36%		(1%)		26%							1/3
155	Left Superior Temporal Gyrus (BA 22)	-52	-36	8	7.29	(1%)	9%		33%	(2%)	(1%)	24%	29%							3/4
133	Left Thalamus	-18	-24	10	7.09									46%	27%	27%				2/3
30	Left Inferior Frontal Gyrus (BA 47/11)	-22	32	-4	5.68			32%	41%				27%							1/3
51	Right Fusiform Gyrus (BA 20)	48	-34	-26	6.28			33%				36%	31%							1/3
30	Right Postcentral Gyrus (BA 2)	50	-26	32	5.76							60%	39%						(1%)	1/2
190	Right Superior Temporal Gyrus (BA 21)	44	-22	-4	8.49			26%	25%			27%	22%							1/4

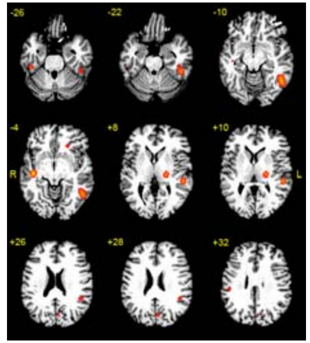


Figure 1: ALE map for Controls > Dyslexics in the axial planes of each local maximum (subject left = image right).

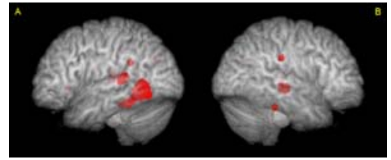


Figure 2: Volume rendered ALE map for Controls > Dyslexics

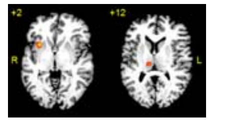
- The left posterior inferior temporal/fusiform gyrus (BA 37) cluster was the largest, and had two local maxima.
- The left posterior inferior (BA 37) and superior temporal (BA 22) clusters were the most robust findings, each having contributions from 3 papers (4 contrasts).
- Four tasks from one paper (Rumsey et al., 1997) contributed to a right superior temporal gyrus (BA 21) finding.

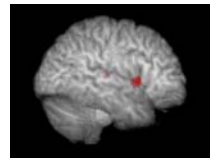
Dyslexics > Controls

Table 2: Meta-analysis of Dyslexics > Controls identified clusters in right anterior insula and thalamus. Values in parentheses are below a cutoff of 10% (1/10).

Cluster Size in voxels	Estimated Localization of Local Maximum	MNI coordinates of Local Maximum			ALE Local Maximum Within Cluster (*10e-3)	% Influence from Studies									Papers/Expts
		X	Y	Z		2	3a		3b		4b	6	7	9	
66	Right Thalamus	14	-20	12	6.09		(8%)	20%		35%				38%	2/3
113	Right Insula (BA 13)	34	18	2	7.1	14%	33%		20%	33%					2/4

Figures 3 and 4: ALE map in axial slices (subject left = image right) and volume rendered over a semi-transparent brain.





SUMMARY

- During reading, dyslexic readers tend to underactivate posterior and anterior portions of the left hemisphere as well as posterior portions of the right hemisphere.
- During reading, dyslexic readers tend to overactivate right insular cortex and right thalamus.
- The most robust findings were left temporal parietal, left extrastriate, and right superior temporal hypoactivity and right anterior insula hyperactivity in dyslexics.
- Results do not support the notion of a compensatory mechanism in left frontal cortex.

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This poster is available online at http://csl.georgetown.edu/publications/DyslexiaMetaAnalysisPoster-SFN2005.pdf

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