Neurologie de la dyslexie : données récentes de la recherche

Michel Habib

La partie visible : 3 groupes de symptômes

VISUELS

- Confusion entre des lettres visuellement proches : b/d, m/n, n/u
- difficulté de reconnaissance globale des mots familiers

AUDITIFS

- Confusion de sons proches : t/d, ch/j, c/g, f/v, etc... (surtout à l'écrit) + le trouble "phonologique"

SEQUENTIELS

- Inversions diverses (lettres, syllabes, etc..., en lecture, en écriture et même à l'oral)

→ impossibilité d'acquérir la conversion graphème-phonème

Les mécanismes sous-jacents :

pourquoi l'incapacité à la conversion grapho-phonémique?

- Le trouble phonologique
  - Présent chez la grande majorité des dyslexiques
  - Considéré comme causal par la majorité des auteurs
  - Dériverait d'un trouble de la mise en place précoce des représentations phonémiques
- Le trouble visuo-attentionnel
  - Fréquent, surtout après plusieurs années d'évolution
  - Peut mettre l'enfant dans l'incapacité d'apprendre la conversion grapho-phonémique serait la cause unique que dans une minorité de cas

Trouble phonologique : répercussions langagières…

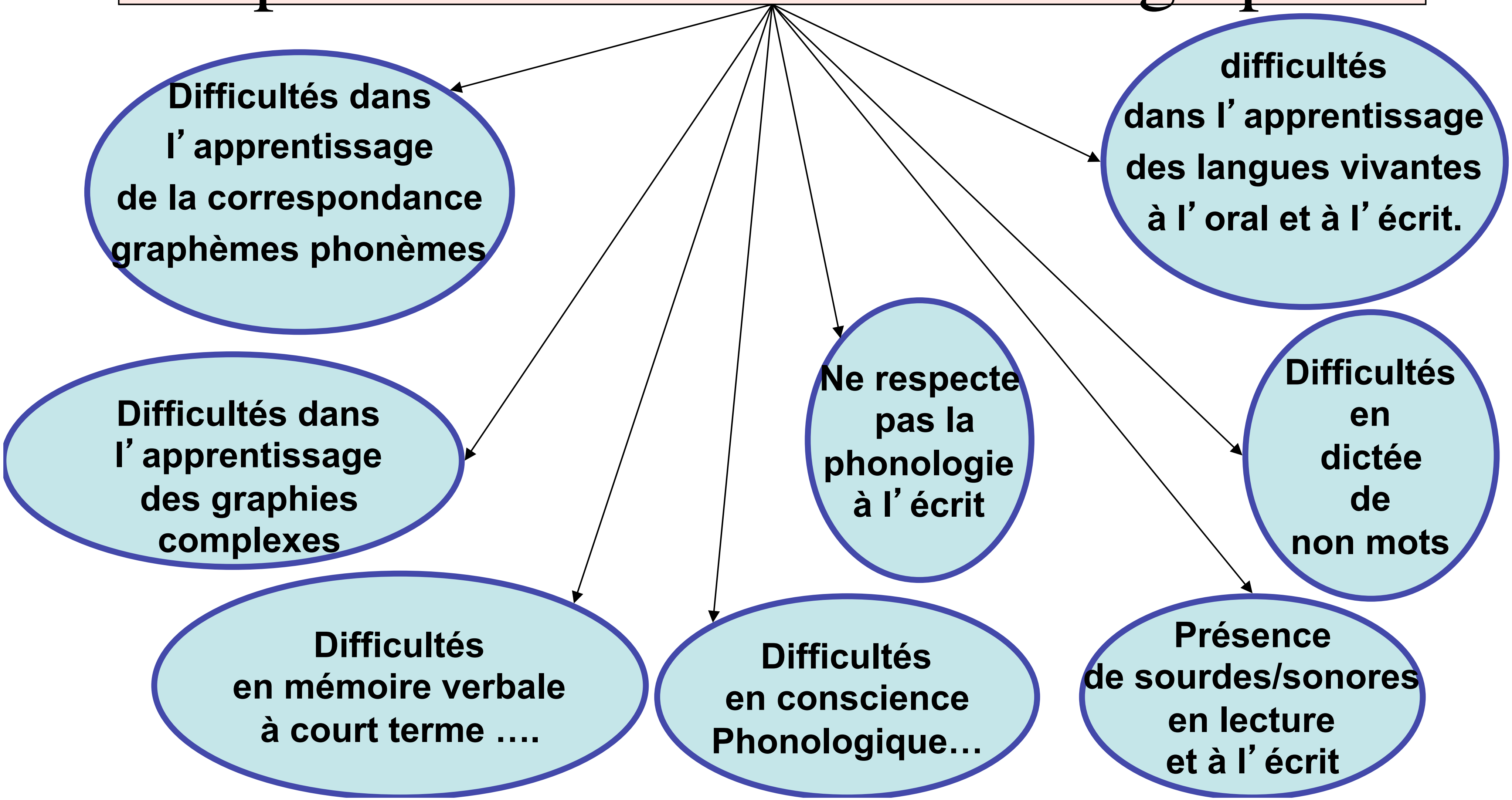
Difficultés de répétition de mots et de non mots

des difficultés quant à l'apprentissage de nouvelles formes sonores (médicaments, noms propres, sigles, termes techniques) → apprentissage des leçons et des poésies

Difficultés d'accès à la forme phonologique des mots : hésitations, manques du mot ou temps de latence élevés (Wolf, 1984; Snowling et al, 1988)

Performances déficitaires en évocation lexicale sur le critère formel (Frith et al, 1995).

Trouble phonologique : répercussions en lecture/orthographe



Différentes formes de dyslexie

- Les dyslexies phonologiques

Difficultés d'acquisition de la procédure analytique

- Les dyslexies de surface

Difficultés d'acquisition de la procédure lexicale

- Les dyslexies mixtes

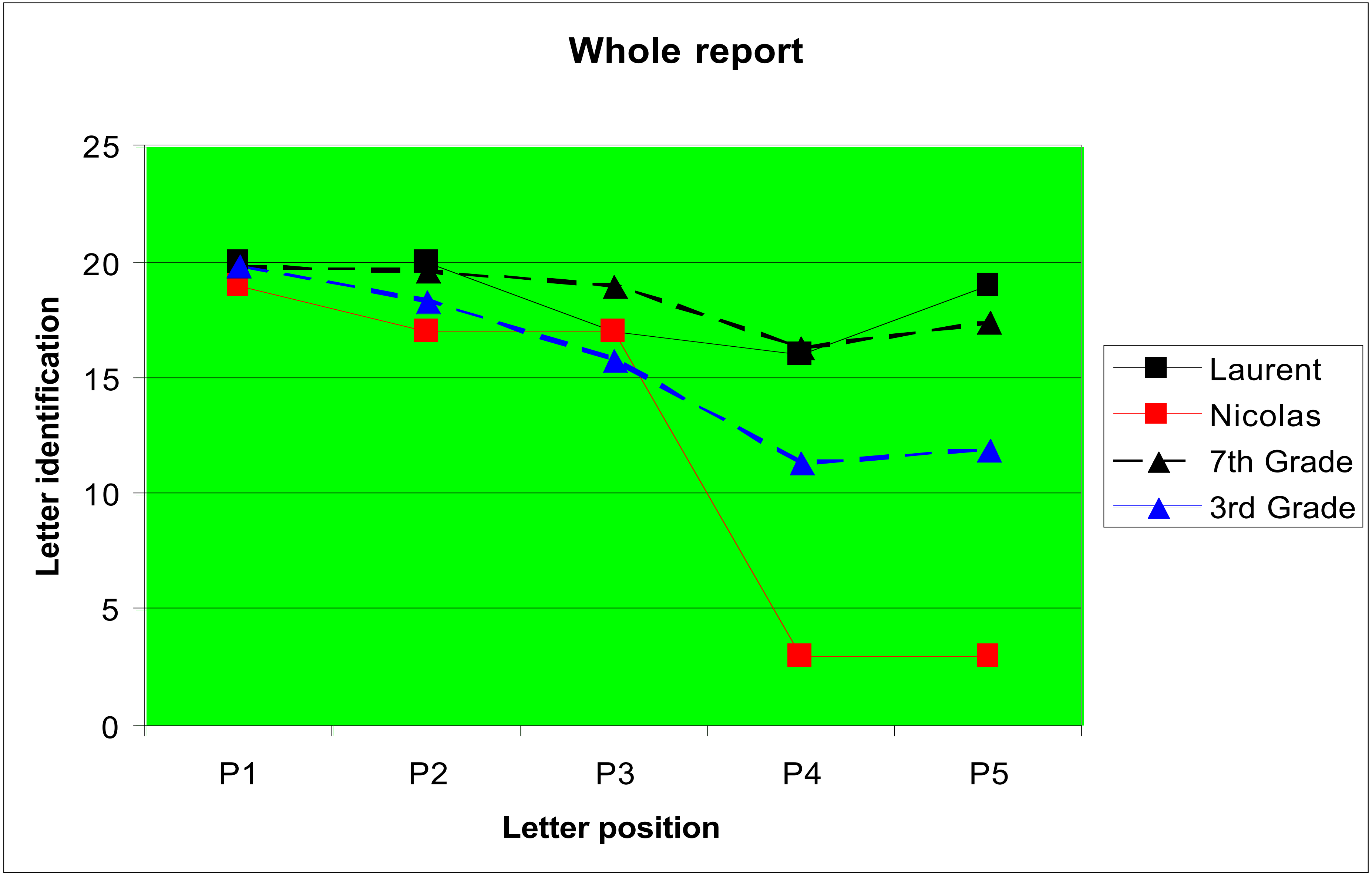
Difficultés d'acquisition des procédures analytiques et lexicales

Epreuve visuo-attentionnelle (S. Valdois)

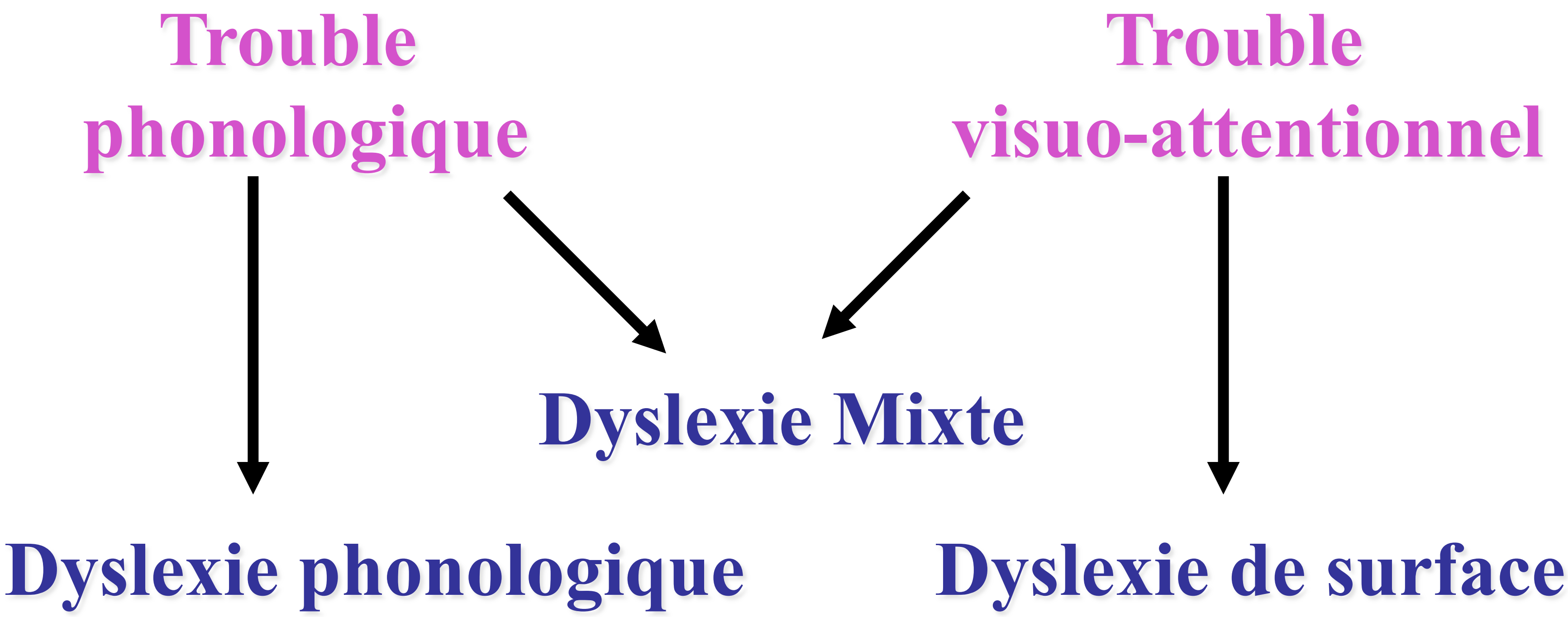
Report Global

A V T.S R

Réponse → **AVTSR**



Whole report
Letter identification
25
20
15
10
5
0
P1
P2
P3
P4
P5
Letter position
Laurent
Nicolas
7th Grade
3rd Grade


Trouble phonologique
Trouble visuo-attentionnel
Dyslexie Mixte
Dyslexie phonologique
Dyslexie de surface

Trouble visuo-attentionnel: conséquences

Ne peut se constituer un lexique orthographique même s'il est un grand lecteur. D'où…

une orthographe d'usage très déficitaire

grosses difficultés en copie : aménagements scolaires

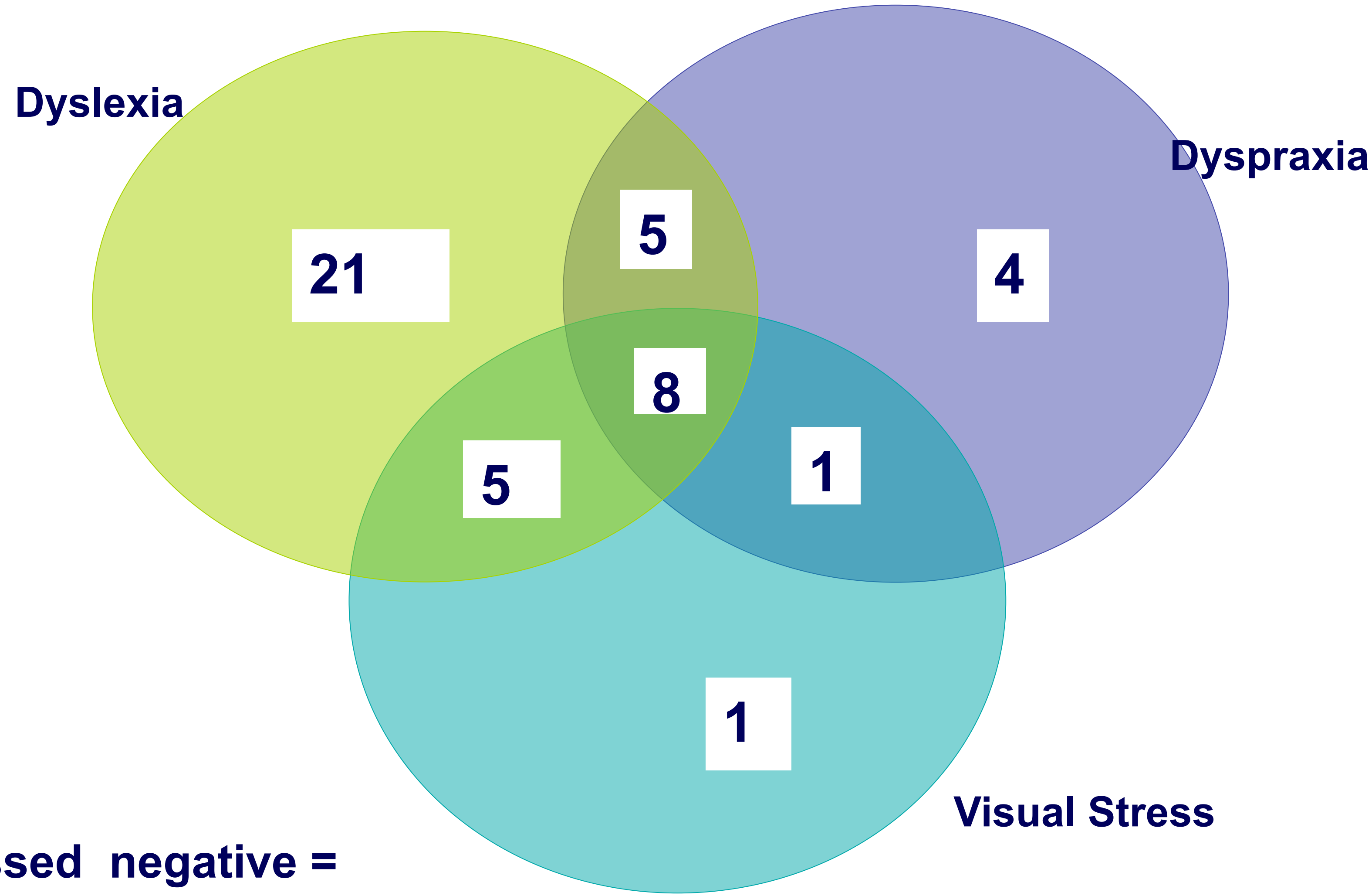
Difficultés en anglais À l'écrit

écriture phonétique : il écrit comme il entend et dans un même texte, un mot peut être écrit à chaque ligne de façon différente mais correcte sur le plan phonologique.

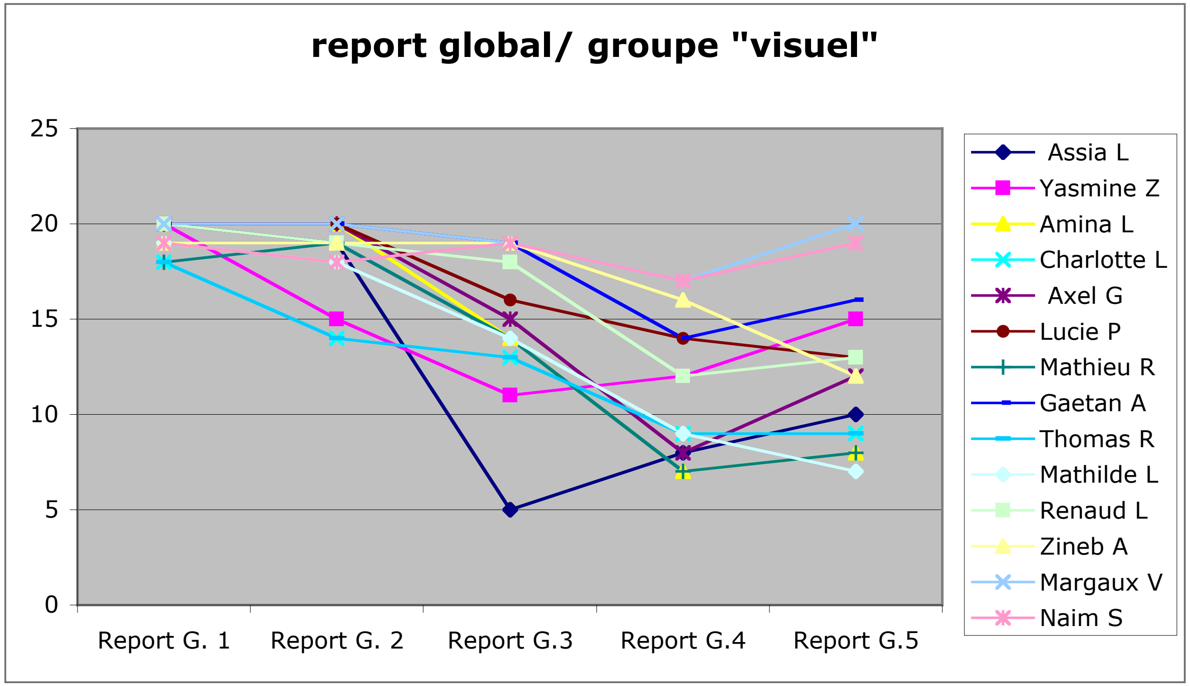
une lecture lente et très syllabée (très analytique) : il déchiffre le même mot plusieurs fois comme si c'était la 1ère fois.

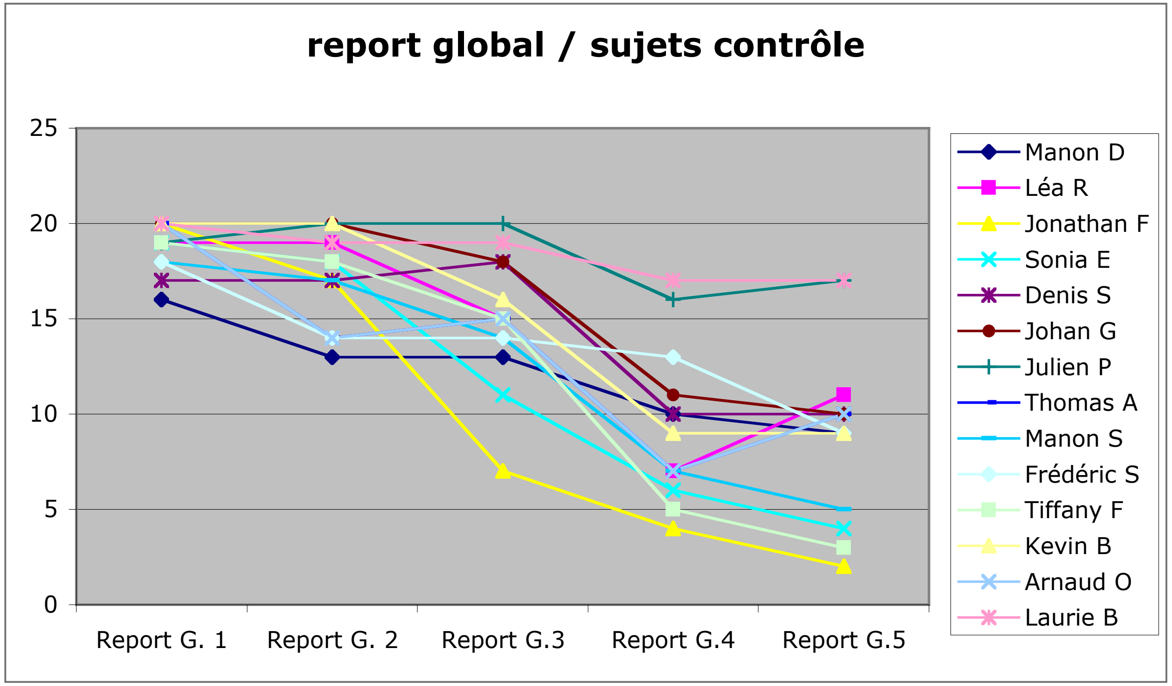
Fautes qui ne tiennent pas compte des occurrences en français

Co-morbidity of dyslexia, dyspraxia and visual stress from the 60 assessments used.



Assessed negative = 15





Comparaison de 14 dyslexiques (μ=9a7m) sans difficultés visuelles apparentes et 14 dyslexiques (μ=10a2m) suivis en orthoptie pour "trouble neurovisuel" ("visual stress")

Même âge moyen, de lecture (Alouette)

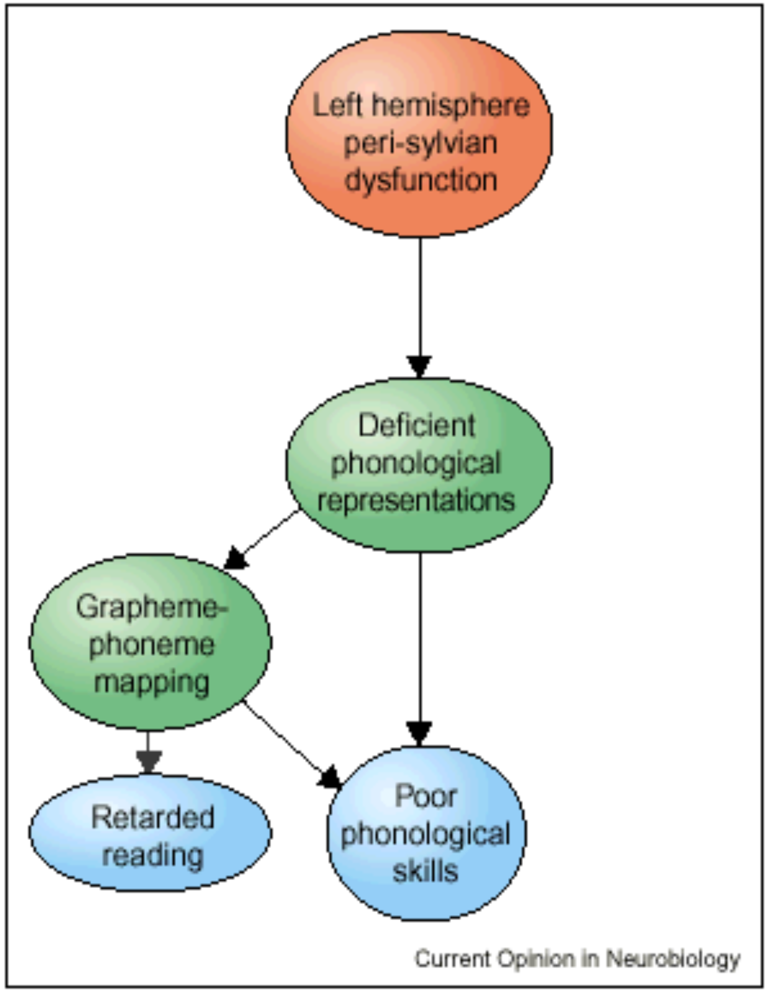
Trouble phonologique moins sévère dans le groupe "visuel"

ENVIRONNEMENT

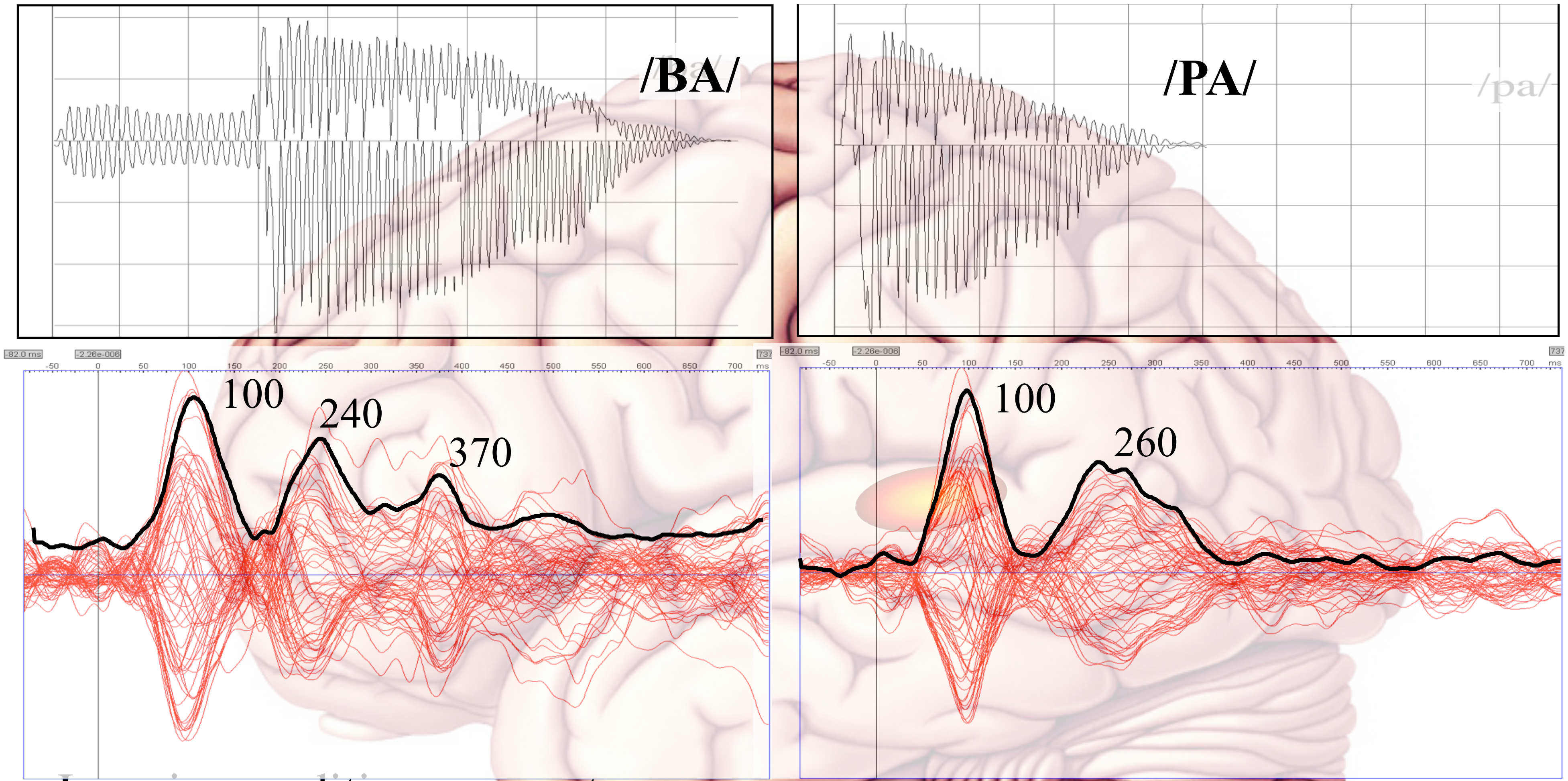
Niveau neurobiologique

Niveau cognitif

Niveau comportemental

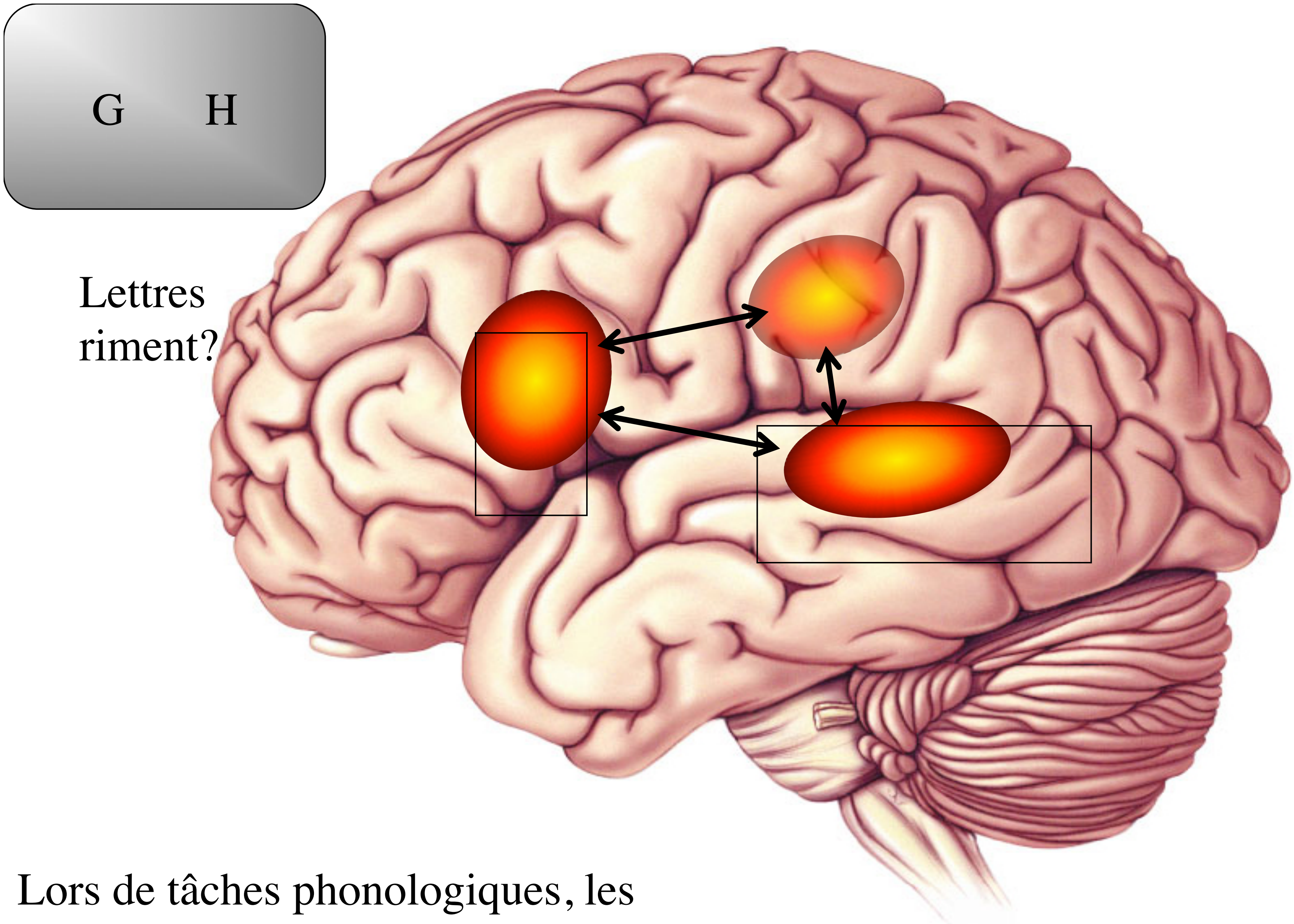


F. Ramus, *Current Opinion in Neurobiology*, 2003



Les aires auditives ne sont pas capables de recruter des groupes de neurones de façon synchrone à la succession d'éléments acoustiques caractérisant les phonèmes

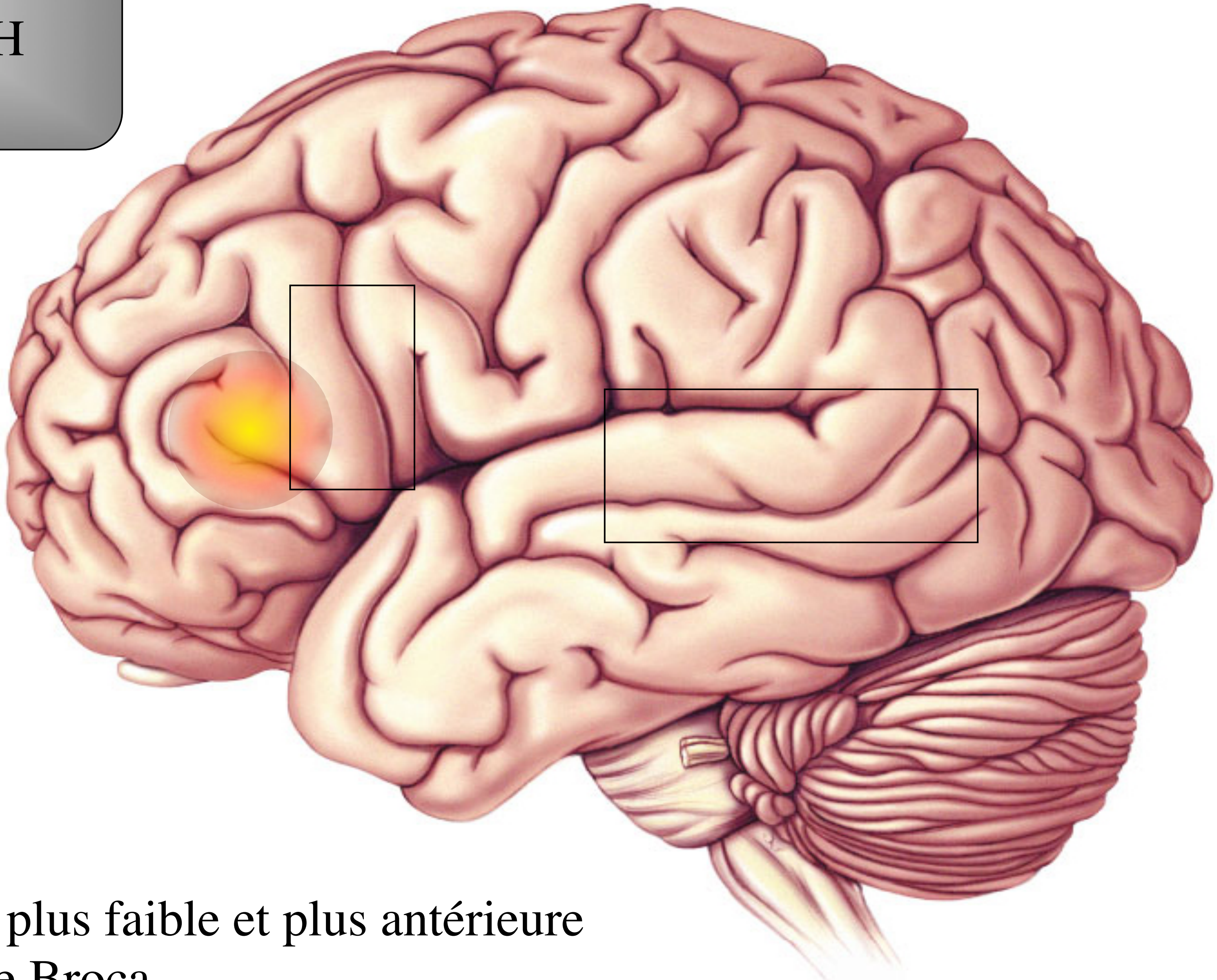
Giraud et al., *Cerebral Cortex* (2005)



Lors de tâches phonologiques, les aires du langage ne peuvent s'activer correctement

Temple et al., *P.N.A.S.* (2003)

Enfant dyslexique

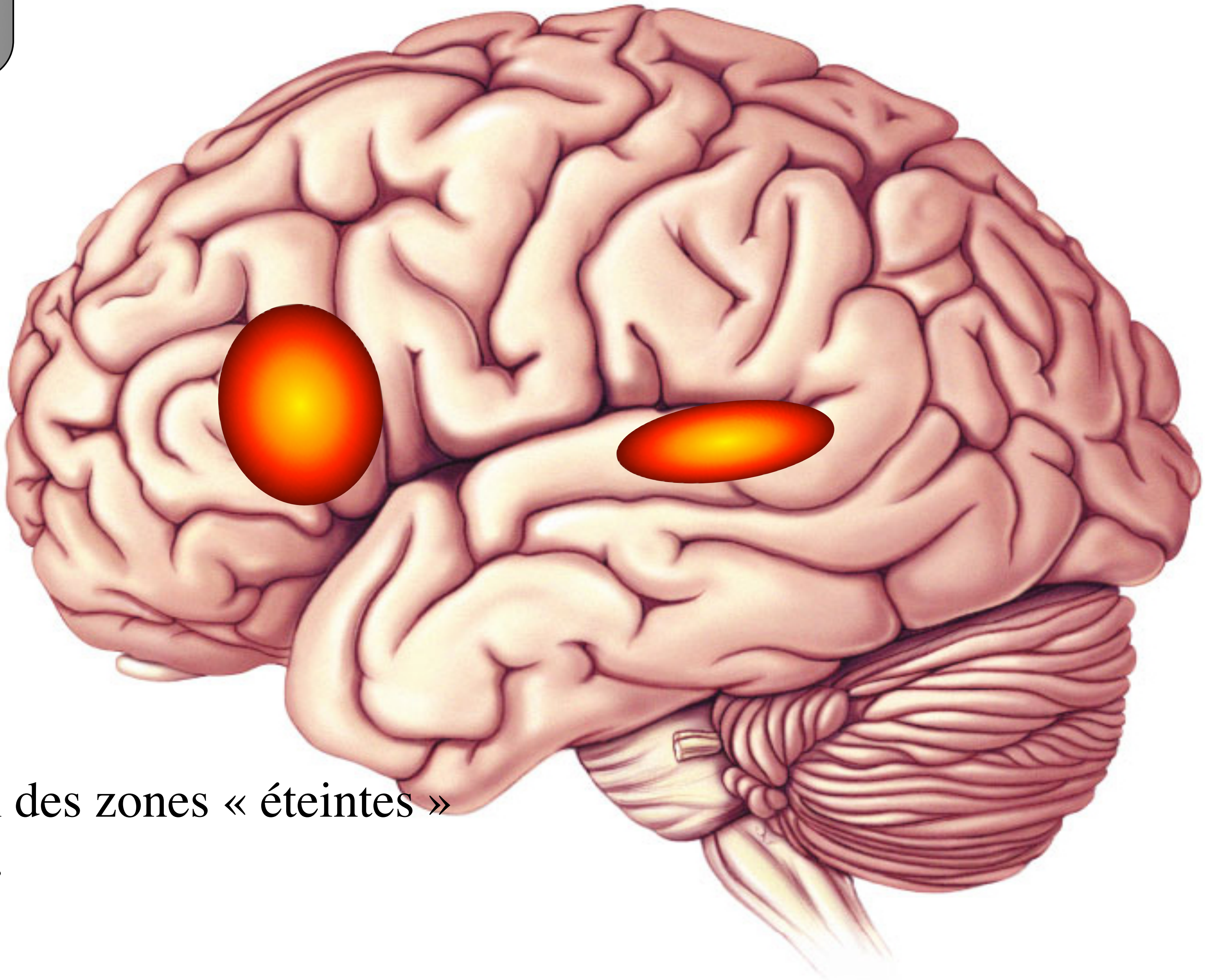


Activation plus faible et plus antérieure
de l'aire de Broca
Absence d'activation postérieure

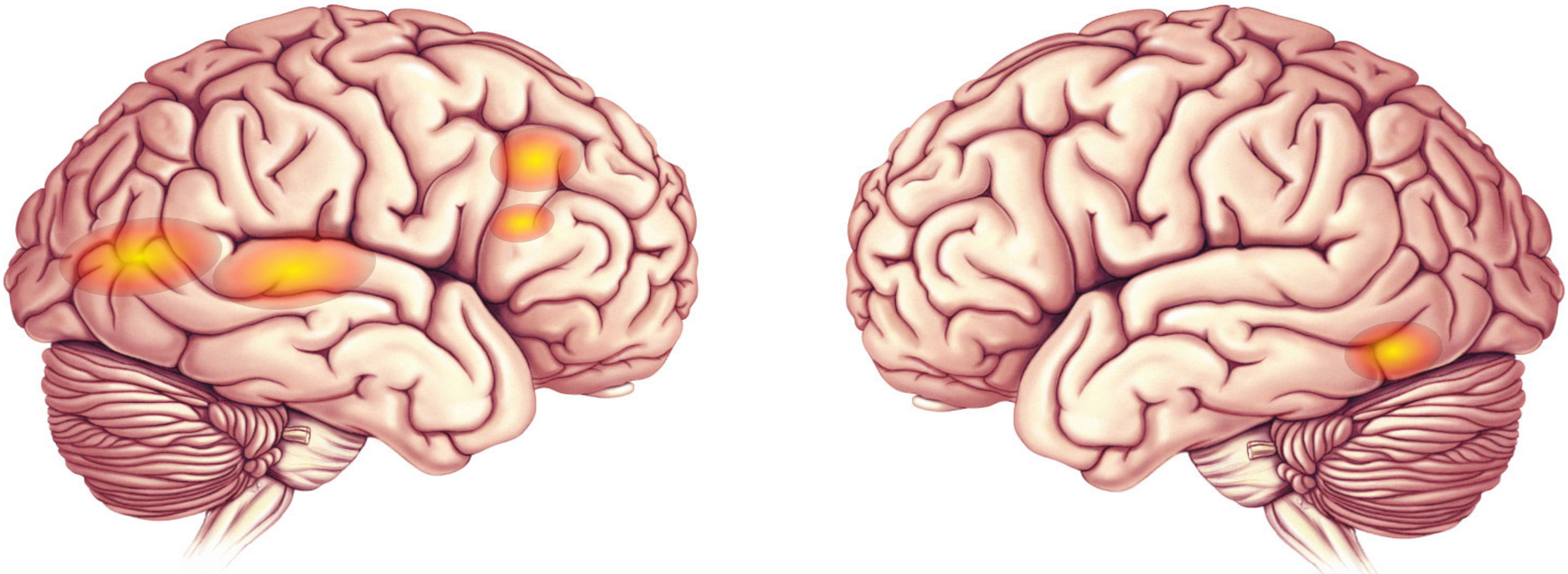
Temple et al., *P.N.A.S.* (2003)

G H

Enfant dyslexique après entraînement (Fastforword®)



Réapparition des zones « éteintes »
Mais aussi…



… apparition de zones non activées précédemment (et non activées chez le témoin) : mécanisme de compensation? réorganisation?

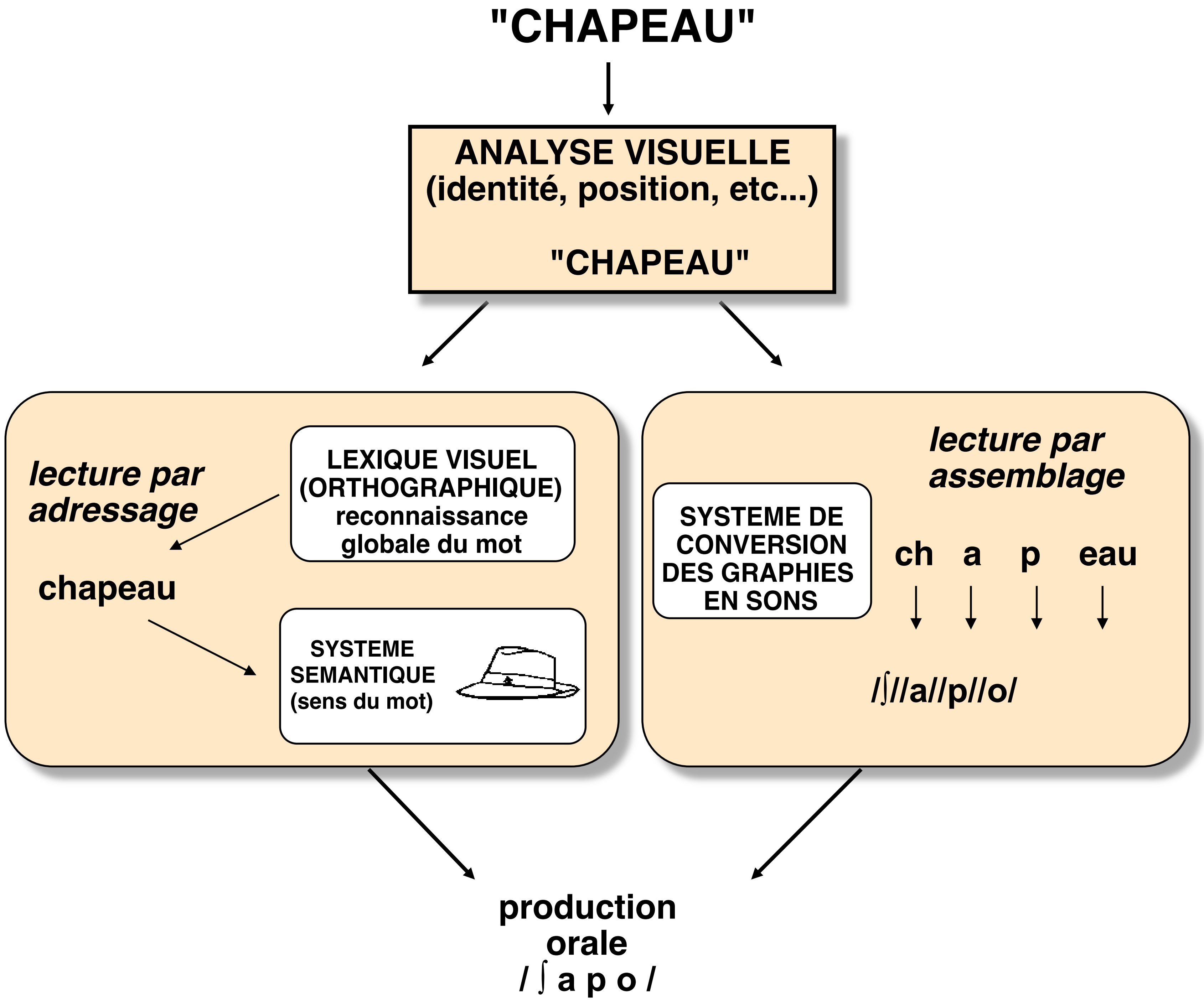
Conclusion n°1

- Les aires du langage sont insuffisamment activées chez le dyslexique lors d'exercices phonologiques
- Un entraînement intensif de quelques semaines, focalisé sur le système déficient, non seulement réactive les zones affaiblies mais sollicite des zones "muettes" des deux hémisphères
- Donc l'entraînement (une intervention extérieure) a modifié l'organisation cérébrale dans le sens d'une probable meilleure connectivité entre des zones habituellement inutilisées

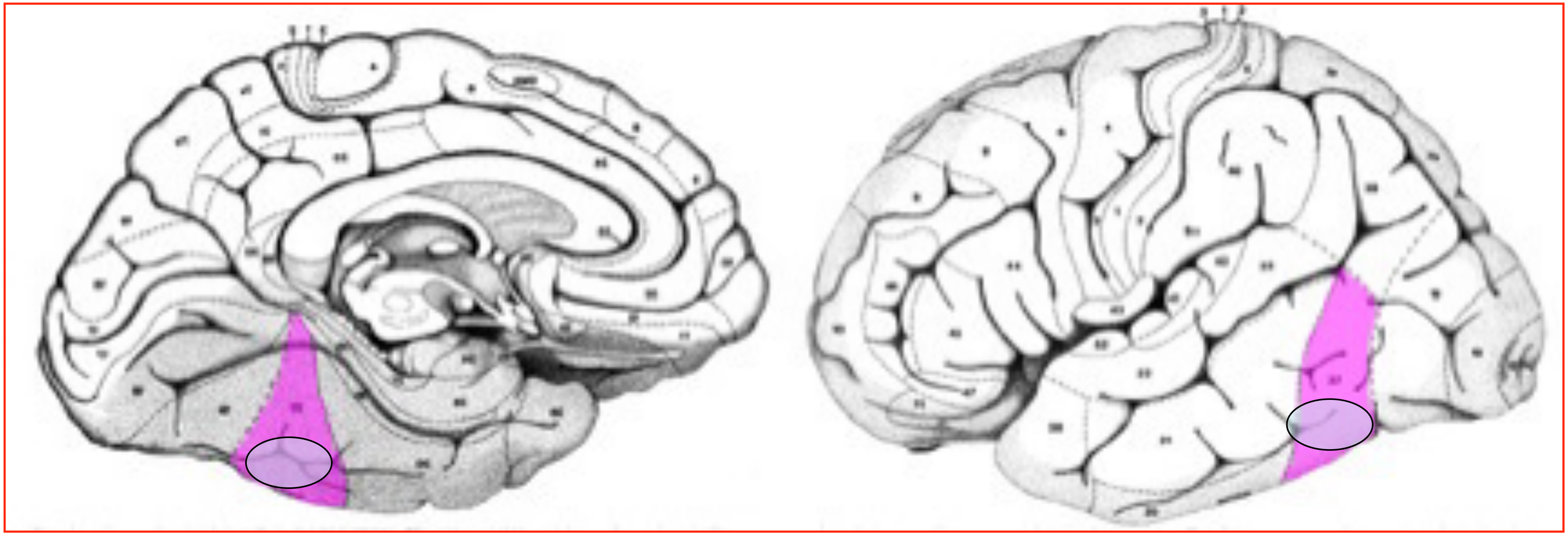
bol

confortablement

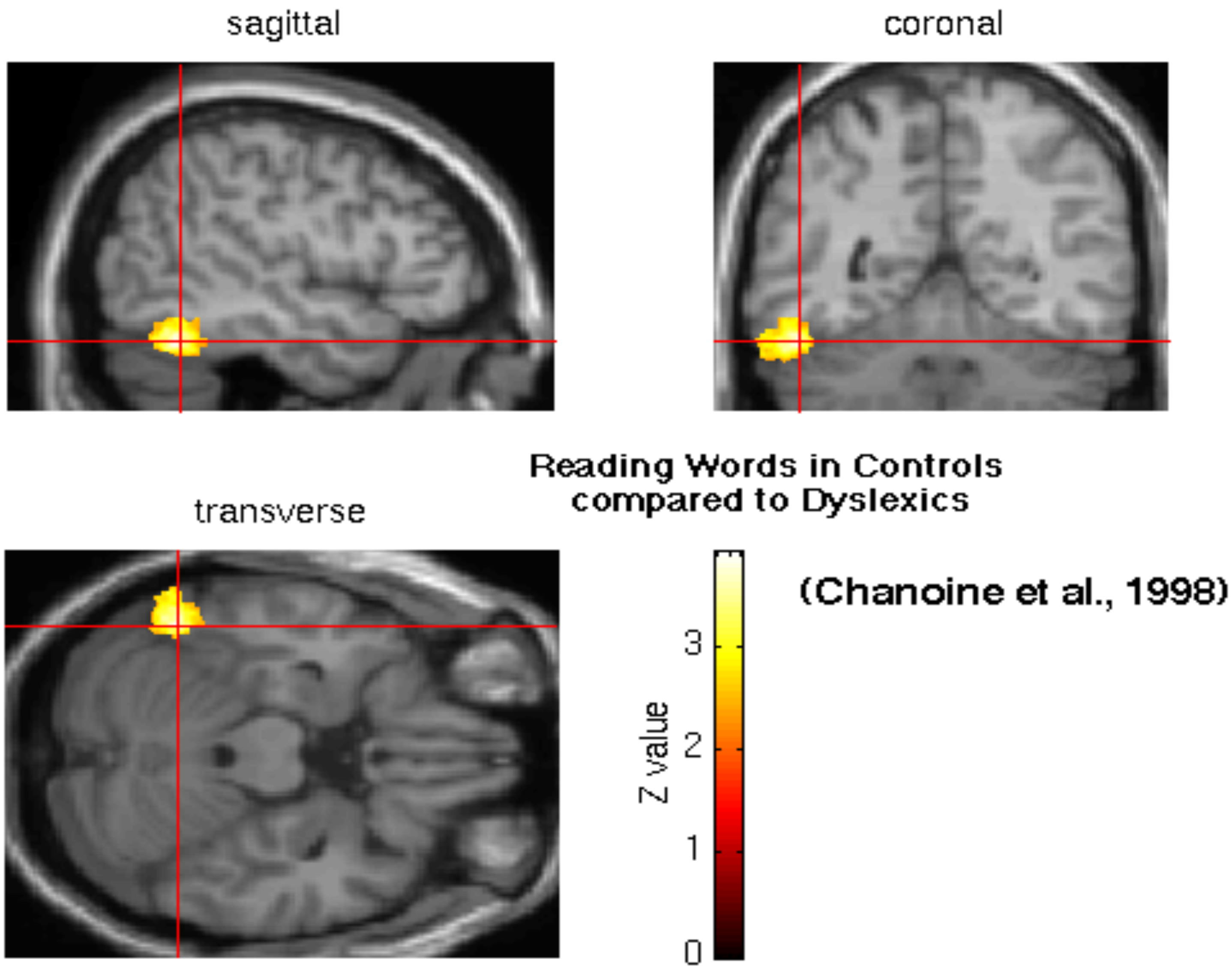
tambenefoneclor


"CHAPEAU"
ANALYSE VISUELLE
(identité, position, etc...)
"CHAPEAU"
lecture par adressage
LEXIQUE VISUEL
(ORTHOGRAPHIQUE)
reconnaissance
globale du mot
chapeau
SYSTEME
SEMANTIQUE
(sens du mot)
lecture par assemblage
SYSTEME DE
CONVERSION
DES GRAPHIES
EN SONS
ch a p eau
/ʃ//a//p//o/
production
orale
/ ʃ a p o /

ILBA 37 : aire de la forme visuelle des mots



Attribue un statut linguistique à une suite de lettres



Most significant difference dyslexics/controls = left infero-lateral Brodman's area 37

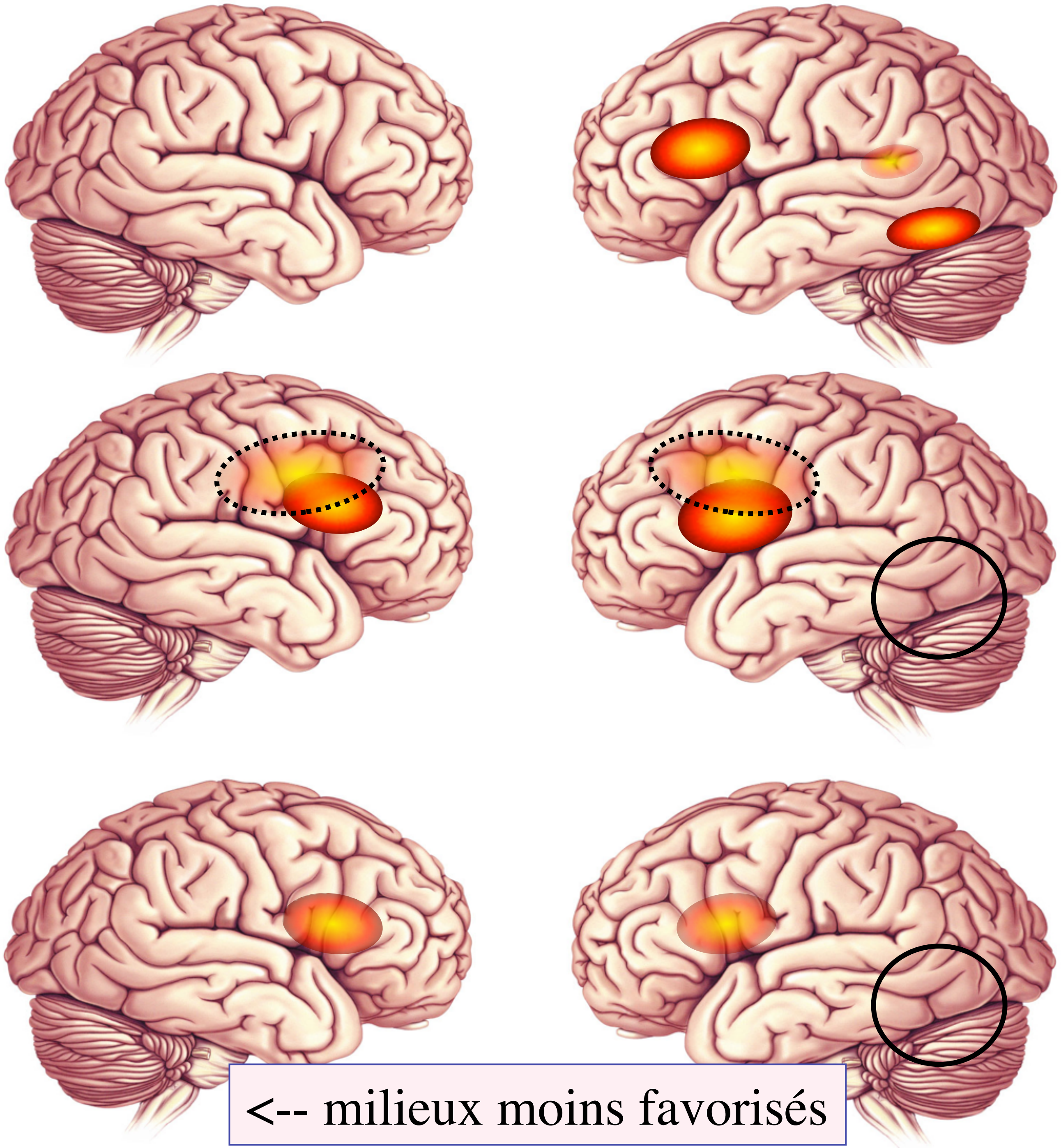
LEAT JETE

Riment?

Témoins
non dys

Dyslexiques
"compensés"

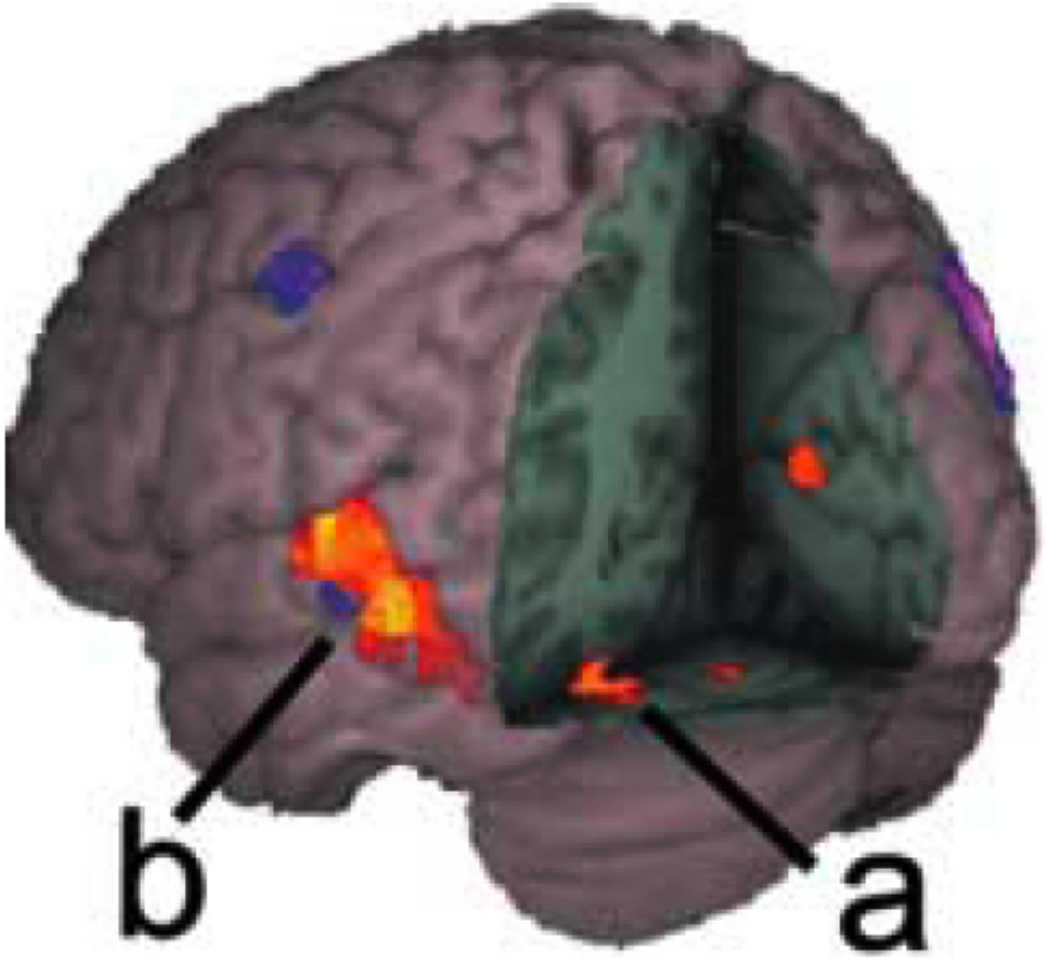
Dyslexiques
"persistants"



<-- milieux moins favorisés

Shaywitz et al., Biol. Psychiatry, 2003

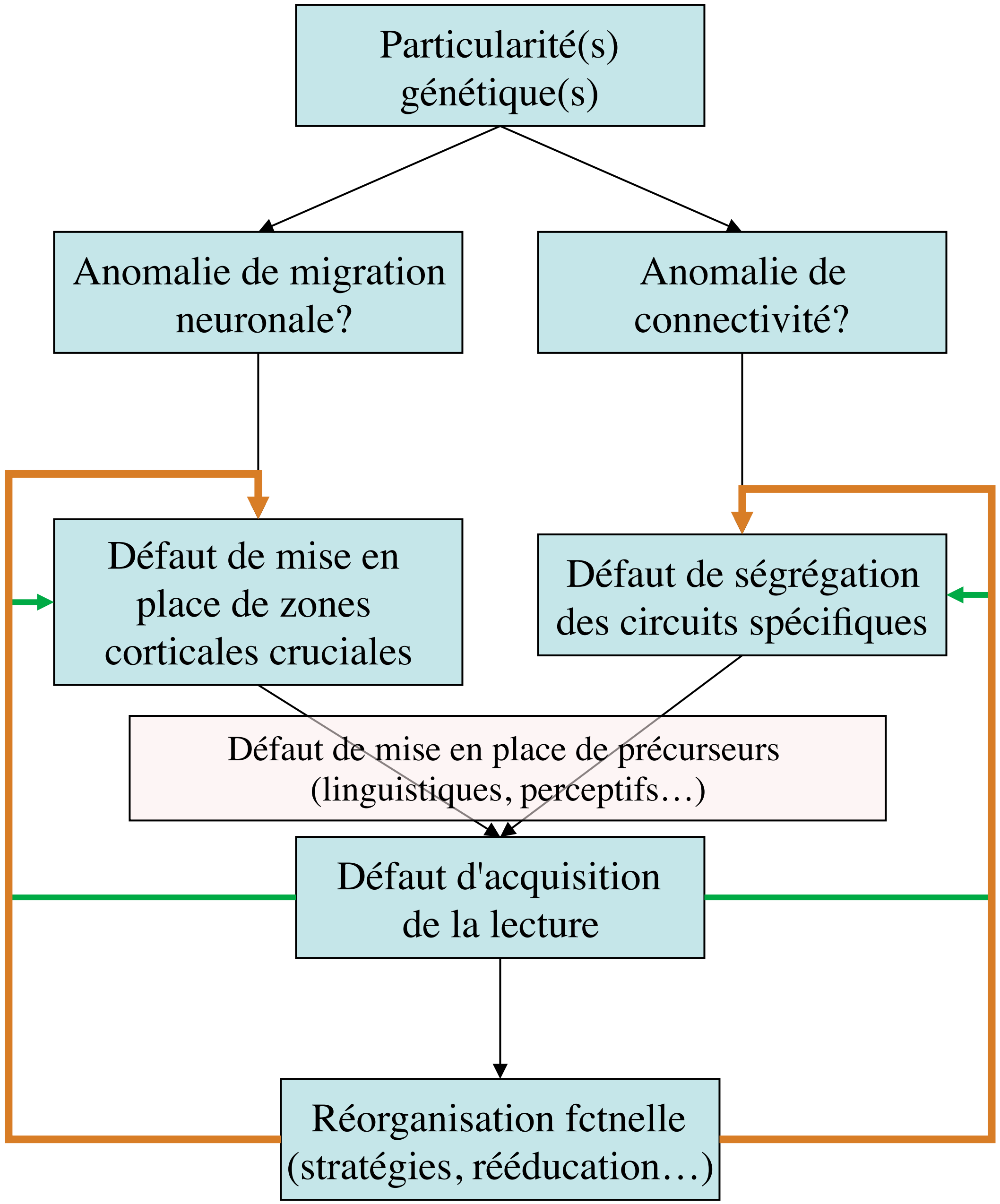
Zones de corrélation entre le niveau de conscience phonologique et le statut socio-économique

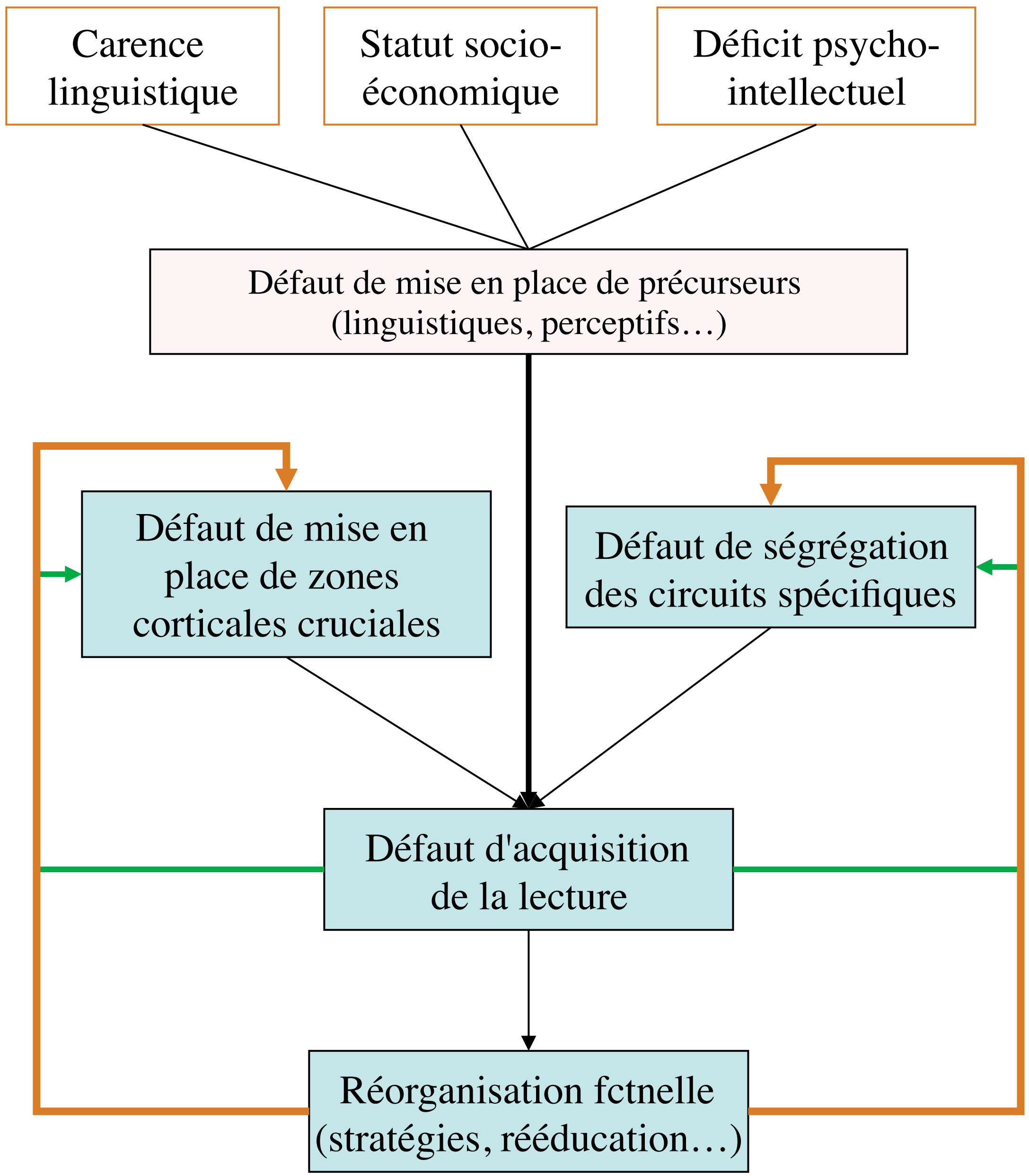


Noble et al., 2006

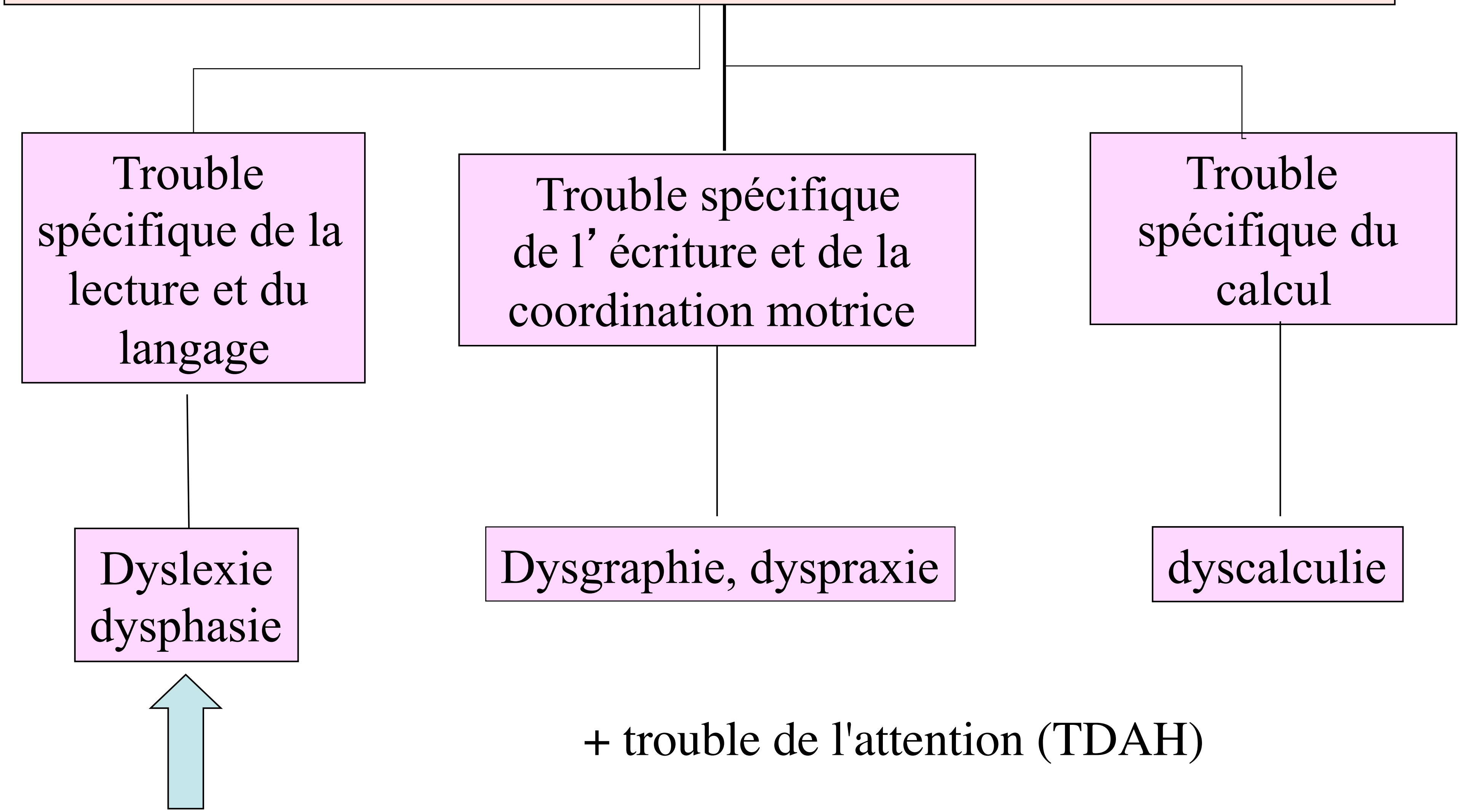
Conclusion n°2

- A égalité de sévérité initiale, le milieu dans lequel évolue l'individu va déterminer au moins en partie non seulement sa capacité de récupération, mais également l'aptitude de son cerveau à recruter d'autres zones pour faciliter cette récupération
- La reconnaissance rapide des mots, finalité de la lecture, est sous la dépendance d'une aire spécialisée qui attribue un statut linguistique à une suite de lettres
- L'absence de mise en jeu de l'aire de la forme visuelle des mots est la conséquence commune à terme, mais variable selon divers facteurs d'environnement, incluant le statut socio-économique.

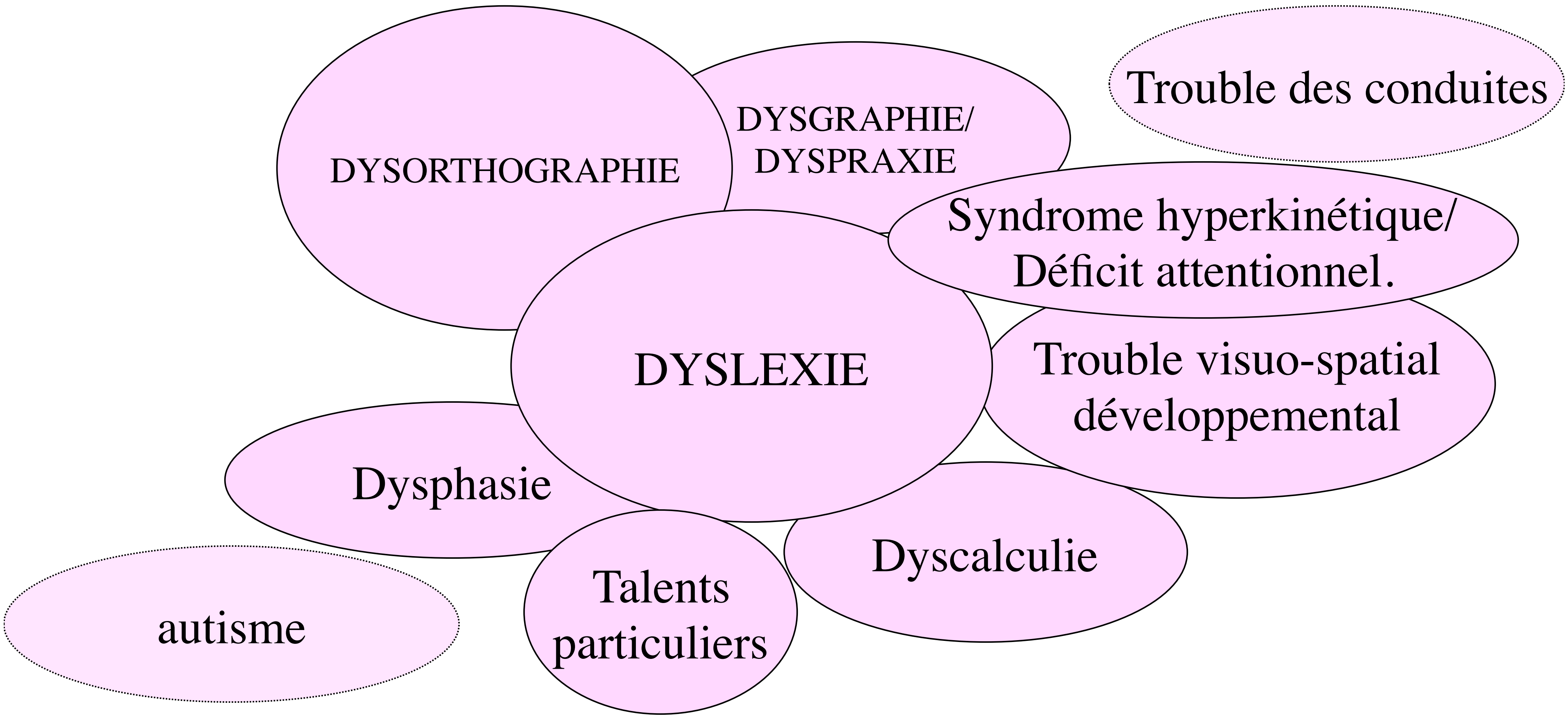

Particularité(s) génétique(s)
Anomalie de migration neuronale?
Anomalie de connectivité?
Défaut de mise en place de zones corticales cruciales
Défaut de ségrégation des circuits spécifiques
Défaut de mise en place de précurseurs (linguistiques, perceptifs…)
Défaut d'acquisition de la lecture
Réorganisation fctnelle (stratégies, rééducation…)


Carence linguistique
Statut socio-économique
Déficit psycho-intellectuel
Défaut de mise en place de précurseurs (linguistiques, perceptifs…)
Défaut de mise en place de zones corticales cruciales
Défaut de ségrégation des circuits spécifiques
Défaut d'acquisition de la lecture
Réorganisation fctnelle (stratégies, rééducation…)

Troubles spécifiques d'apprentissage ("learning disorders")



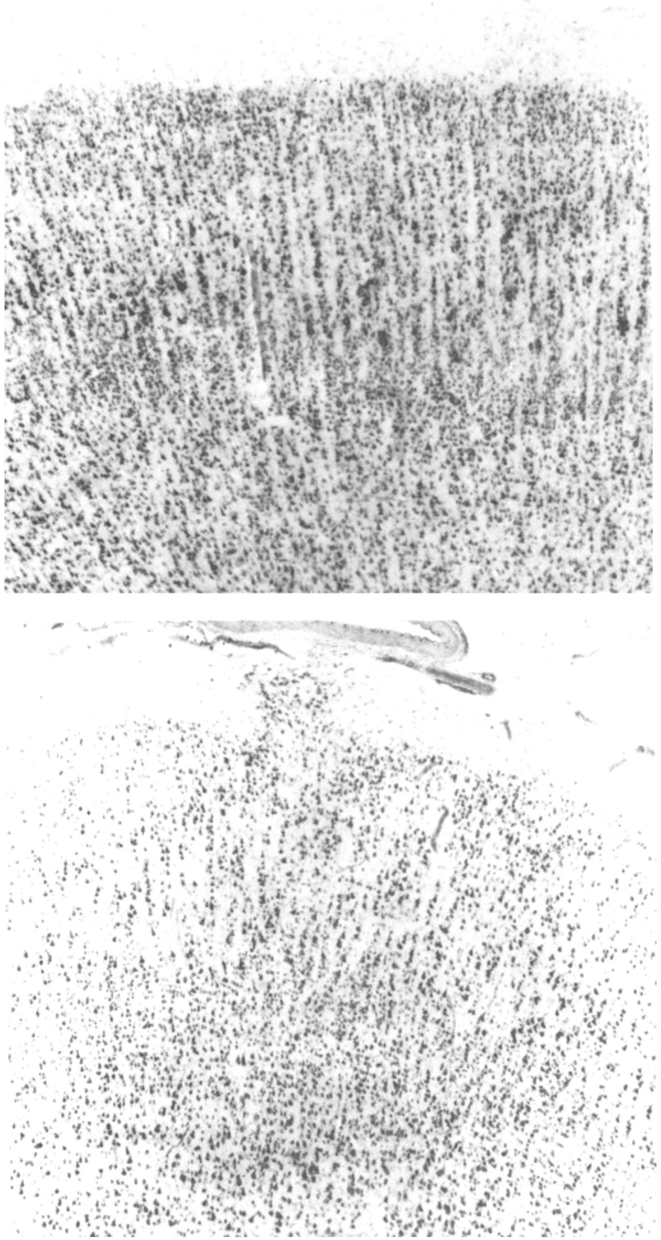
+ trouble de l'attention (TDAH)

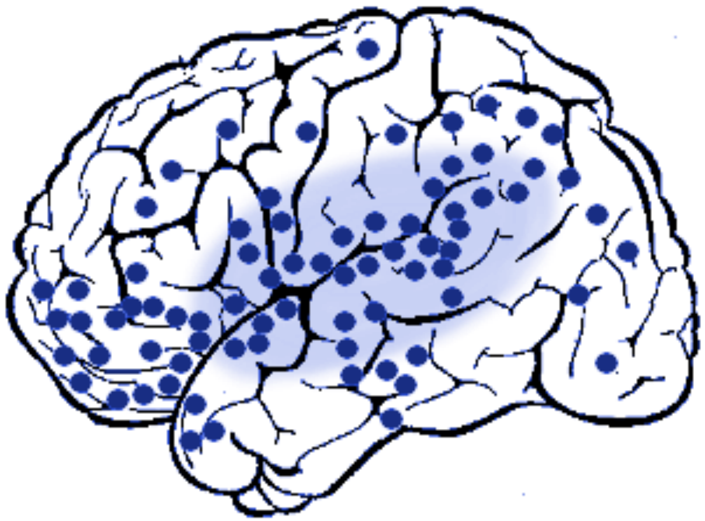

DYSORTHOGRAPHIE
DYSGRAPHIE/
DYSPRAXIE
Trouble des conduites
Syndrome hyperkinétique/
Déficit attentionnel.
DYSLEXIE
Trouble visuo-spatial
développemental
Dysphasie
Dyscalculie
Talents
particuliers
autisme

Le cerveau du dyslexique

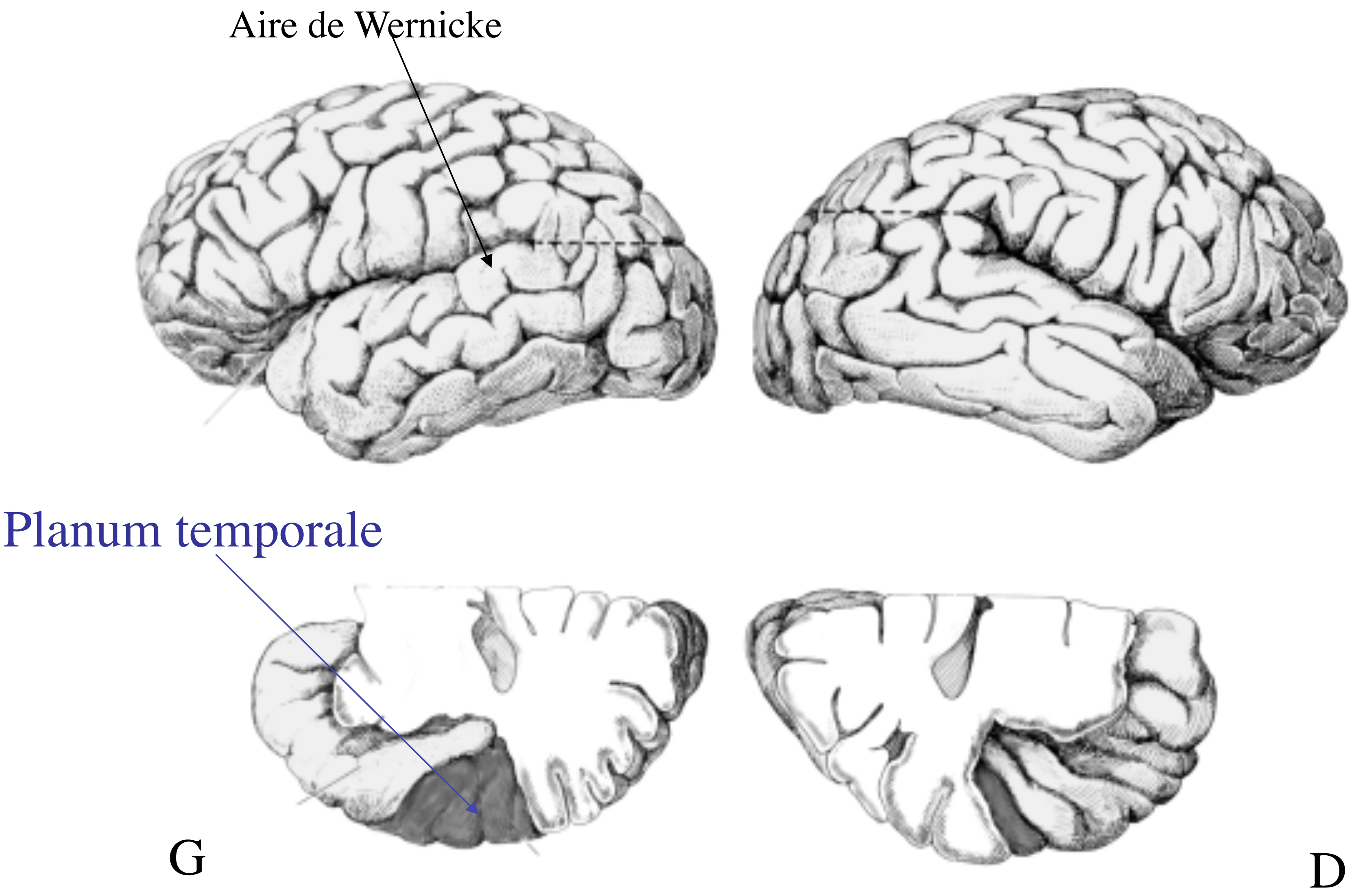
- Possède une organisation déficiente au niveau de l'aire du langage (génétique)
- Ne distingue pas parfaitement les phonèmes contenus dans la parole
- Ne peut manipuler volontairement les sons de la langue (conscience phonologique)
- Ne peut associer graphèmes et phonèmes
- Ne développe pas de procédure de reconnaissance globale des mots

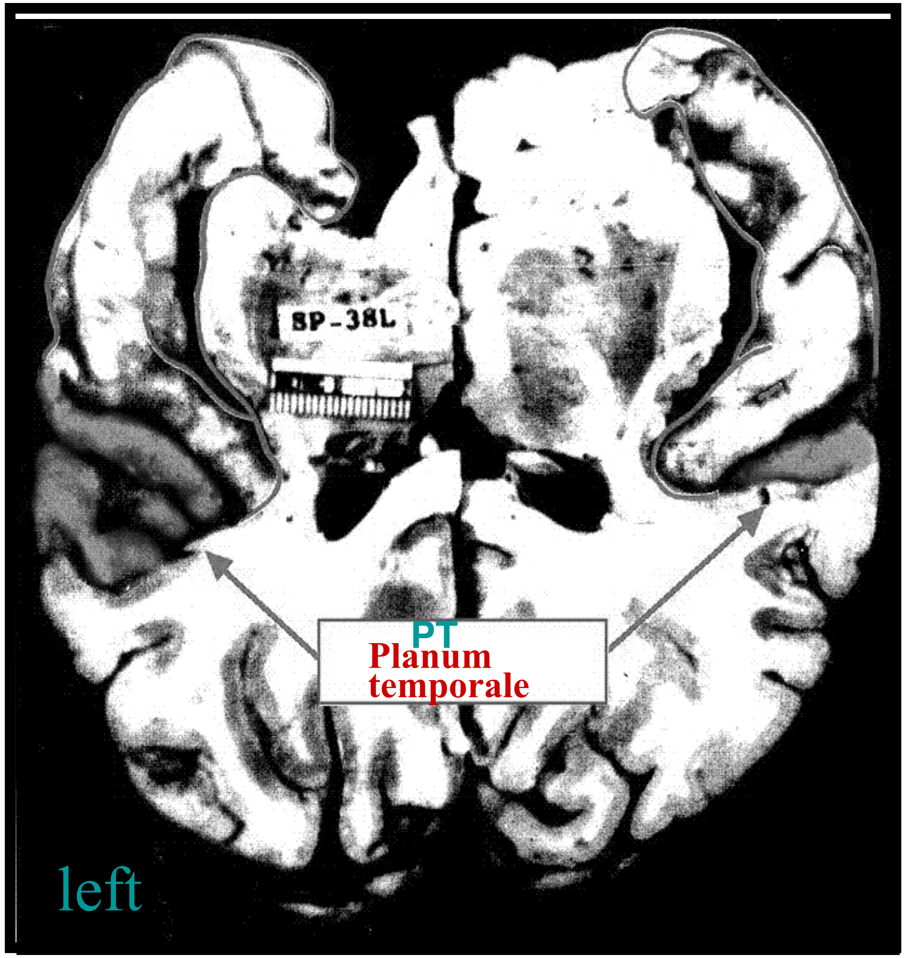
I/ Le cerveau du dyslexique



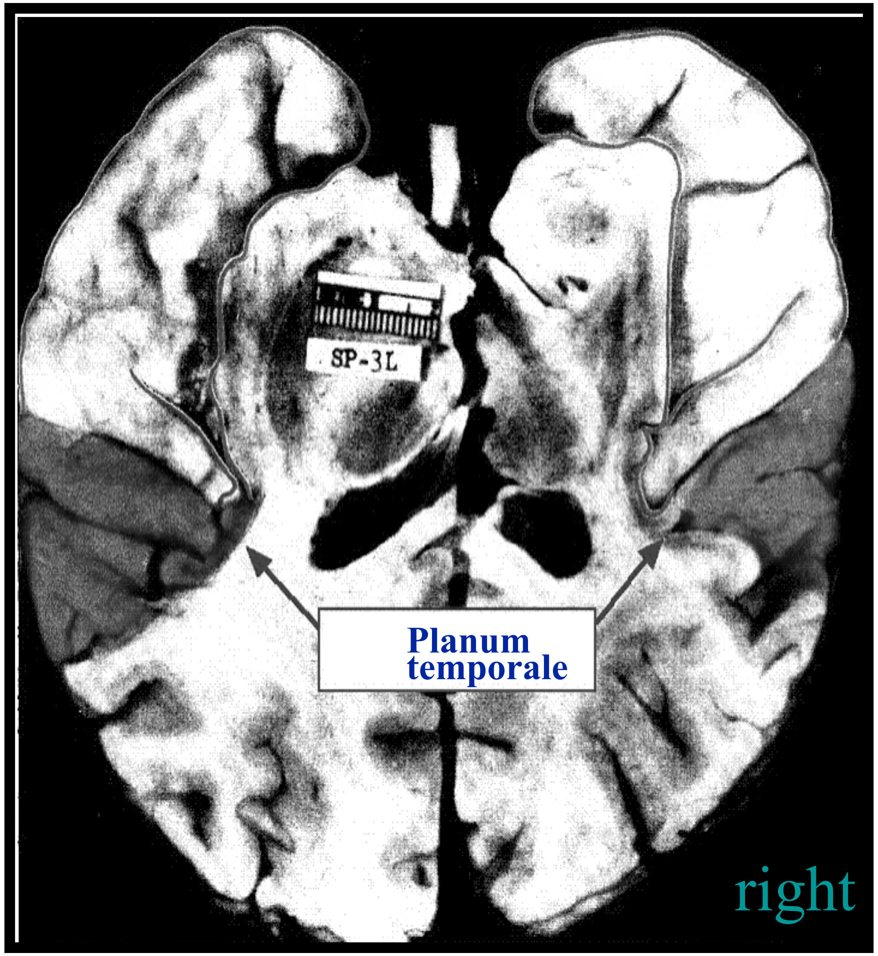


Ectopies sur le cerveau dyslexique
(Galaburda et al., 1979, 1985)


Aire de Wernicke
Planum temporale
G
D



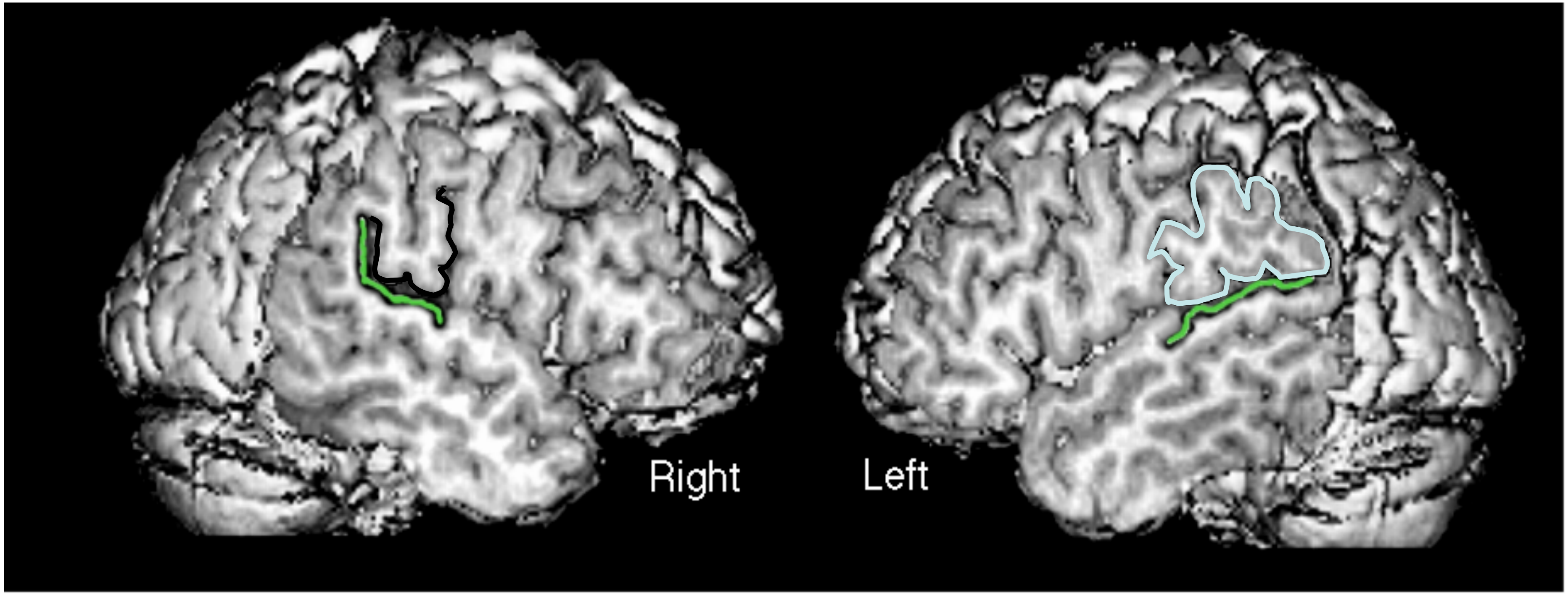
NON DYSLEXIC

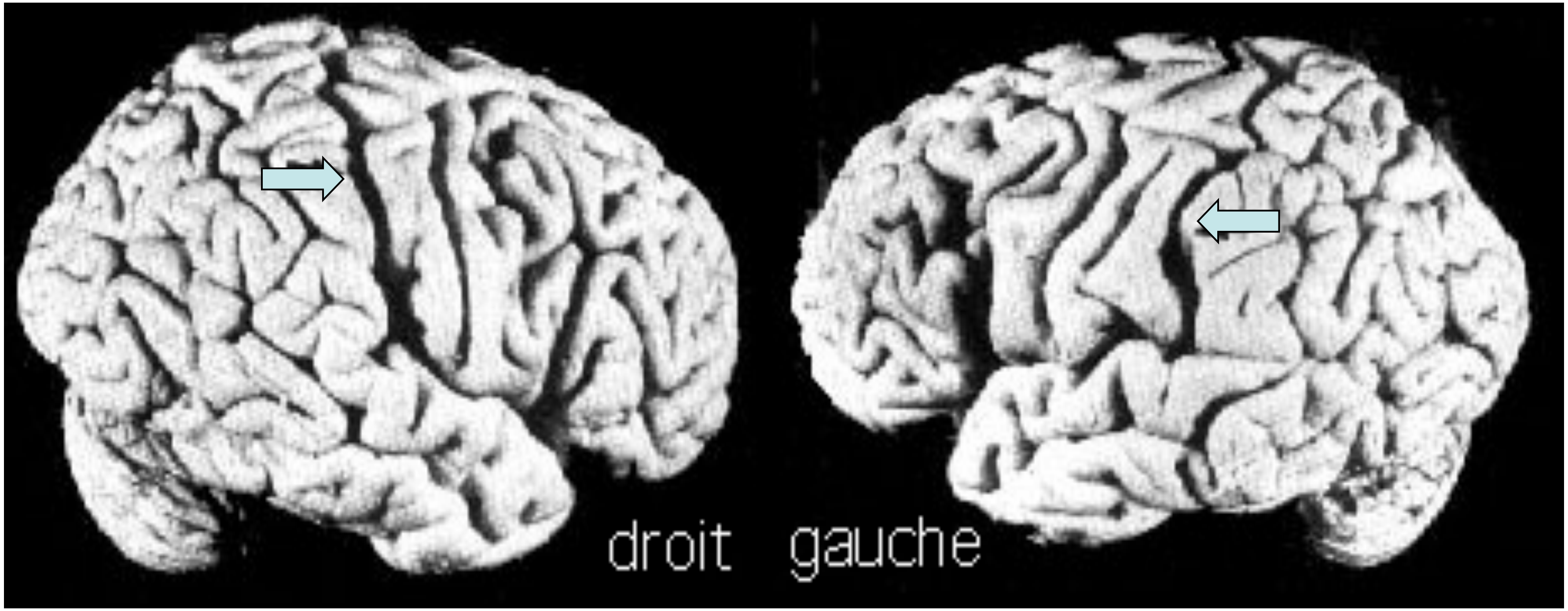


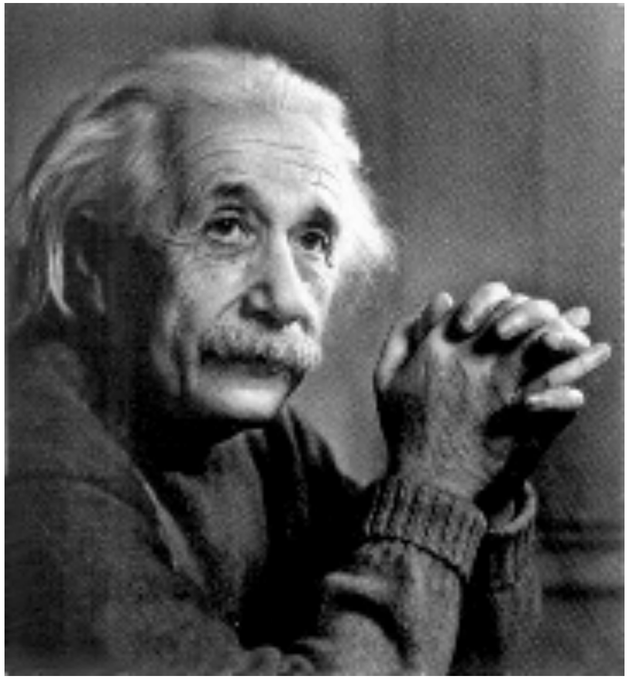
DYSLEXIC

Absence of planum asymmetry in the dyslexic brain
From Galaburda et al., 1979; 1985

Dyslexie : opercule pariétal gauche plus vaste







Einstein's brain : no parietal opercula (from Witelson et al., 1999)

ELSEVIER

Brain and Language xxx (2006) xxx–xxx

www.elsevier.com/locate/b&l

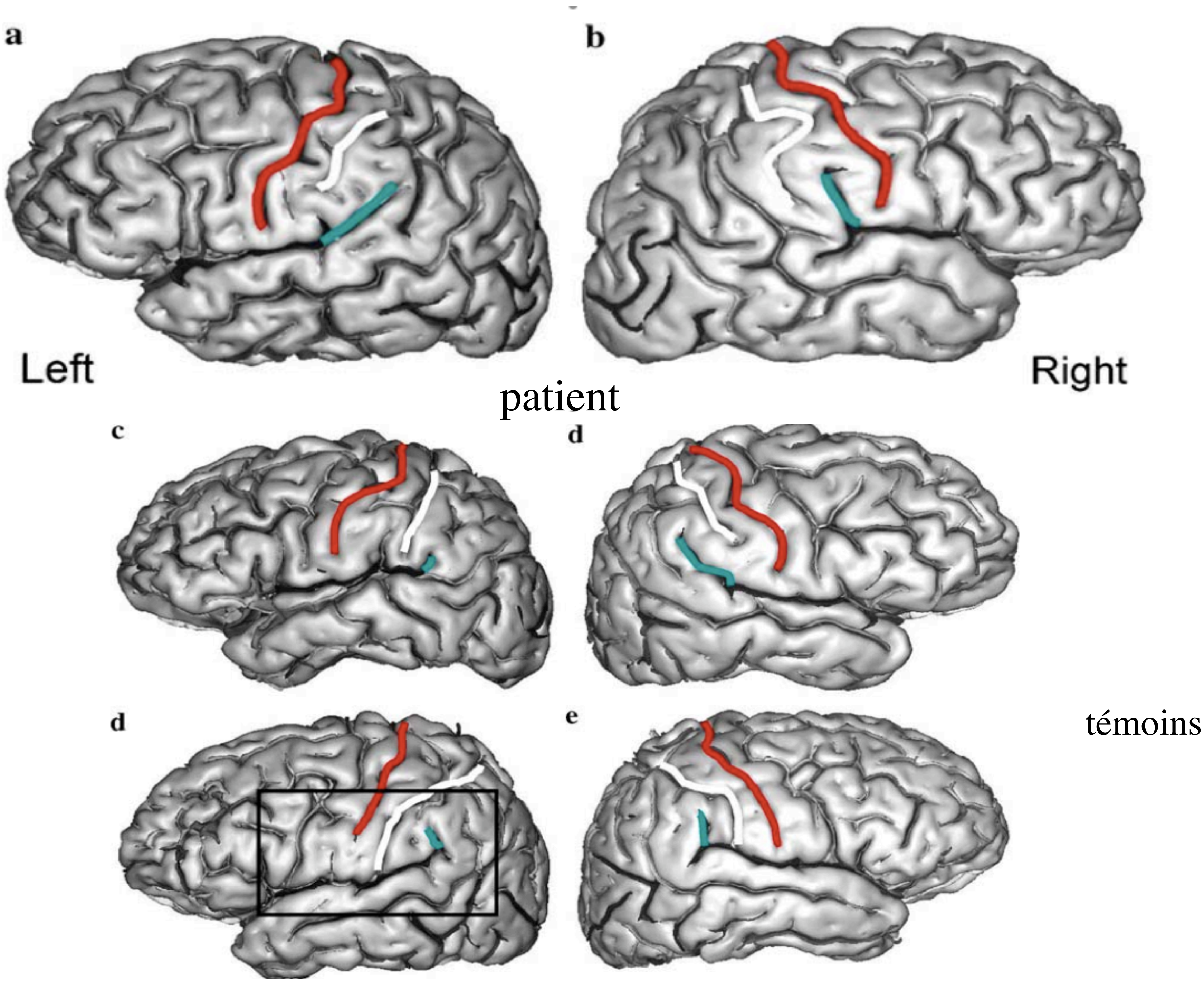
Neuroanatomical and behavioral asymmetry in an adult compensated dyslexic ☆

Christine Chiarello [a,*], Linda J. Lombardino [b], Natalie A. Kacinik [a,c], Ronald Otto [d], Christiana M. Leonard [b]

Table 1
Standardized test results for T.F.

Category	Skill (measure)	Score*	Percentile
Nonverbal IQ	(Ravens Advanced Progressive Matrices)	29	86
Reading	Untimed word reading aloud (WRMT-R Word Identification)	93	32
	Timed word reading aloud (TOWRE Sight Word Efficiency)	83	13
	Untimed nonword reading aloud (WRMT-R Word Attack)	92	29
	Timed nonword reading aloud (TOWRE Phonemic Decoding Efficiency)	94	35
	Word comprehension (WRMT-R Word Comprehension)	109	72
	Text comprehension (WRMT-R Passage Comprehension)	124	95
Spelling	Untimed written spelling of spoken words (WRAT3)	104	61
Grammar	Grammaticality judgment (CASL Grammaticality Judgment)	92	30
	Syntax Construction (CASL Syntax Construction)	100	50
Rapid naming	Letter naming (CTOPP Rapid Letter Naming)	10	50
	Digit naming (CTOPP Rapid Digit Naming)	10	50
Span memory	(WAIS-R Digits Forward)	11	52
	(WAIS-R Digits Backward)	6	14
Math	Timed arithmetic computations (WJ COG III Math Fluency)	96	39
	Untimed computations and solving equations (WJ COG III Calculation)	112	78

* Note: Scores listed are standard scores for all tests except WAIS digit spans, and Raven's Matrices.


a
b
Left
Right
patient
c
d
d
e
témoins

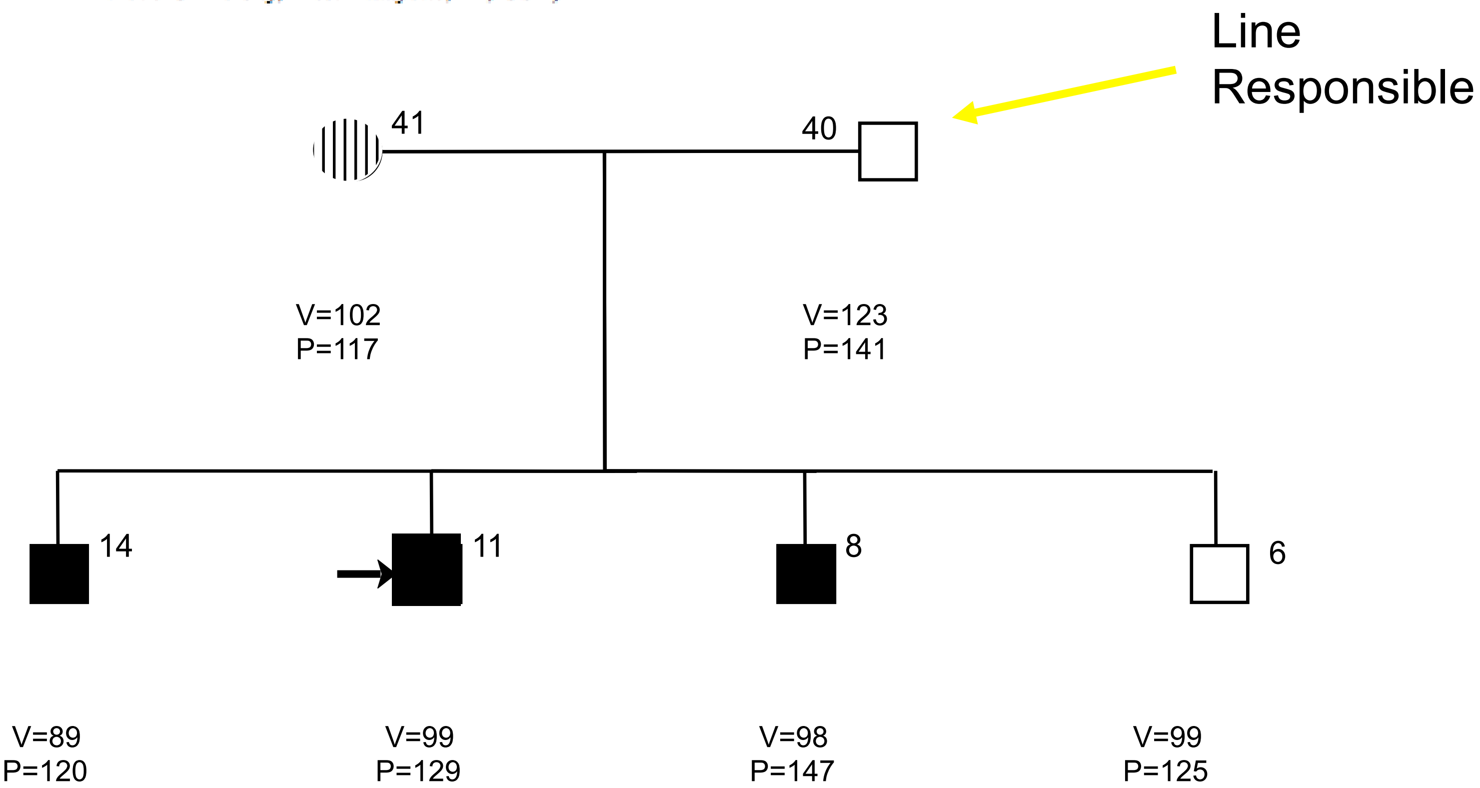
RESEARCH REPORT

Cortex, (2006) 42, 1107-1118

BRAIN MORPHOLOGY AND NEUROPSYCHOLOGICAL PROFILES IN A FAMILY DISPLAYING DYSLEXIA AND SUPERIOR NONVERBAL INTELLIGENCE

Jason G. Craggs[1], Juliana Sanchez[1], Michelle Y. Kibby[2], Jeffrey W. Gilger[3] and George W. Hynd[4]

([1]Center for Clinical and Developmental Neuropsychology, University of Georgia, Athens, GA, USA; [2]Washington State University, Pullman, WA, USA; [3]California State University, Los Angeles, CA, USA; [4]Purdue University, West Lafayette, IN, USA)



V = Verbal IQ

P = Performance IQ

Unaffected – No linguistic deficit

RD status unclear

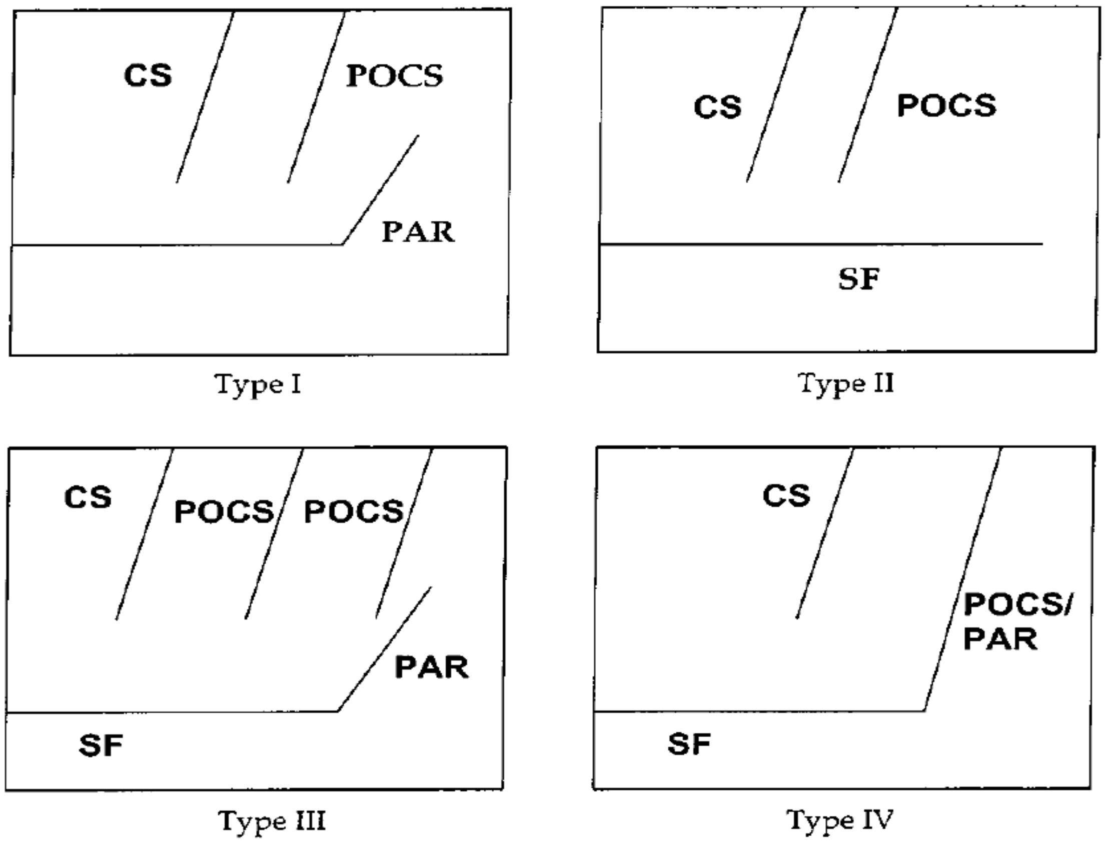
RD

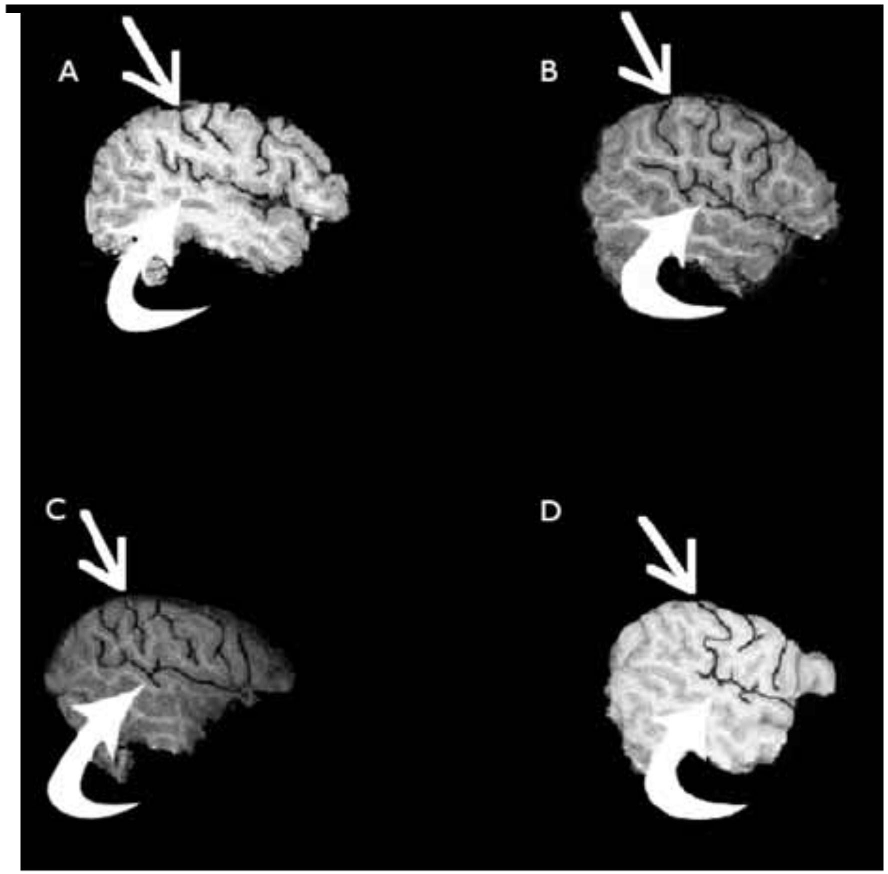
TABLE II

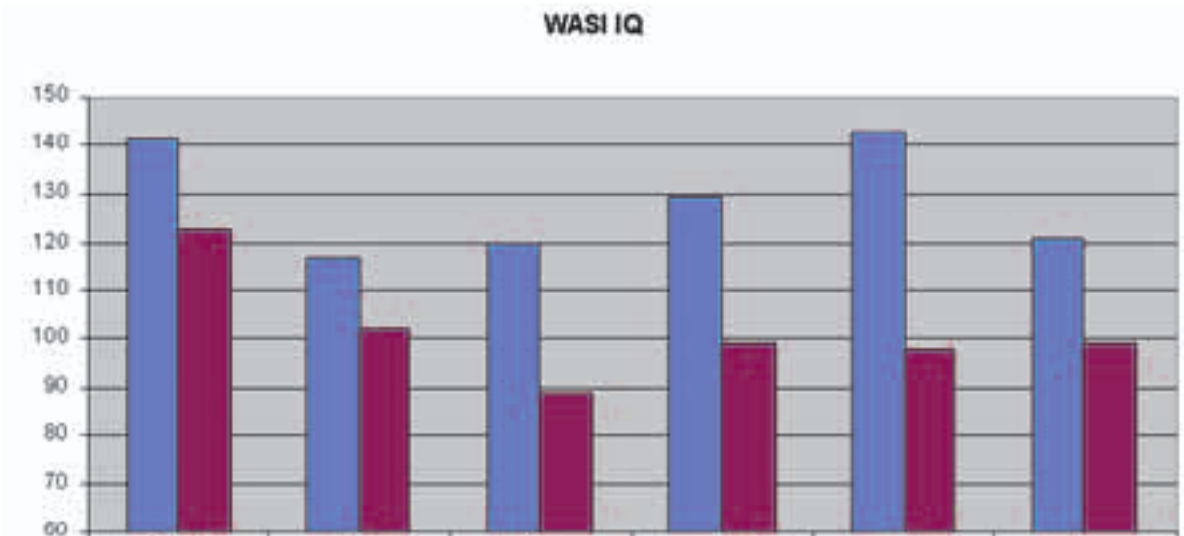
Frequency of typology presentation in Steinmetz et al.'s (1990) sample

Type	Left hemisphere (62)	Right hemisphere (58)	Overall (120)
I	41 (66%)	48 (83%)	89 (74.16%)
II	9 (15%)	–	9 (7.5%)
III	10 (16%)	2 (3%)	12 (10%)
IV	2 (3%)	8 (14%)	10 (8.33%)

Note: Reported frequencies are combined from post-mortem and MRI data.
Parentheses indicate number of hemispheres used.







	Dad	Mom	D	M	J	L
PIQ	141	117	120	129	143	121
VIQ	123	102	89	99	98	99

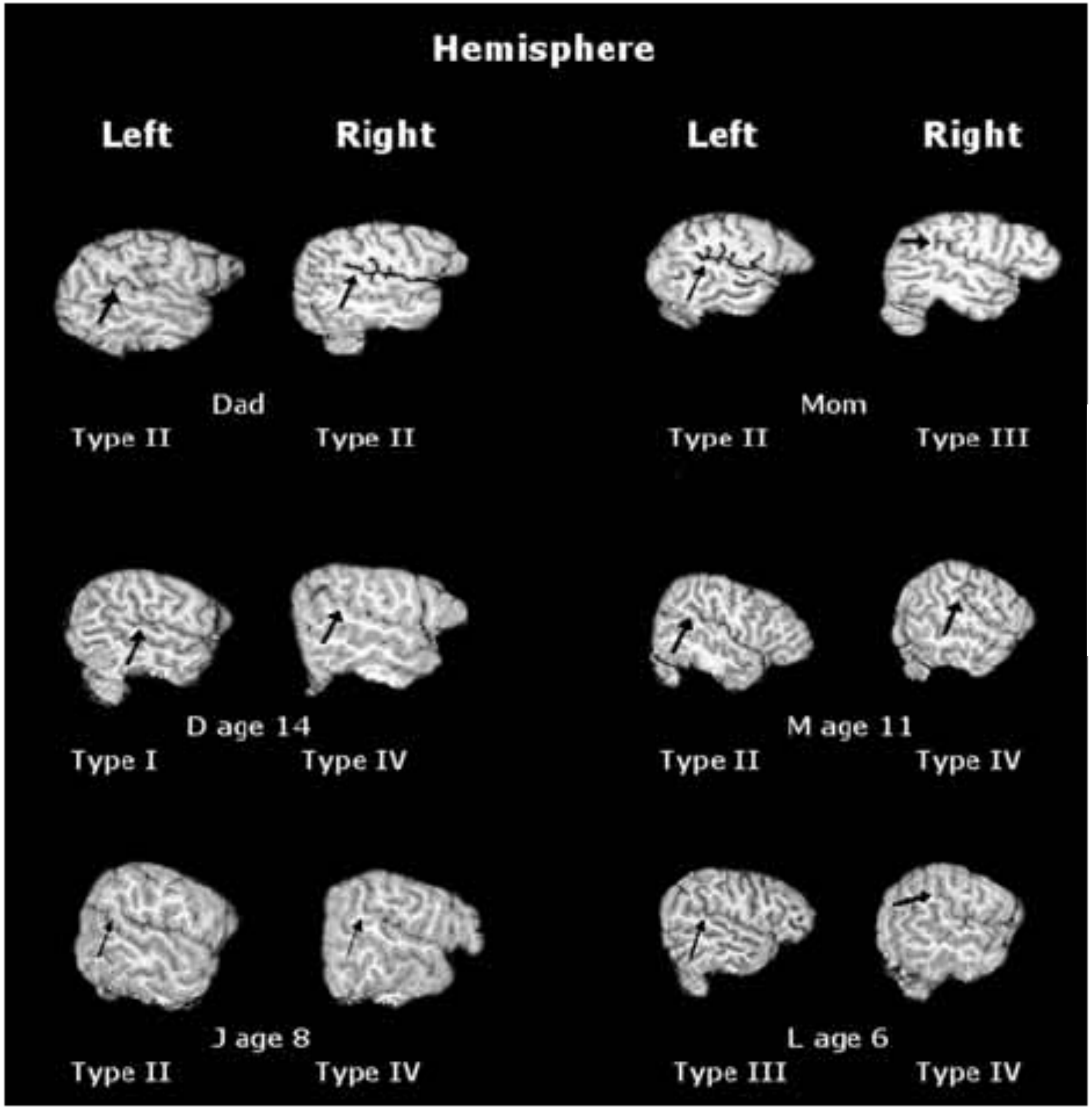
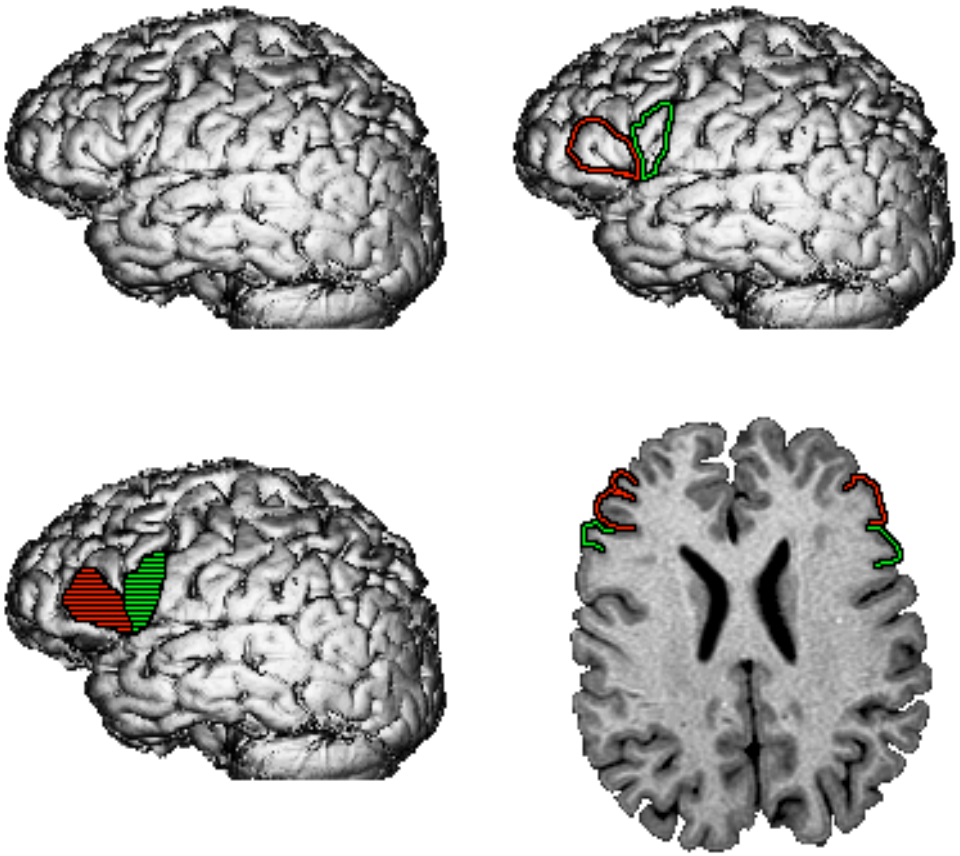
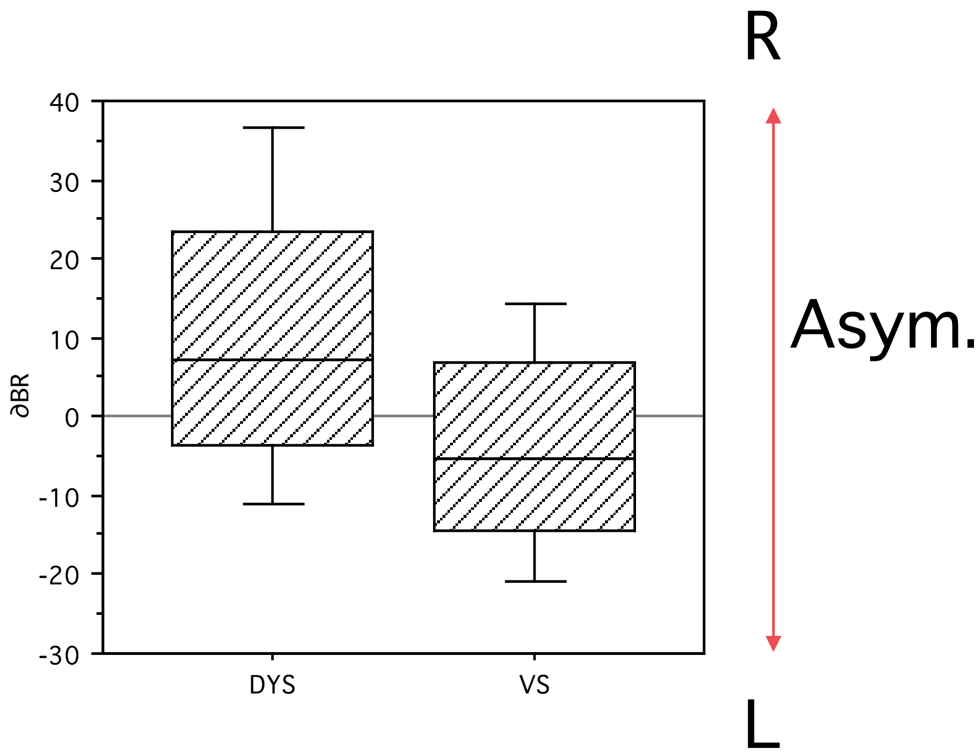


TABLE X

Steinmetz et al. (1990) prevalence rates in the current family

	Left hemisphere	Right hemisphere	Overall
Type I	16%	0	8%
Type II	67%	16%	42%
Type III	16%	16%	17%
Type IV	0	67%	33%





Robichon et al. (2000) : réduction (inversion) d’asymétrie de l’aire de Broca chez les adultes dyslexiques

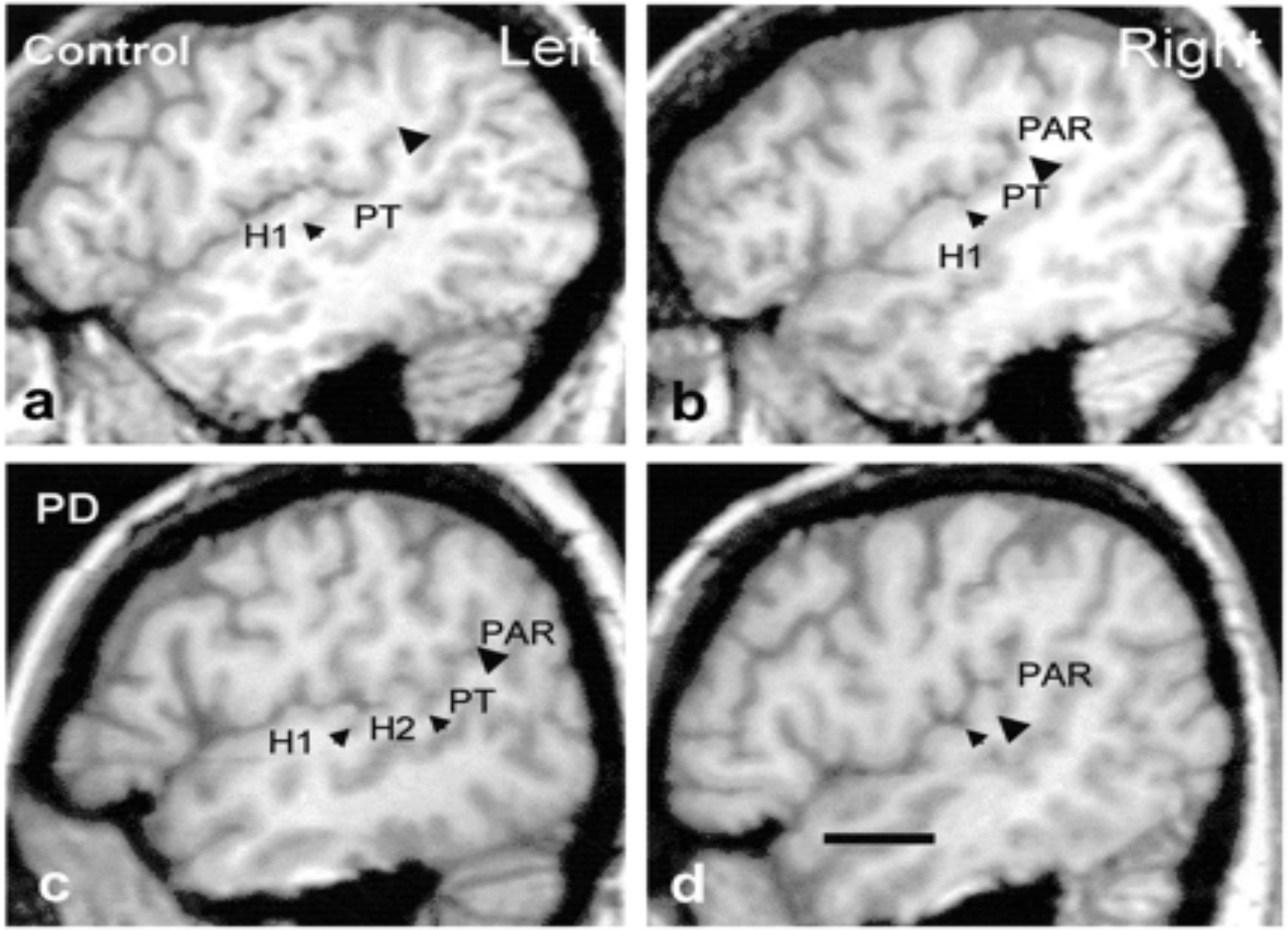
Anatomical Risk Factors for Phonological Dyslexia

Christiana M. Leonard, Mark A. Eckert, Linda J. Lombardino[1], Thomas Oakland[2], John Kranzler[2], Cecile M. Mohr, Wayne M. King and Alan Freeman

Department of Neuroscience, [1]Department of Communication Sciences and Disorders, and [2]Department of Education Foundations, University of Florida Brain Institute, Gainesville, FL 32611, USA

Leonard et al. (2001) : extreme leftward asymmetry of temporal and parietal cortices

(15 college students vs 15 dyslexic adolescents)



Cerebral Cortex Feb 2001;11:148–157; 1047–3211/01/$4.00

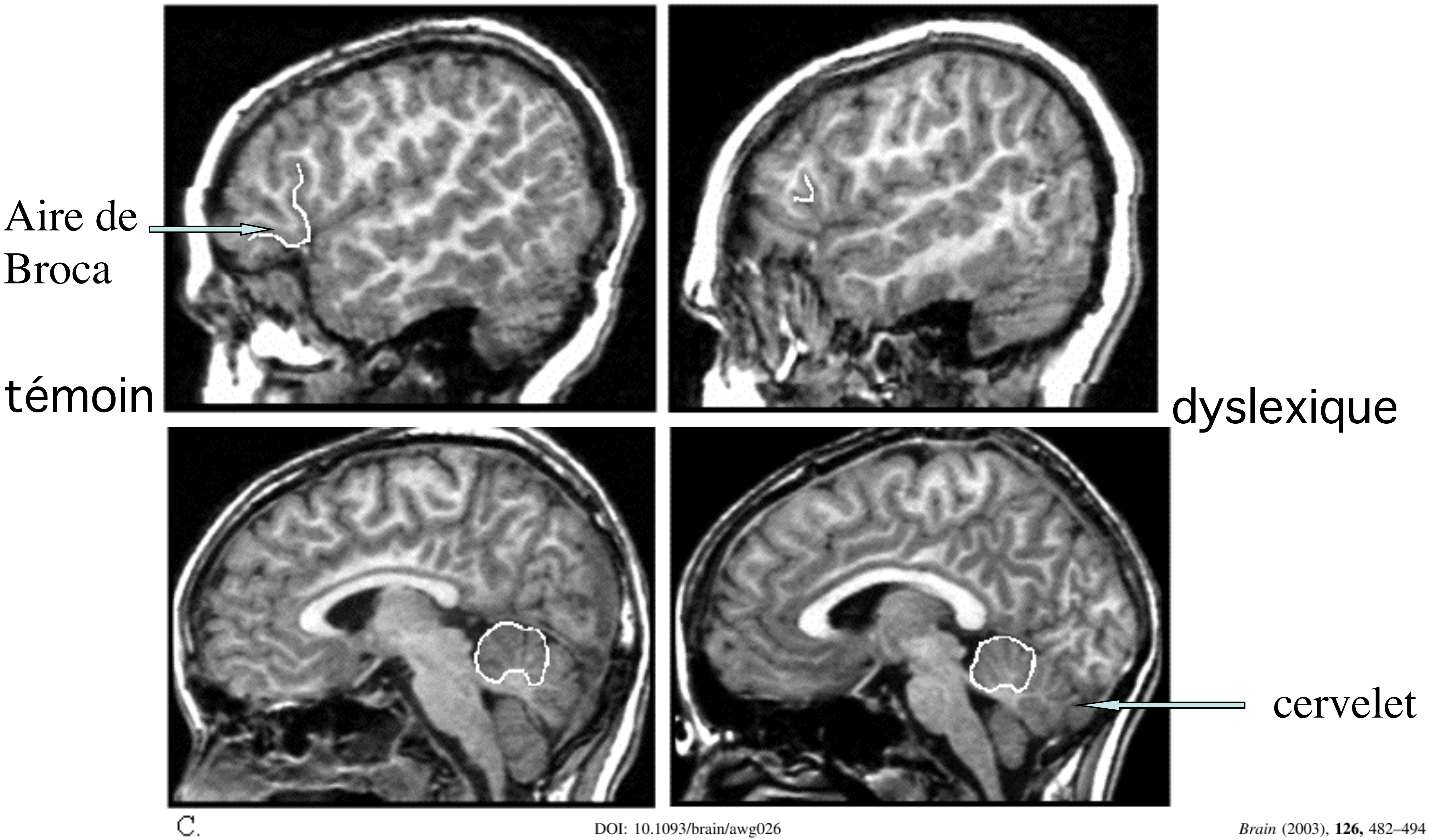
DOI: 10.1093/brain/awg026 *Brain* (2003), **126,** 482–494

Anatomical correlates of dyslexia: frontal and cerebellar findings

Mark A. Eckert,[1] Christiana M. Leonard,[1] Todd L. Richards,[2] Elizabeth H. Aylward,[2] Jennifer Thomson[3] and Virginia W. Berninger[3]

[1]*Department of Neuroscience, McKnight Brain Institute of the University of Florida, Gainesville, FL, Departments of* [2]*Radiology and* [3]*Education, University of Washington, Seattle, WA, USA*

Correspondence to: Mark Eckert, PO Box 100244, Department of Neuroscience, University of Florida McKnight Brain Institute, Gainesville, FL 32610, USA
E-mail: eckert@ufl.edu

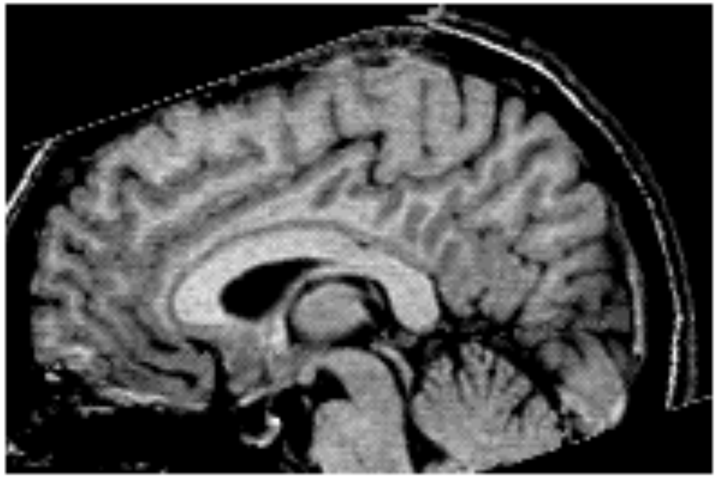


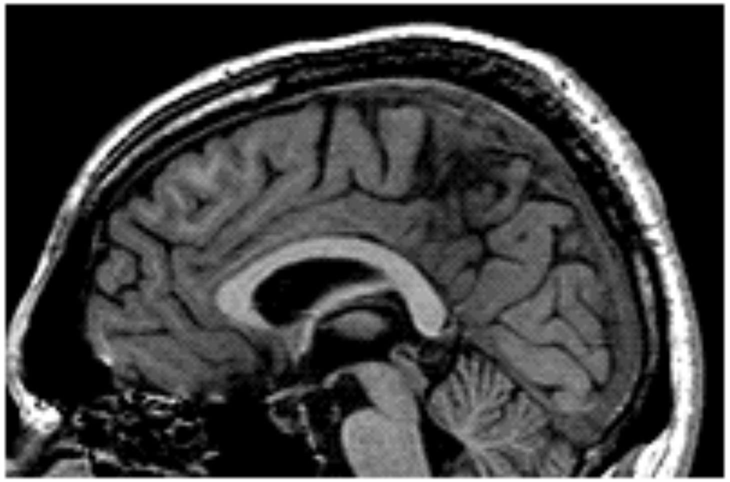
DOI: 10.1093/brain/awg026 *Brain* (2003), **126,** 482–494

Anatomical correlates of dyslexia: frontal and cerebellar findings

Mark A. Eckert,[1] Christiana M. Leonard,[1] Todd L. Richards,[2] Elizabeth H. Aylward,[2]
Jennifer Thomson[3] and Virginia W. Berninger[3]

Hypertrophie du corps calleux





dyslexique (2136) **témoin**

PERGAMON

Neuropsychologia 40 (2002) 1035–1044

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Less developed corpus callosum in dyslexic subjects—a structural MRI study

Kerstin von Plessen[a,*], Arvid Lundervold[b], Nicolae Duta[c], Einar Heiervang[a], Frederick Klauschen[b], Alf Inge Smievoll[d], Lars Ersland[e], Kenneth Hugdahl[f]

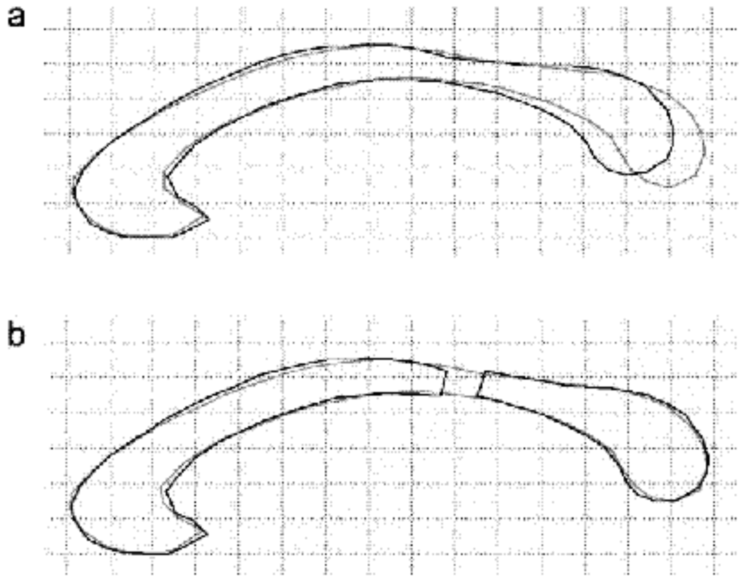


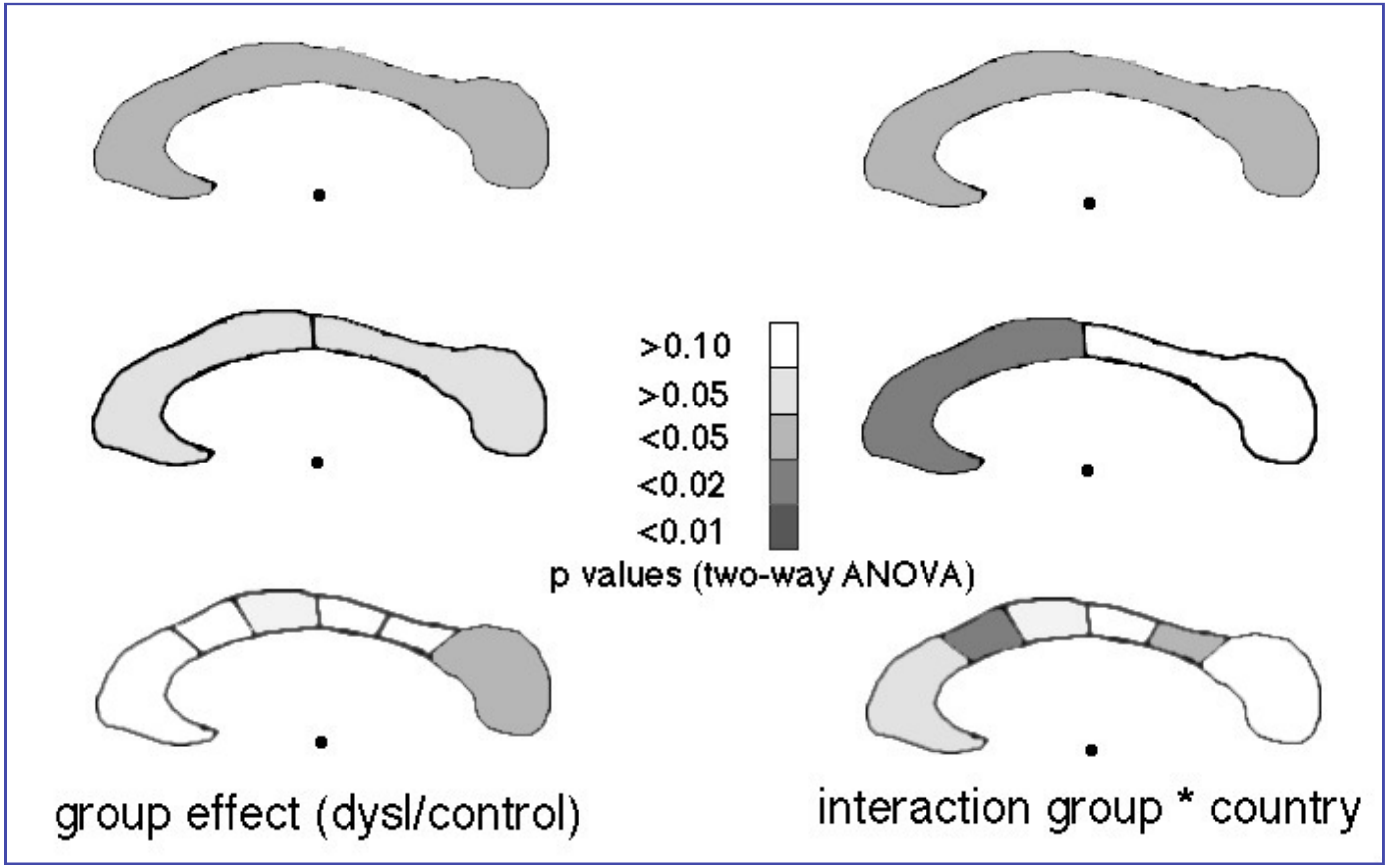
Fig. 4. Comparing the control (shown in grey) and dyslexic (shown in black) average CC shapes (prototypes) (a). The dyslexic prototype is cut into two pieces that are aligned separately at rostrum and splenium (b). The posterior midbody region in the dyslexic subjects is significantly shorter than in the control subjects.

Areas analysis : No areal differences
Shape analysis : shorter posterior midbody

Table 2
Mean values (SD) for CC area measurements

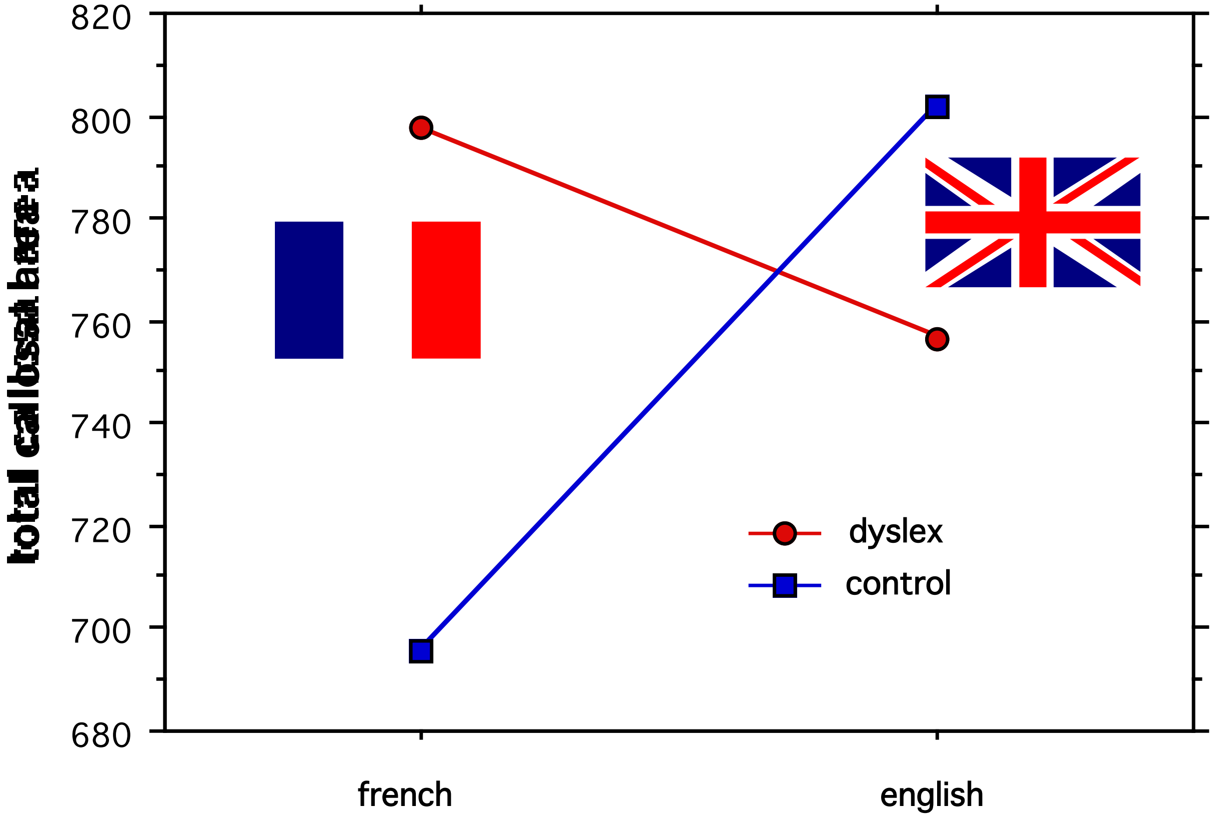
	Dyslexic group, n =20 (mm^2)	Control group, n = 20 (mm^2)
Total CC area	662.6 (79.9)	659.85 (99.9)
Midsagittal cortical brain area	10582 (781)	10999 (838)
Anterior third	294.9 (41.9)	288.3 (49.1)
Mid-third	135.2 (20.1)	138.8 (23.7)
Posterior third	225.6 (34.5)	232.9 (38.5)

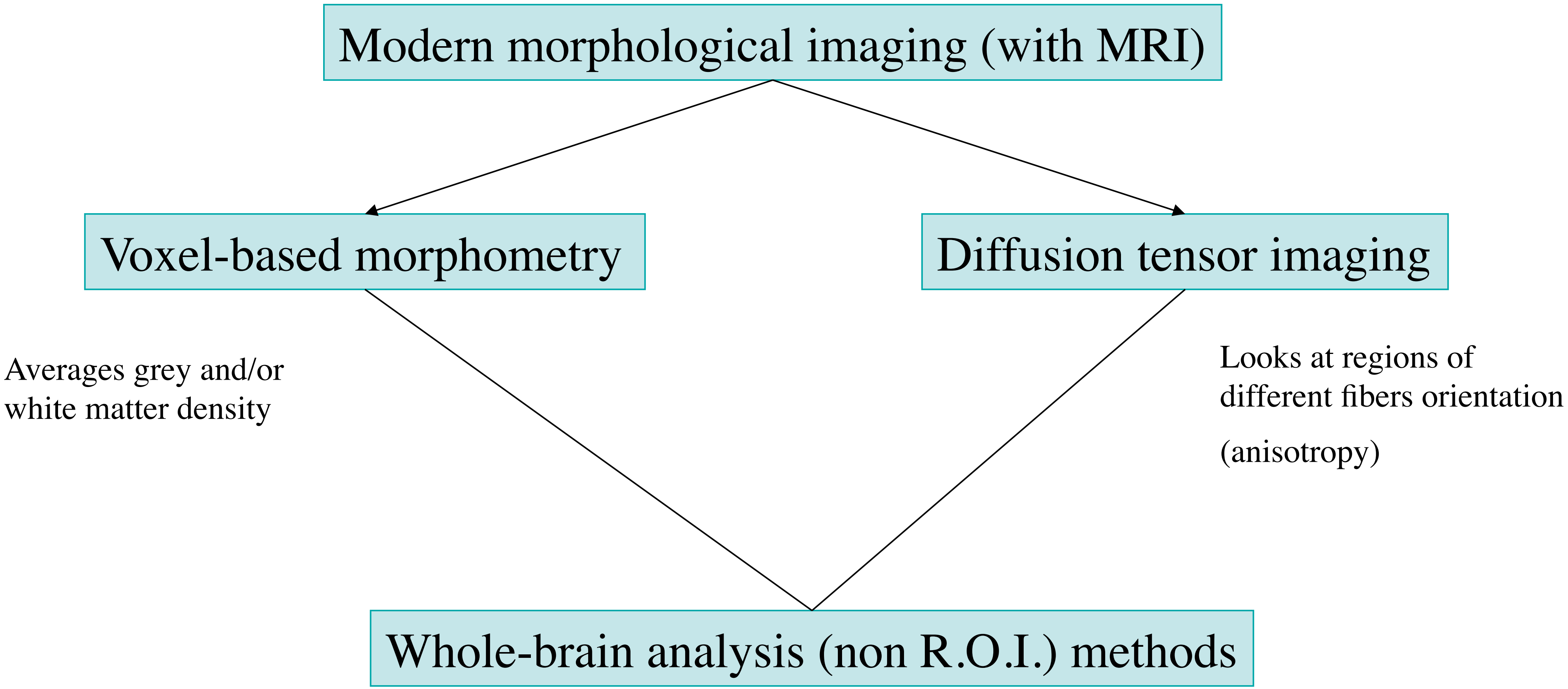
Effect of group (DYS/CONT) and country (FR/ENGL) on callosal size



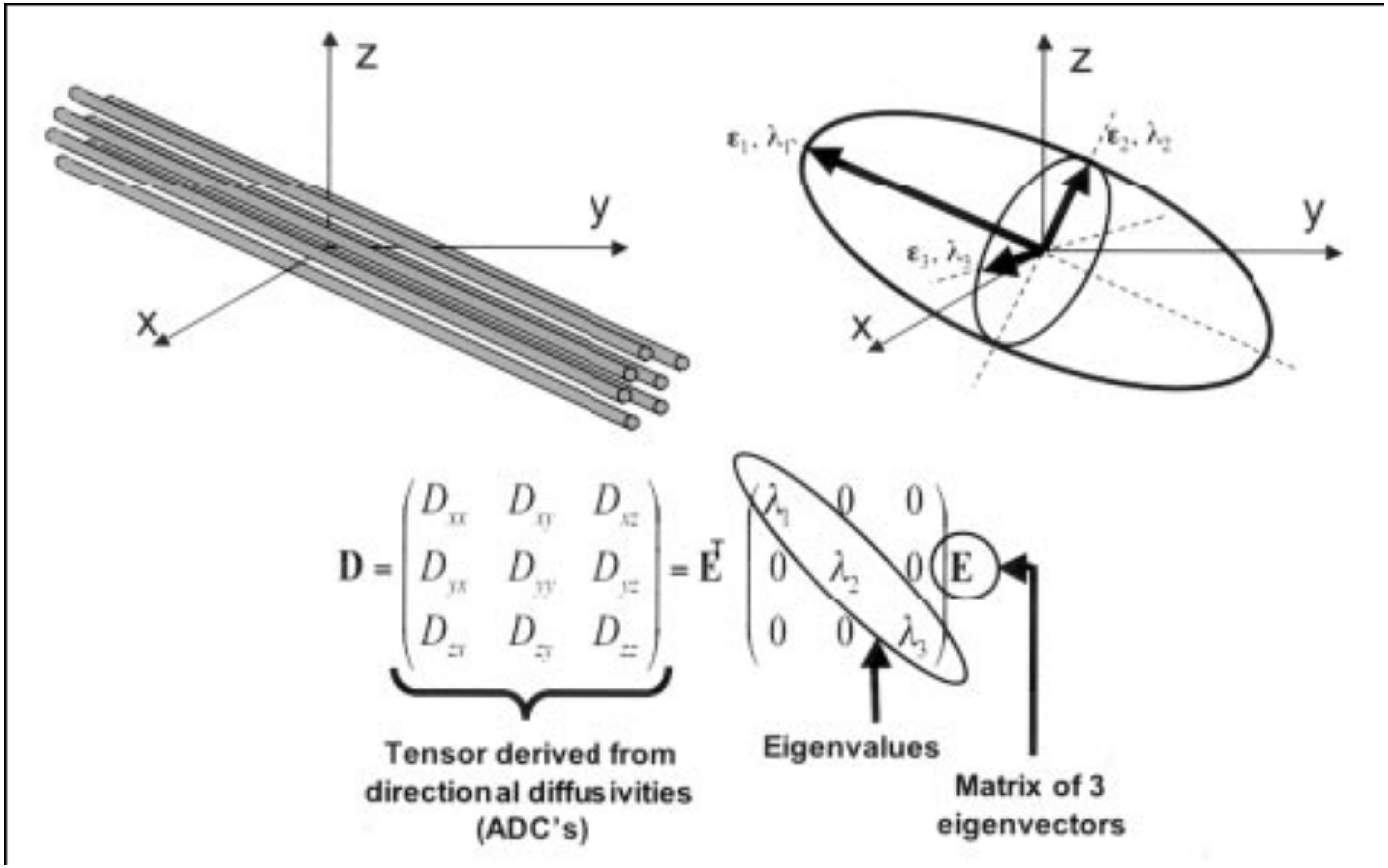
Total callosal area : group x country interaction

$F(1,60)=9.337; p=0.033$

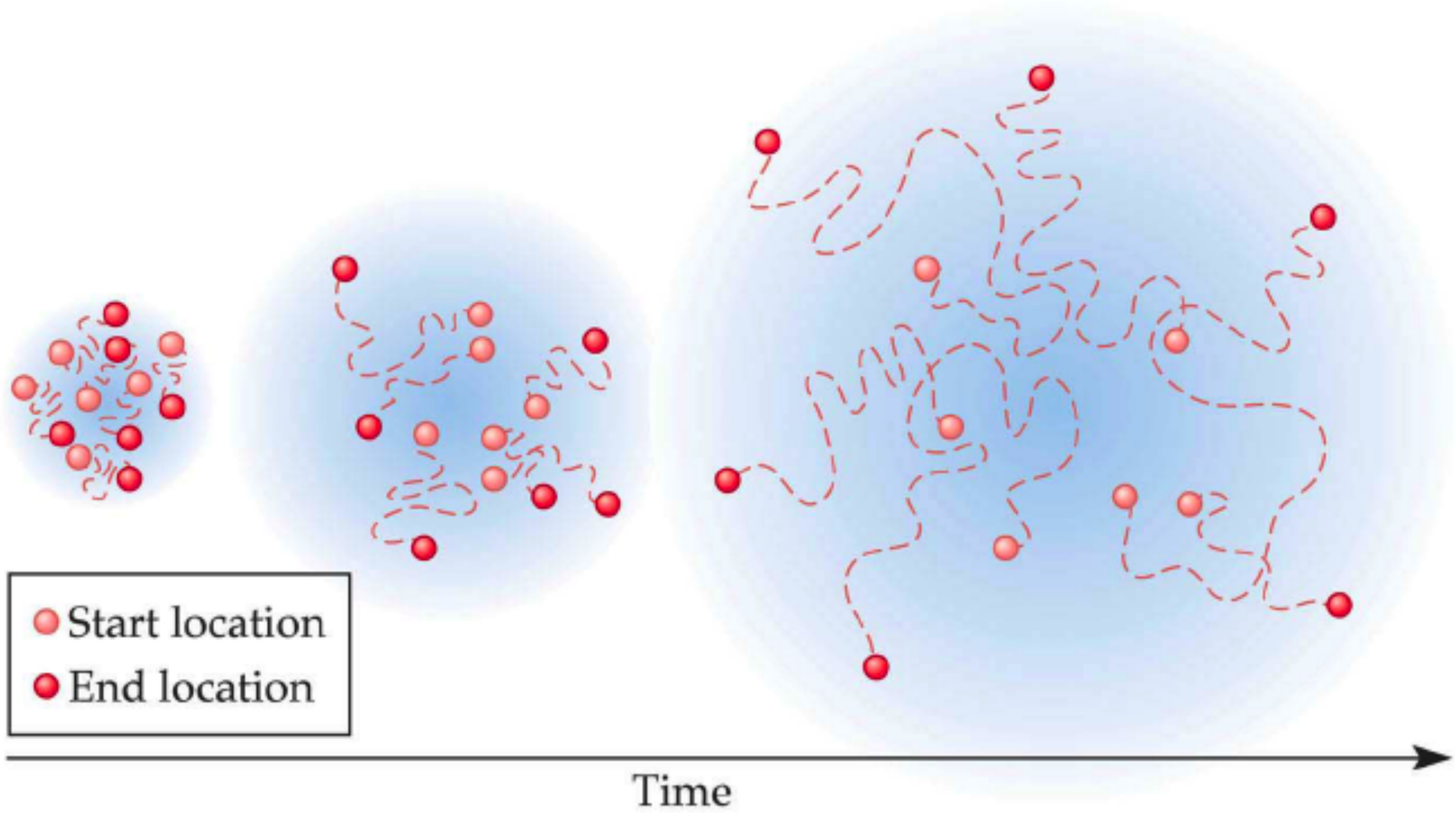



Modern morphological imaging (with MRI)
Voxel-based morphometry
Diffusion tensor imaging
Averages grey and/or white matter density
Looks at regions of different fibers orientation (anisotropy)
Whole-brain analysis (non R.O.I.) methods

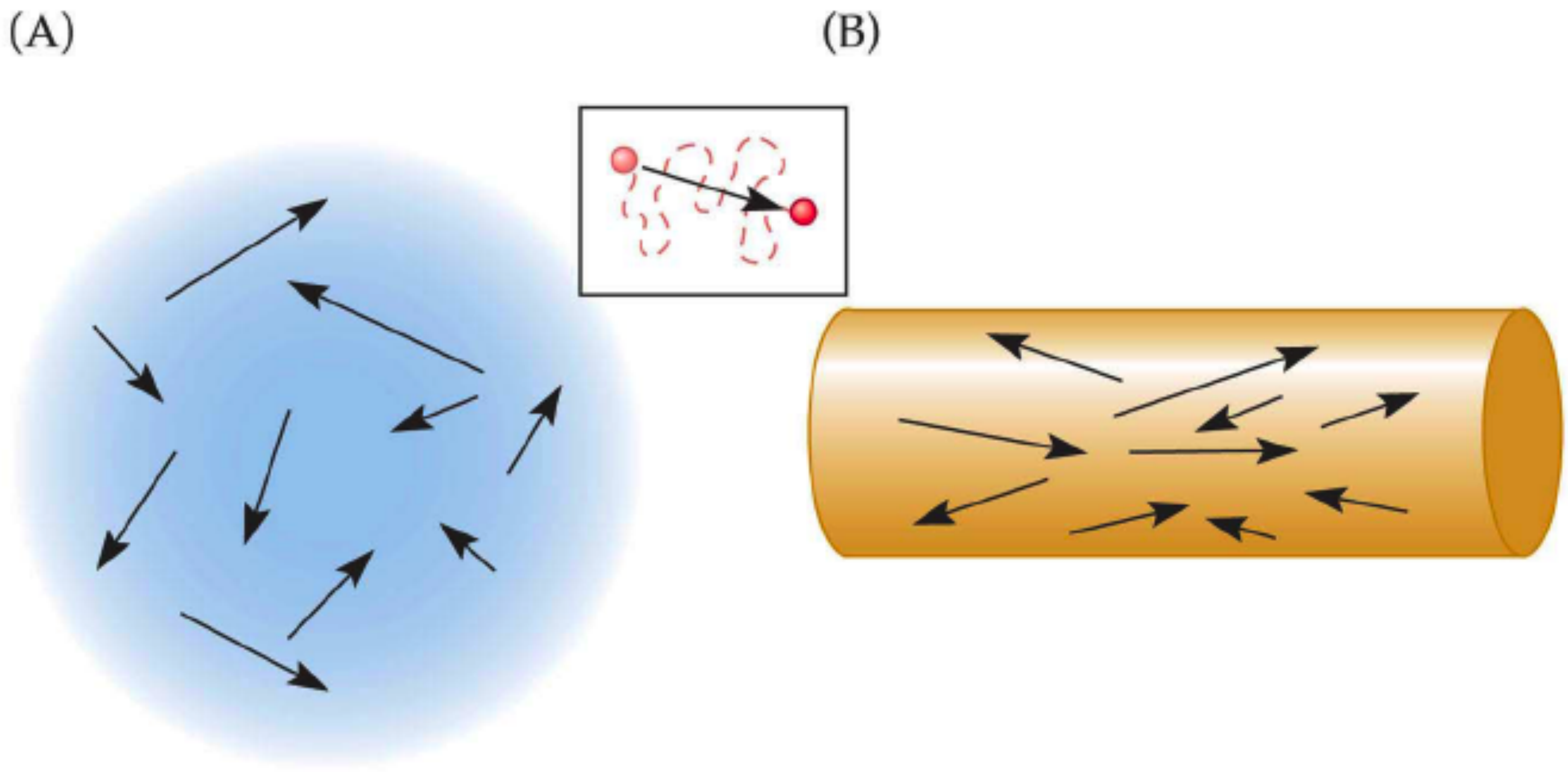
Diffusion Anisotropy



5.17 Diffusion. Over time, molecules within gases or liquids will move freely through the medium.

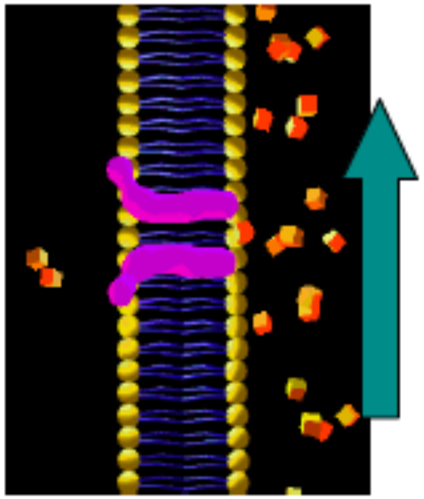


5.18 Isotropic and anisotropic diffusion.

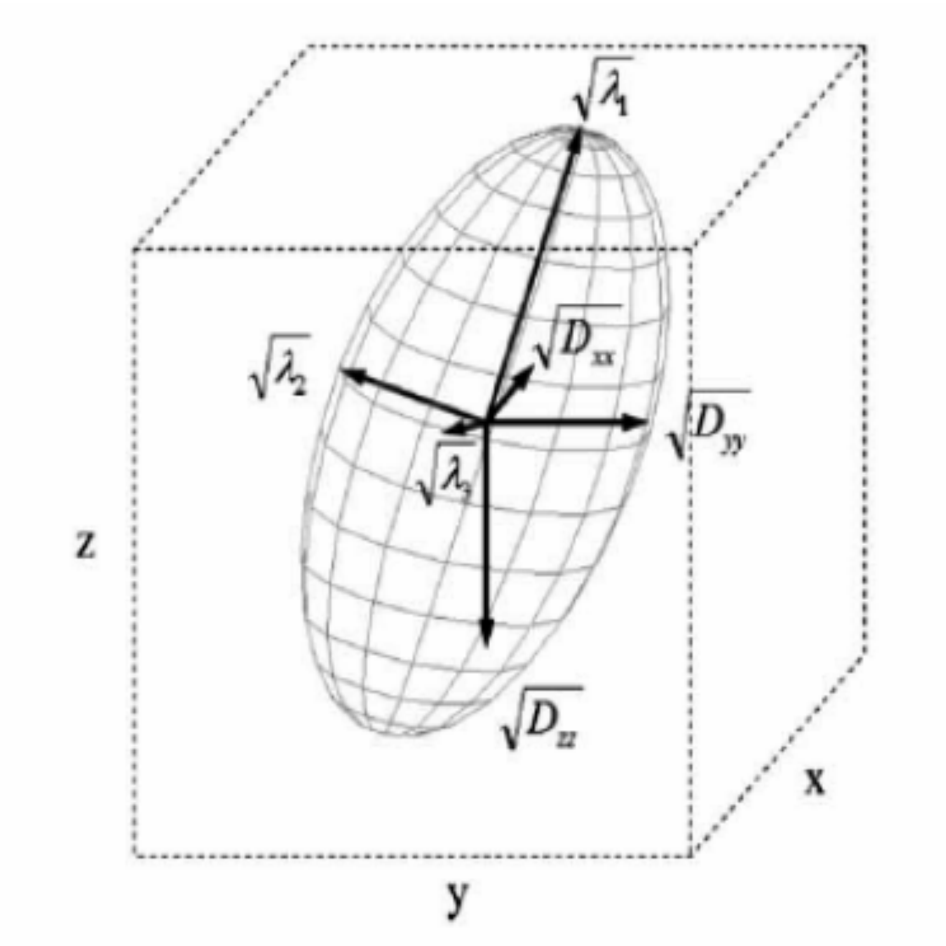


H_2O Diffusion Probes Microscopic Structures In the Brain

Along the axon, within the cytoskeleton, there is a large Apparent Diffusion Coefficient (ADC)



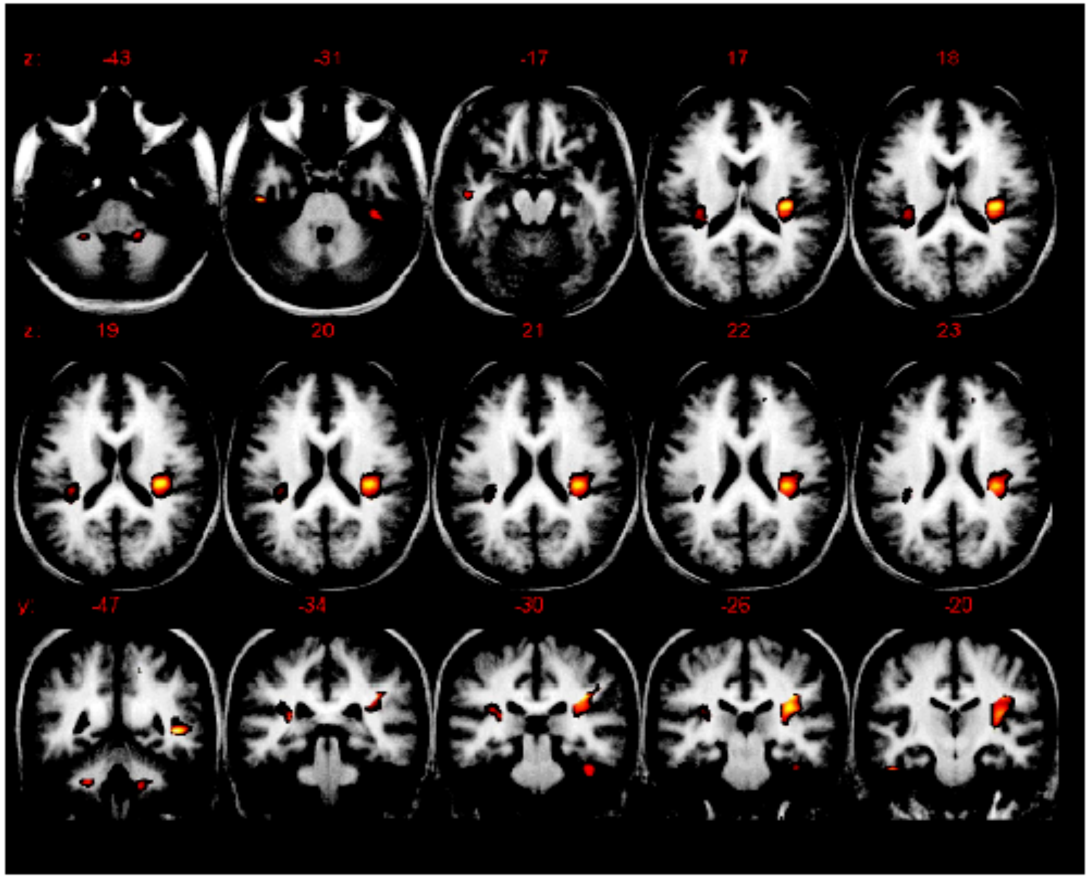
Mathematical Description:
An Ellipsoid (Diffusion Tensor)



This surface summarizes the mean distance from the starting position that a typical particle (water molecule) will travel in diffusion time T = ½

Regional reductions of gray matter volume in familial dyslexia

S.M. Brambati, BS; C. Termine, MD; M. Ruffino, BS; G. Stella, PhD; F. Fazio, MD; S.F. Cappa, MD; and D. Perani, MD



- •10 dyslexic subjects (5 females, 5 males; age range 13 to 57 years, mean 31.6 years) belonging to four different families characterized by the presence of a proband with persistent, severe developmental

dyslexia

- •11 matched controls
- •Regions of reduction in grey matter volume
  - •PT bilat
  - •inferior temporal bilat
  - •Left sup and inf tempor gyrus

NEUROLOGY 2004;63:742–745

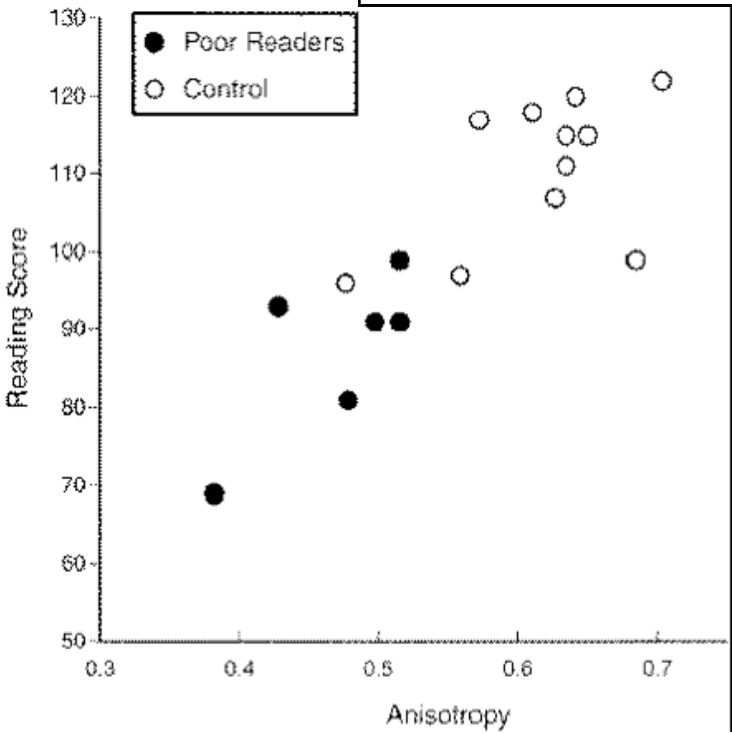
Neuron, Vol. 25, 493–500, February, 2000, Copyright ©2000 by Cell Press

Microstructure of Temporo-Parietal White Matter as a Basis for Reading Ability: Evidence from Diffusion Tensor Magnetic Resonance Imaging

Torkel Klingberg,*§ Maj Hedehus,† Elise Temple,*
Talya Salz,*‡ John D. E. Gabrieli,*†
Michael E. Moseley,† and Russell A. Poldrack*
*Department of Psychology
†Department of Radiology
Stanford University
Stanford, California 94305
‡Scientific Learning Corporation
Berkeley, California 94704

VOI of maximal anisotropy difference between 6 adult dyslexic and 11 controls

Significant correlation with reading scores



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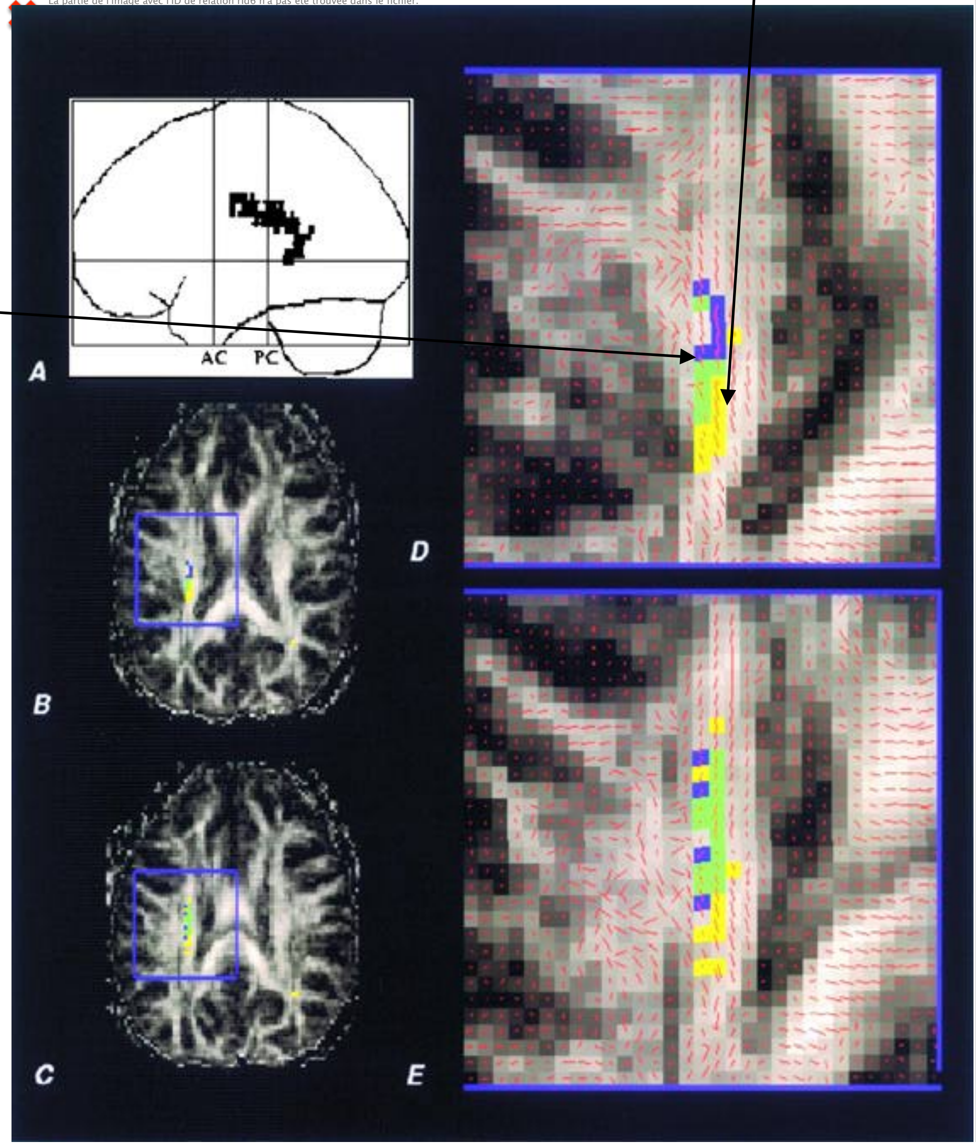
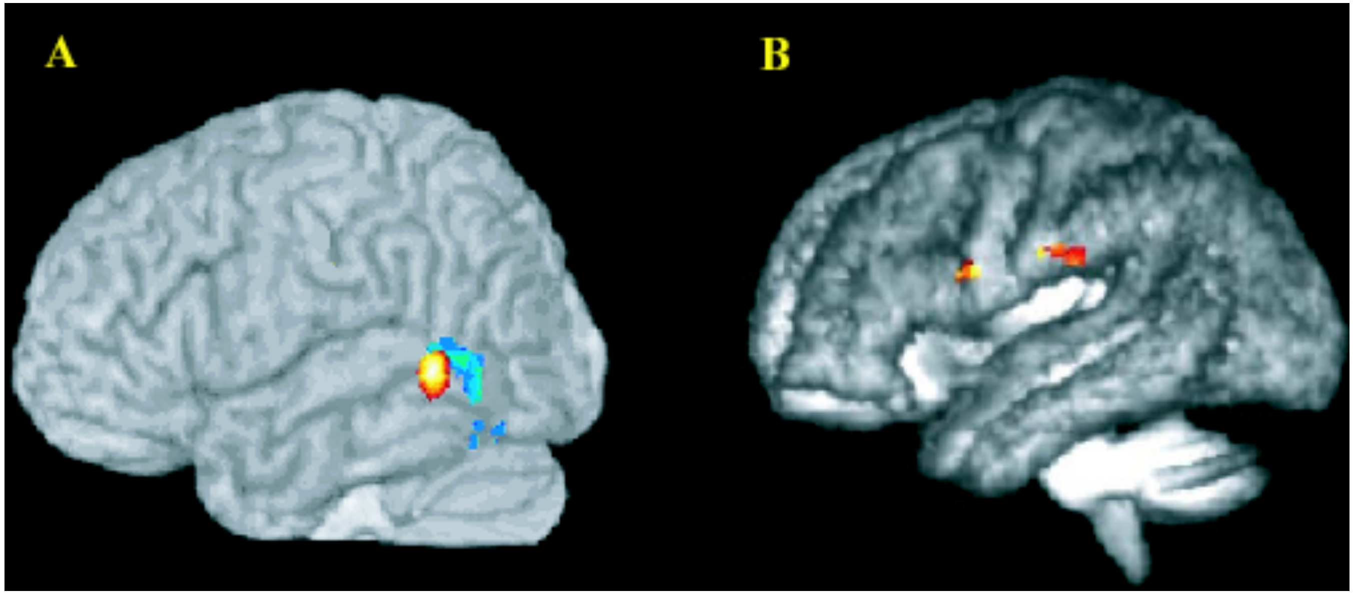


doi:10.1093/brain/awh579

Brain abnormalities underlying altered activation in dyslexia: a voxel based morphometry study

G. Silani,[1] U. Frith,[2] J.-F. Demonet,[3] F. Fazio,[4,5,6] D. Perani,[7] C. Price,[8] C. D. Frith[8] and E. Paulesu[1]



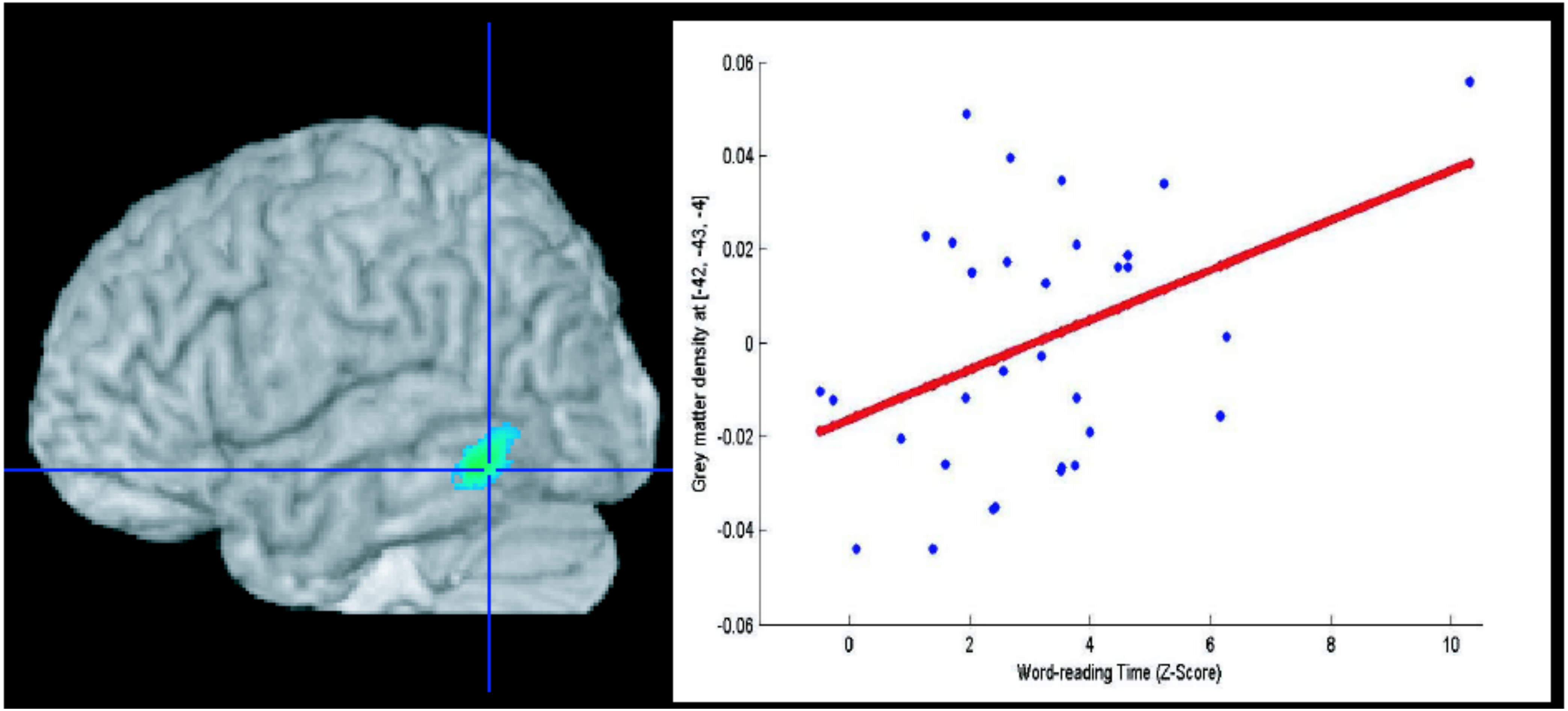
decrease

increase

decrease

Gray matter dyslex/controls

White matter dyslex/controls



Silani et al. (2005) : a lateral temporal zone of increased voxel density correlates inversely with reading performance

CHILDREN'S READING PERFORMANCE IS CORRELATED WITH WHITE MATTER STRUCTURE MEASURED BY DIFFUSION TENSOR IMAGING

Gayle K. Deutsch[1*], Robert F. Dougherty[1], Roland Bammer[2], Wai Ting Siok[1], John D.E. Gabrieli[1] and Brian Wandell[1]

([1]Department of Psychology, Stanford University, Stanford, CA, USA; [2]Department of Radiology, Stanford University, Stanford, CA, USA)

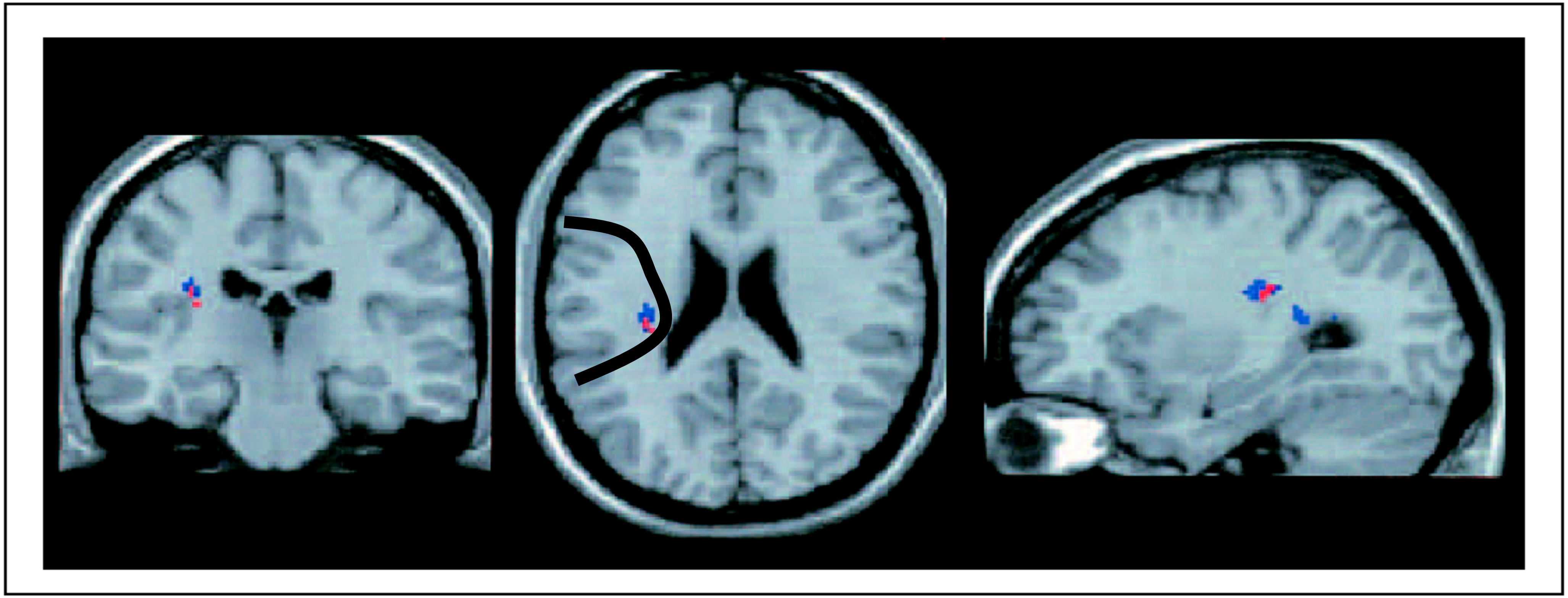
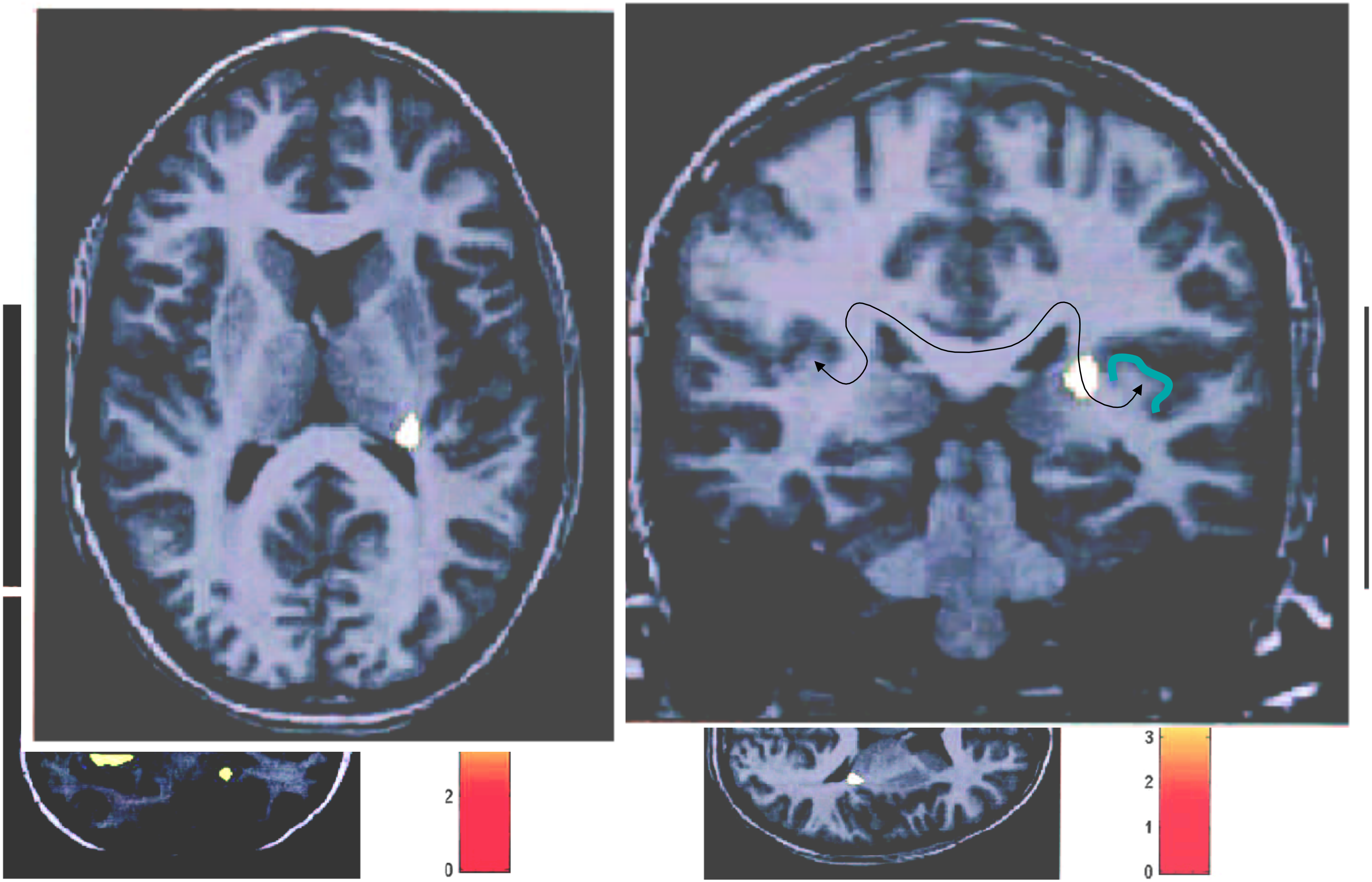


Fig. 1 – *Brain regions that showed significant differences in normal and poor reading children are presented. Left temporo-parietal regions are shown in three slices of the SPM99 T1 canonical brain. Red indicates voxels with significant group differences in FA and blue indicates voxels with significant differences in CI.*

ANATOMICAL SIGNATURES OF DYSLEXIA IN CHILDREN:



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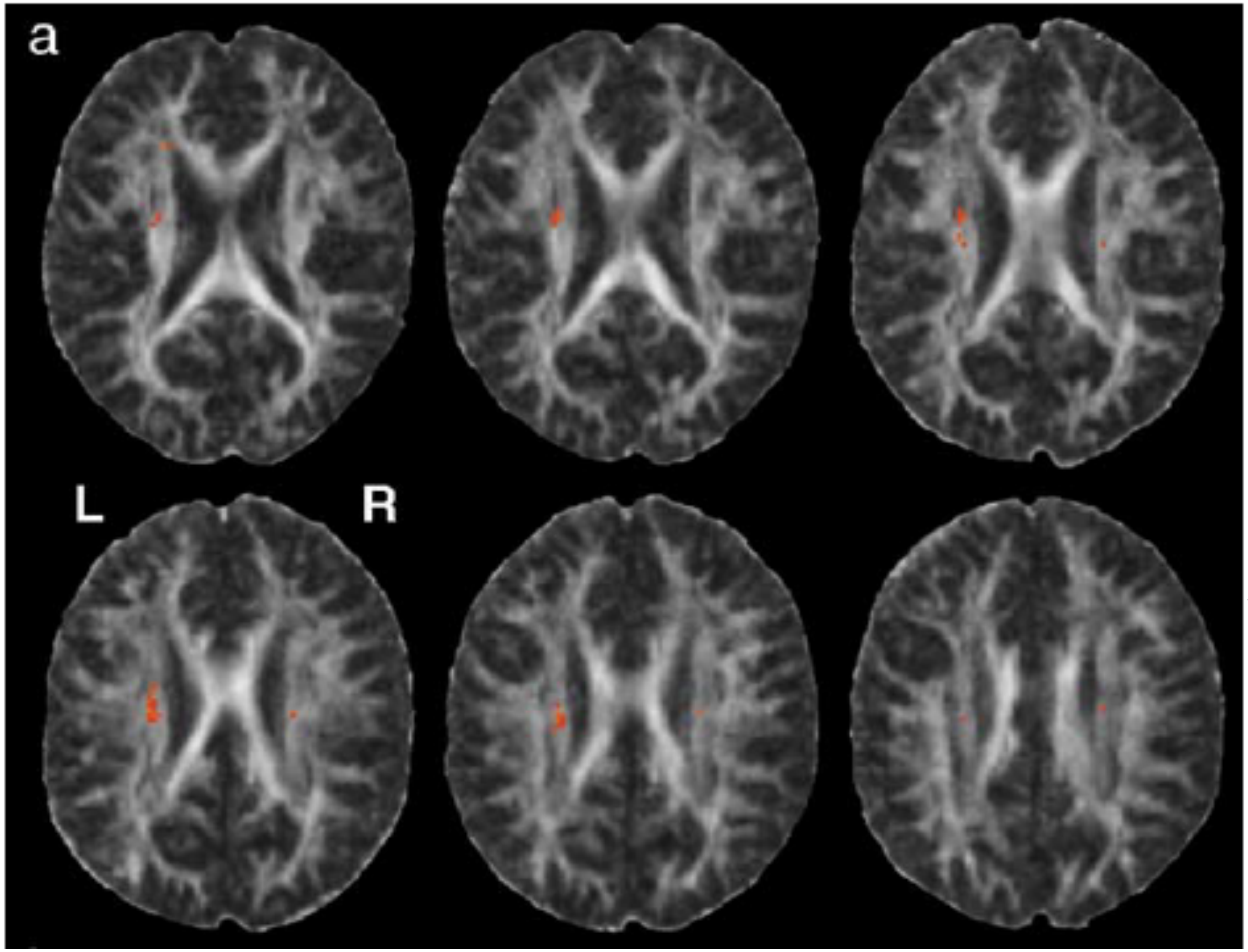
NeuroImage

www.elsevier.com/locate/ynimg
NeuroImage 25 (2005) 1266–1271

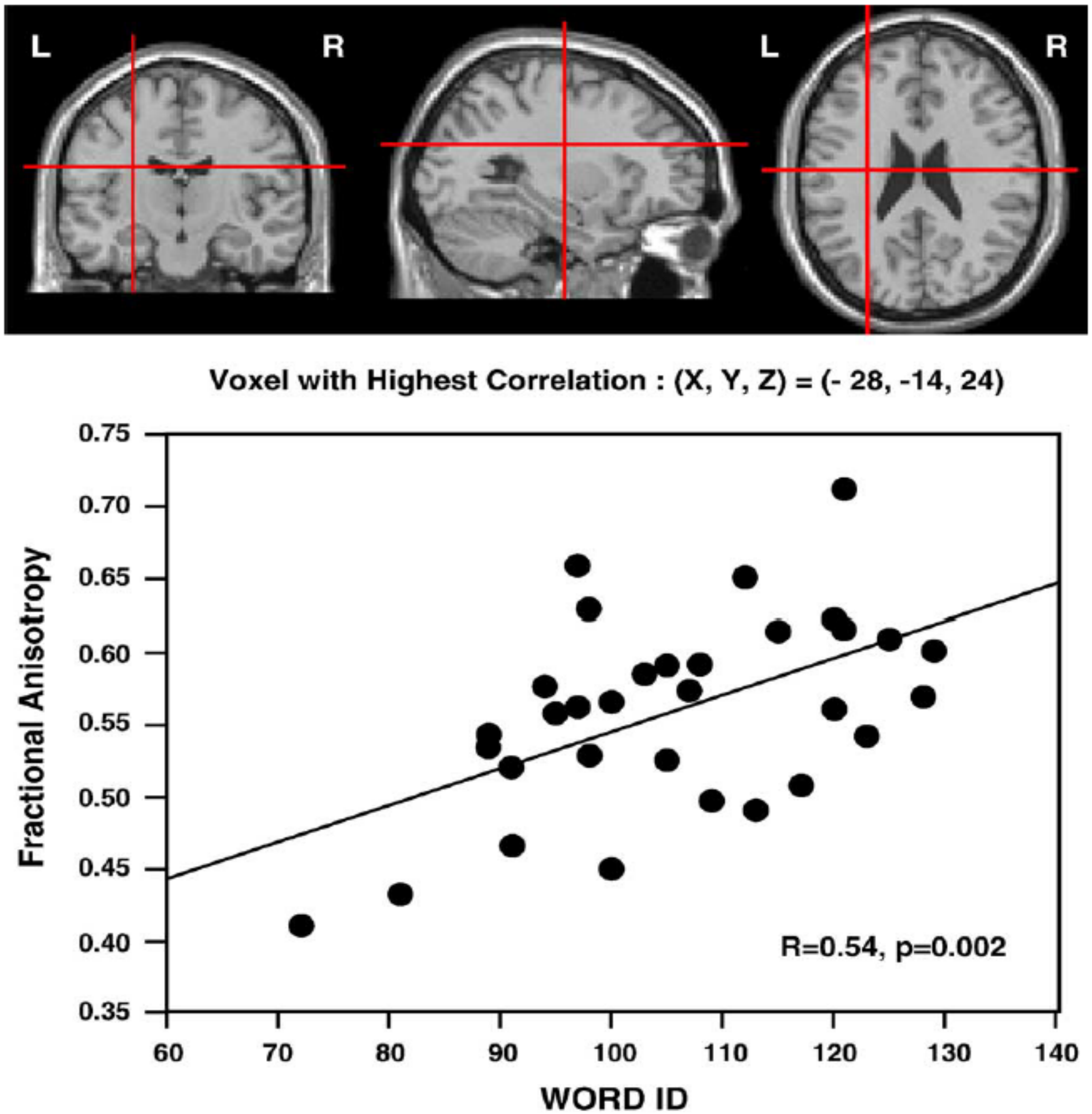
Imaging brain connectivity in children with diverse reading ability

Christian Beaulieu,[a,*] Christopher Plewes,[a] Lori Anne Paulson,[a] Dawne Roy,[b] Lindsay Snook,[a] Luis Concha,[a] and Linda Phillips[b]



- 32 volunteers (14 male, 18 female).
- 8.3–12.9 years mean 11.1 ± 1.3 years
- 30/32 right handed.
- aptitudes en lecture variables évaluées par un test d'identification de mots

Corrélation avec performance en lecture : voxels de plus forte corrélation



Voxel of higher correlation with word identification rate

Neuropsychologia 44 (2006) 2178–2188

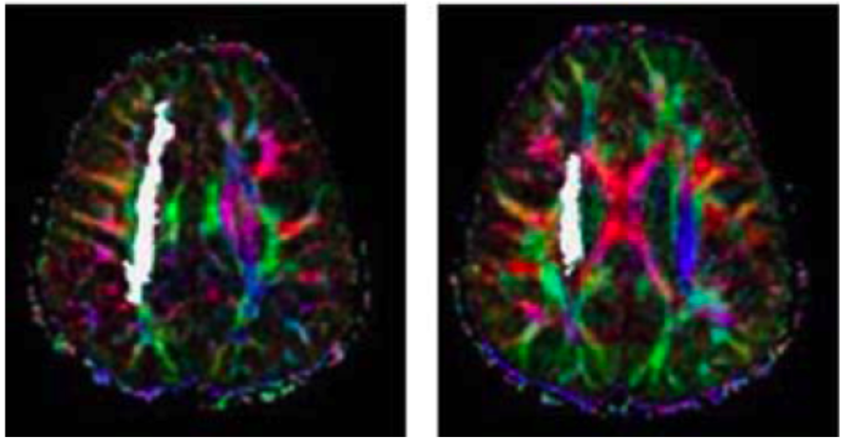
www.elsevier.com/locate/

Left lateralized white matter microstructure accounts for individual differences in reading ability and disability☆

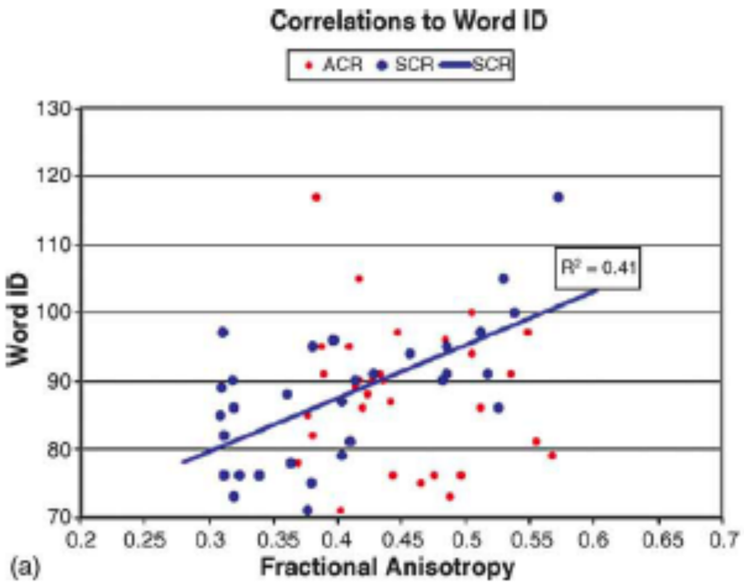
Sumit N. Niogi, Bruce D. McCandliss*

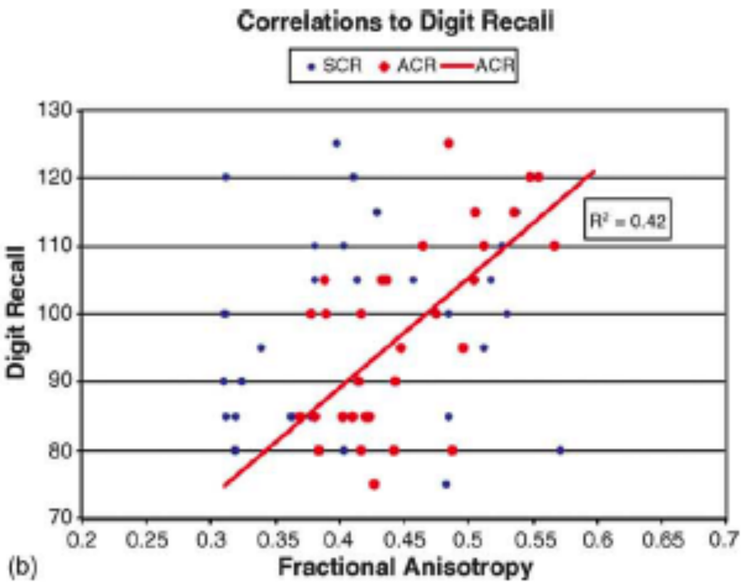
Structure	Word ID	Word Attack	Digit Recall
CS right	0.38	0.14	0.35
CS left	0.58	0.25	-0.11
SCR right	-0.18	-0.02	-0.22
SCR left	0.64	0.37*	0.15
SLF right	-0.22	0.10	0.16
SLF left	-0.12	0.03	-0.16
ACR right	-0.18	-0.30	0.66
ACR left	-0.08	-0.11	0.61
PLIC right	0.28	0.05	0.17
PLIC left	-0.21	0.02	-0.19
LAT SCR	-0.61	-0.28	-0.26
LAT CS	-0.23	-0.12	0.32

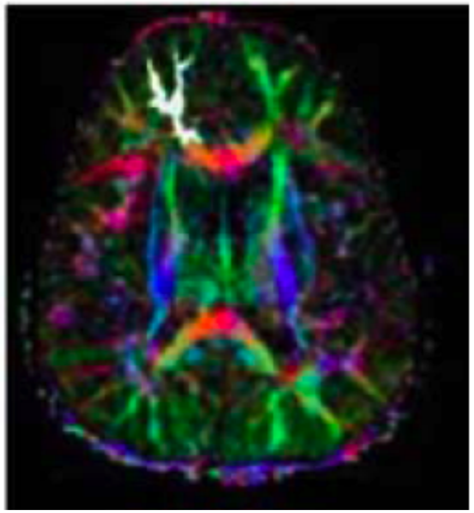
DTI : 31 children, 6-10yr
21 Nl, 10 dlx



Centrum semi-ovale







anterior corona radiata

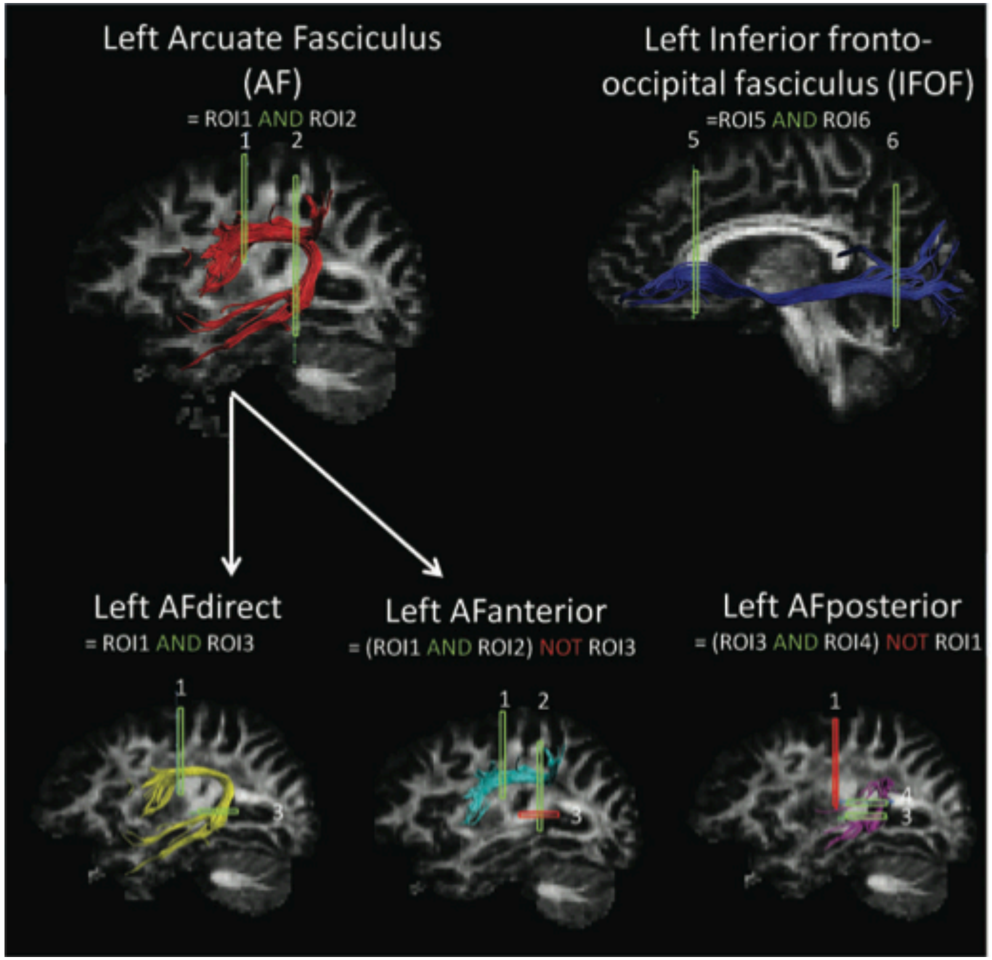
doi:10.1093/brain/awr363 Brain 2012: 135; 935–948 | 935

BRAIN
A JOURNAL OF NEUROLOGY

A tractography study in dyslexia: neuroanatomic correlates of orthographic, phonological and speech processing

Maaike Vandermosten,[1,2,3] Bart Boets,[1,2,4] Hanne Poelmans,[1,2] Stefan Sunaert,[3] Jan Wouters[2] and Pol Ghesquière[1]

1 Parenting and Special Education Research Unit, Katholieke Universiteit Leuven, A. Vesaliusstraat 2, PO Box 3765, 3000 Leuven, Belgium



Correlational analyses (controlled for reading status) demonstrated a specific relation between performance on phoneme awareness and speech perception and the integrity of left arcuate fasciculus as indexed by fractional anisotropy, and between orthographic processing (flashed word identification task) and fractional anisotropy values in left inferior fronto-occipital fasciculus.

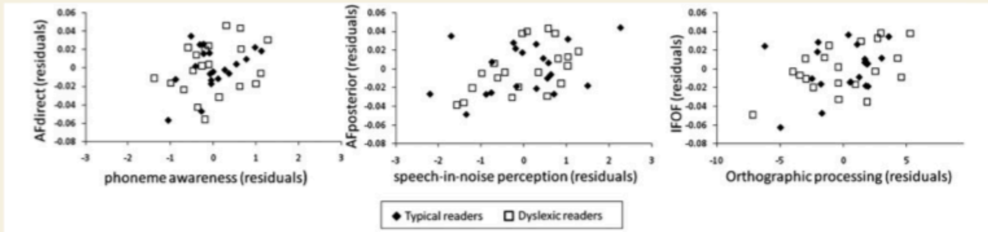


Figure 2 Correlations between (residual) fractional anisotropy values and (residual) reading-related behavioural measures after controlling for group, IQ and quality index of DTI acquisition. AFdirect = acuate fasciculus-direct; AFposterior = arcuate fasciculus-posterior; IFOF = inferior fronto-occipital fasciculus.

Table 4 Unique variance (R^2) in fractional anisotropy explained by individual differences in phoneme awareness and orthographic processing

Predicting variables	Fractional anisotropy left IFOF	Fractional anisotropy left AFdirect
Step 1: control variables	0.04	0.04
Step 2: group variable	0.00	0.10*
Step 3a: phoneme awareness	0.02	0.10*
Step 3b: orthographic processing	0.16**	0.00
Total R^2	0.21	0.24

Step 1 = Control variables (IQ and quality index of DTI acquisition); Step 2 = Control variables + Group variable; Step 3a = Control variables + Group variable + Orthographic processing + Phoneme awareness; Step 3b = Control variables + Group variable + Phoneme awareness + Orthographic processing.
$*P < 0.05$, $**P < 0.01$.
AFdirect = arcuate fasciculus-direct; IFOF = inferior fronto-occipital fasciculus.

Table 5 Unique variance (R^2) in fractional anisotropy explained by individual differences in speech-in-noise perception and orthographic processing

Predicting variables	Fractional anisotropy left IFOF	Fractional anisotropy left AFposterior
Step 1: control variables	0.04	0.02
Step 2: group variable	0.00	0.06
Step 3a: speech-in-noise perception	0.01	0.18**
Step 3b: orthographic processing	0.12*	0.01
Total R^2	0.19	0.26

Step 1 = Control variables (IQ and quality index of DTI acquisition); Step 2 = Control variables + Group variable; Step 3a = Control variables + Group variable + Orthographic processing + Speech-in-noise perception; Step 3b = Control variables + Group variable + Speech-in-noise perception + Orthographic processing.
$*P < 0.05$, $**P < 0.01$.
AFposterior = arcuate fasciculus-posterior; IFOF = inferior fronto-occipital fasciculus.

Neuroscience and Biobehavioral Reviews 36 (2012) 1532–1552

Contents lists available at SciVerse ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

A qualitative and quantitative review of diffusion tensor imaging studies in reading and dyslexia

Maaike Vandermosten[a,b,c,*], Bart Boets[a,b,d], Jan Wouters[b], Pol Ghesquière[a]

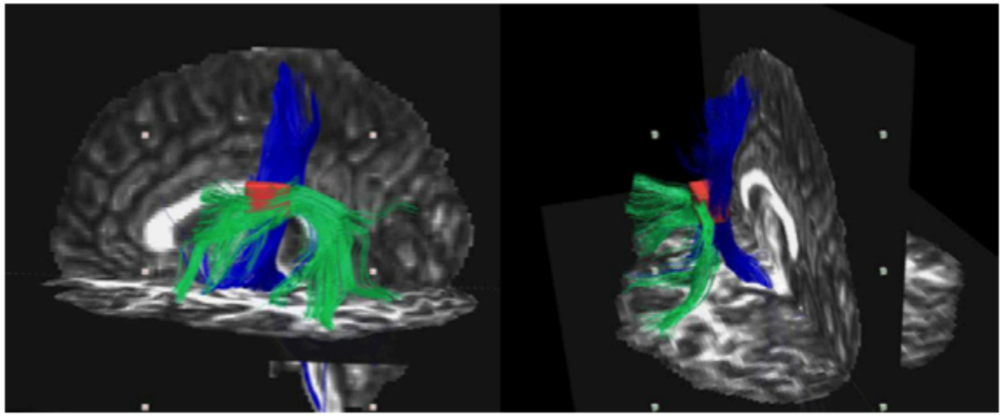


Fig. 3. Fibertracking through the temporoparietal cluster defined by the ALE-meta-analysis (cluster depicted in red). Two major pathways, the left AF (depicted in green) and left CR (depicted in blue), cross this cluster. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

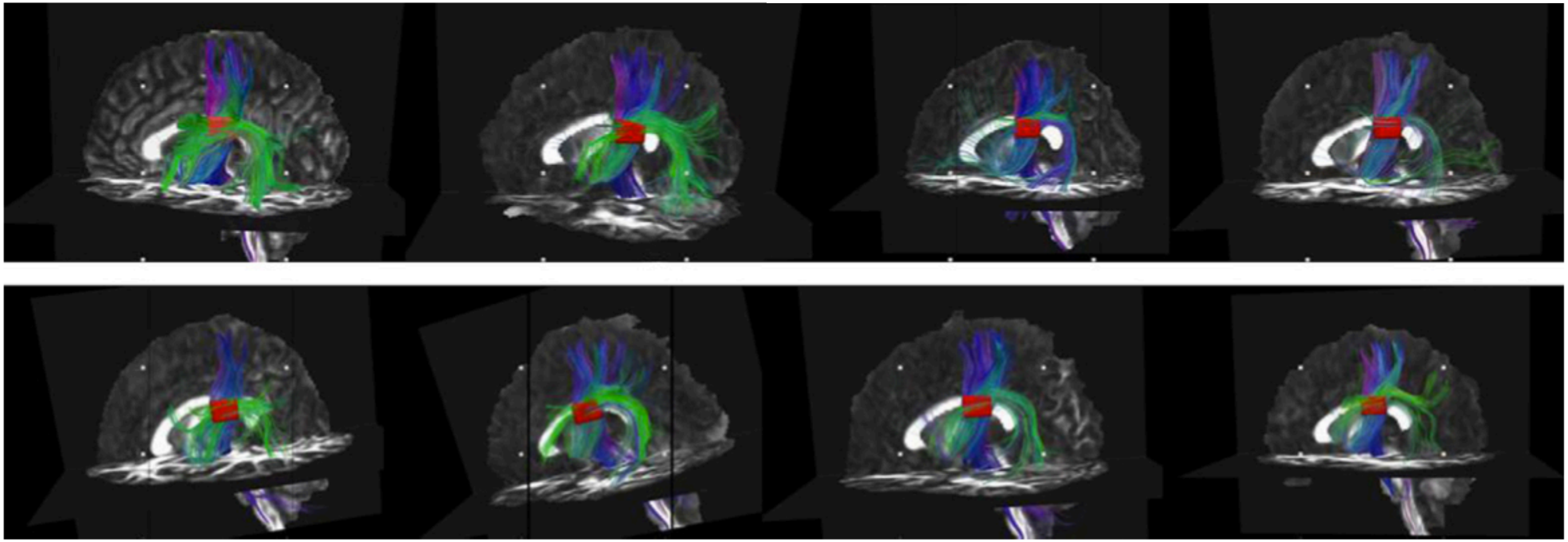
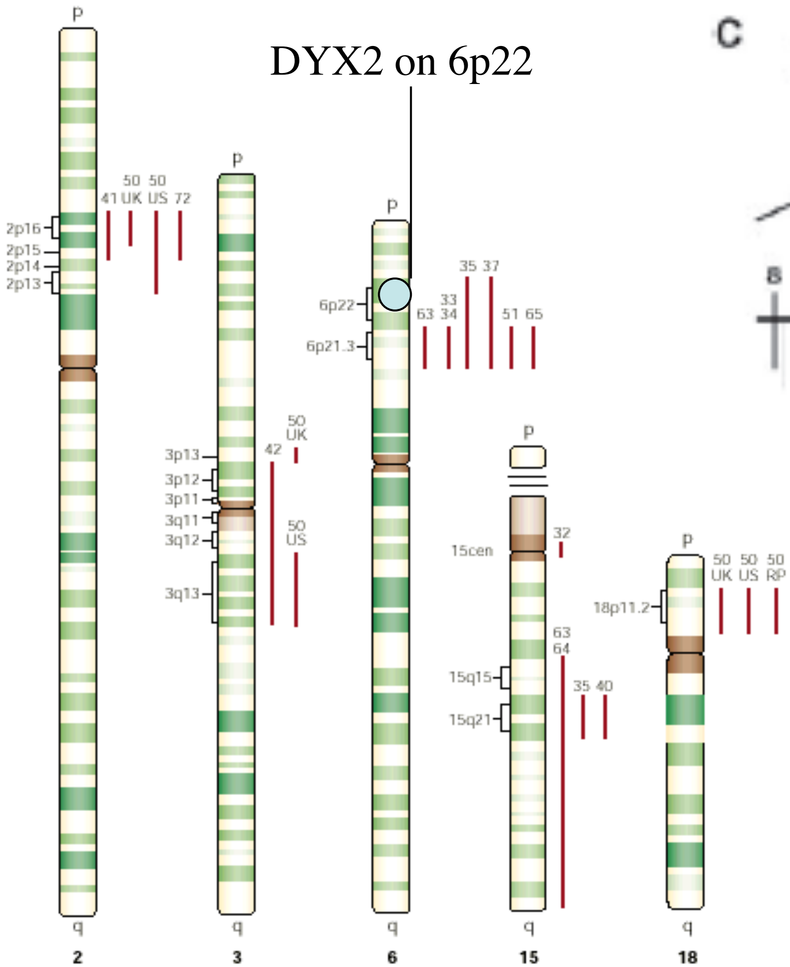
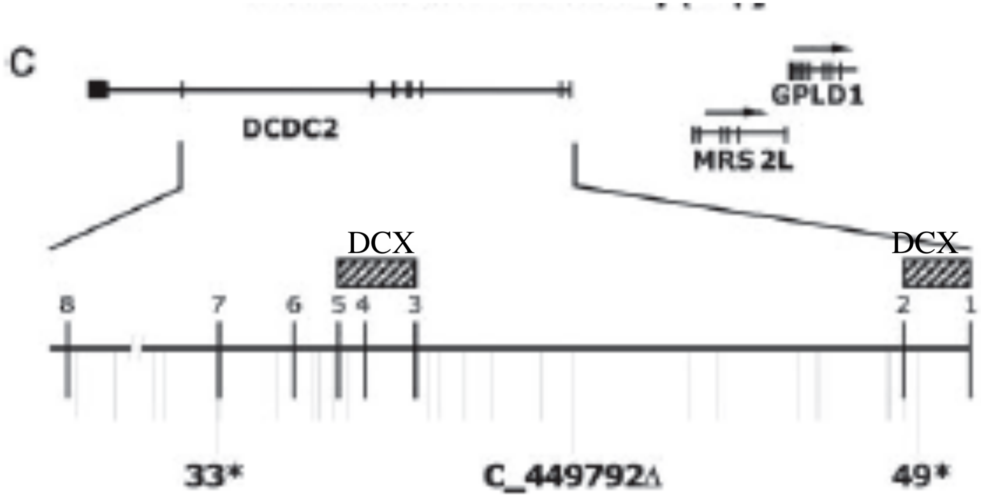


Fig. 4. Fibertracking through the temporoparietal cluster defined by the ALE-meta-analysis (cluster depicted in red) in eight subjects. The upper row represents four normal reading subjects and the lower row four dyslexic readers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this

DCDC2 is associated with reading disability and modulates neuronal development in the brain

Haiying Meng[a], Shelley D. Smith[b], Karl Hager[c], Matthew Held[a], Jonathan Liu[d], Richard K. Olson[e], Bruce F. Pennington[f], John C. DeFries[g], Joel Gelernter[h,i], Thomas O'Reilly-Pol[a], Stefan Somlo[j], Pawel Skudlarski[a], Sally E. Shaywitz[a], Bennett A. Shaywitz[a], Karen Marchione[a], Yu Wang[k], Murugan Paramasivam[k], Joseph J. LoTurco[k], Grier P. Page[l], and Jeffrey R. Gruen[a,m]





DCDC2 : deletion in strong linkage with reading performance

Contains doublecortine (DCX) gene domain (responsible for lissencephaly & double cortex syndrome)

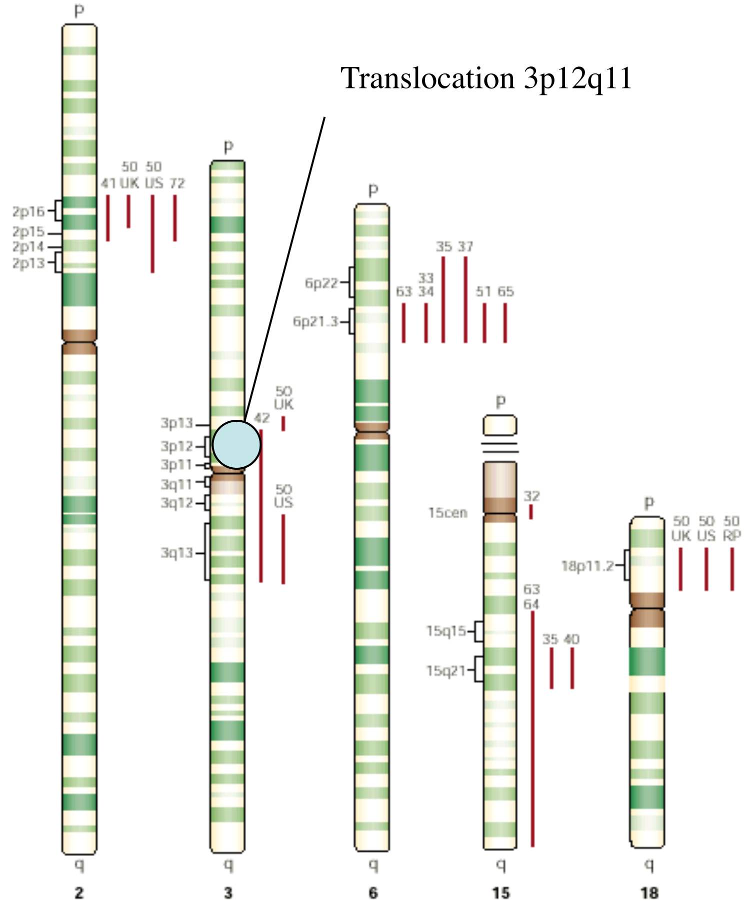
RNA present in cerebral tissue from reading-associated regions

Thus should be associated to abnormal migration

OPEN ACCESS Freely available online
PLoS GENETICS

The Axon Guidance Receptor Gene *ROBO1* Is a Candidate Gene for Developmental Dyslexia

Katariina Hannula-Jouppi[1], Nina Kaminen-Ahola[1], Mikko Taipale[1,2], Ranja Eklund[1], Jaana Nopola-Hemmi[1,3], Helena Kääriäinen[4,5], Juha Kere[1,6*]



ROBO1 has a role in regulating axon crossing across the midline between brain hemispheres and guidance of neuronal dendrites

nature neuroscience

From genes to behavior in developmental dyslexia

Albert M Galaburda, Joseph LoTurco, Franck Ramus, R Holly Fitch & Glenn D Rosen

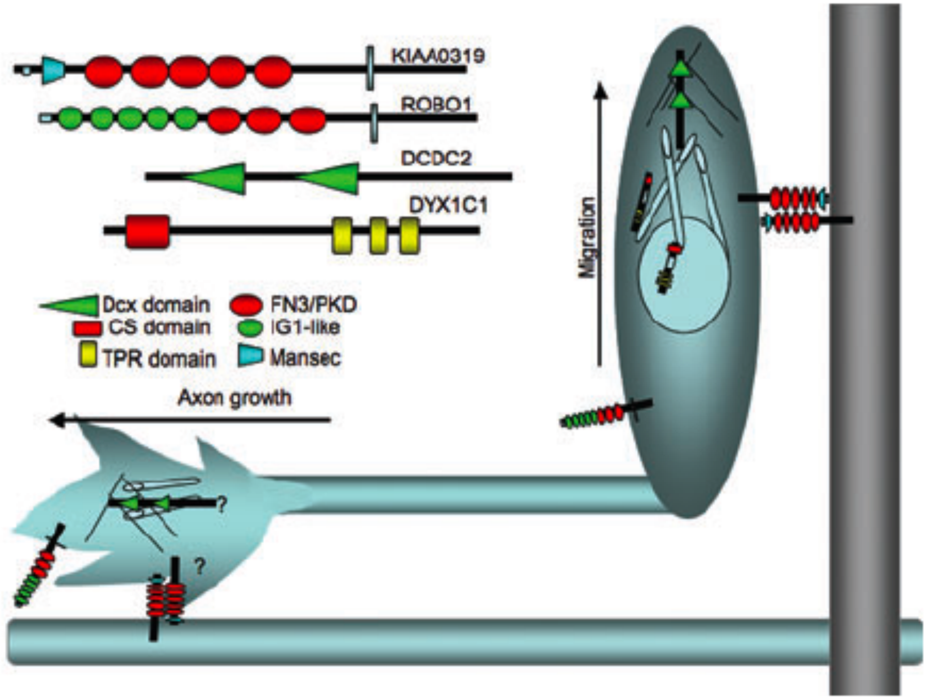


Figure 1 Protein domains and possible functions. KIAA0319 and ROBO1 serve as transmembrane adhesion molecules and receptors that guide axons to appropriate targets. DCDC2, and perhaps DYX1C1, are proposed to act as downstream targets that then serve to modulate changes in cytoskeletal dynamic processes involved in the motility of developing neurons. Critical future studies must now address whether there are links between the functions of these proteins in migration and axonal pathfinding.

Three Dyslexia Susceptibility Genes, *DYX1C1*, *DCDC2*, and *KIAA0319*, Affect Temporo-Parietal White Matter Structure

Fahimeh Darki, Myriam Peyrard-Janvid, Hans Matsson, Juha Kere, and Torkel Klingberg

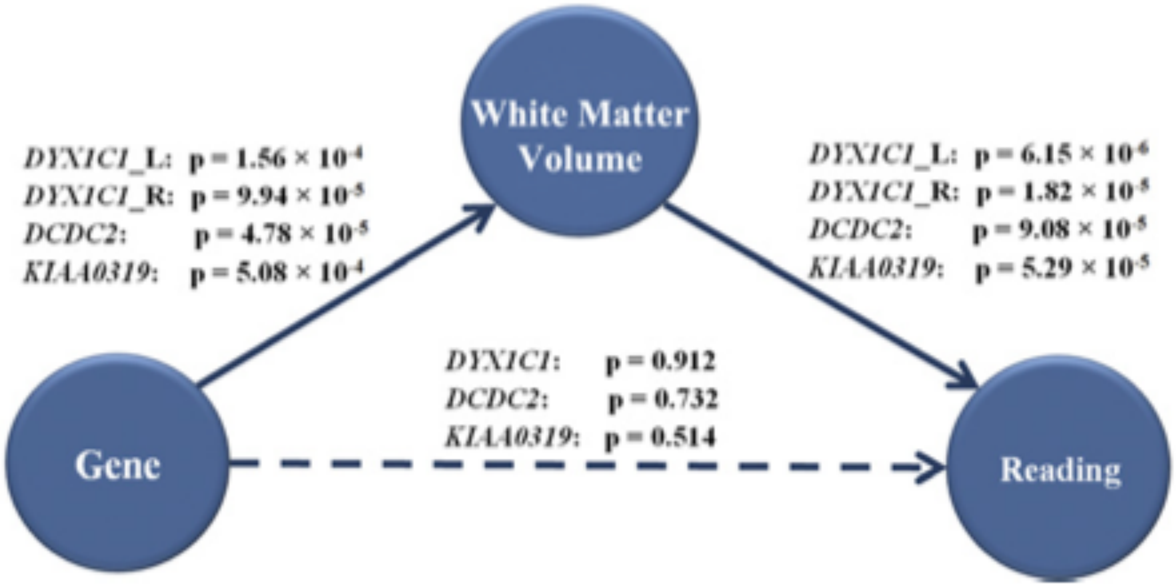
Background: Volume and integrity of white matter correlate with reading ability, but the underlying factors contributing to this variability are unknown.

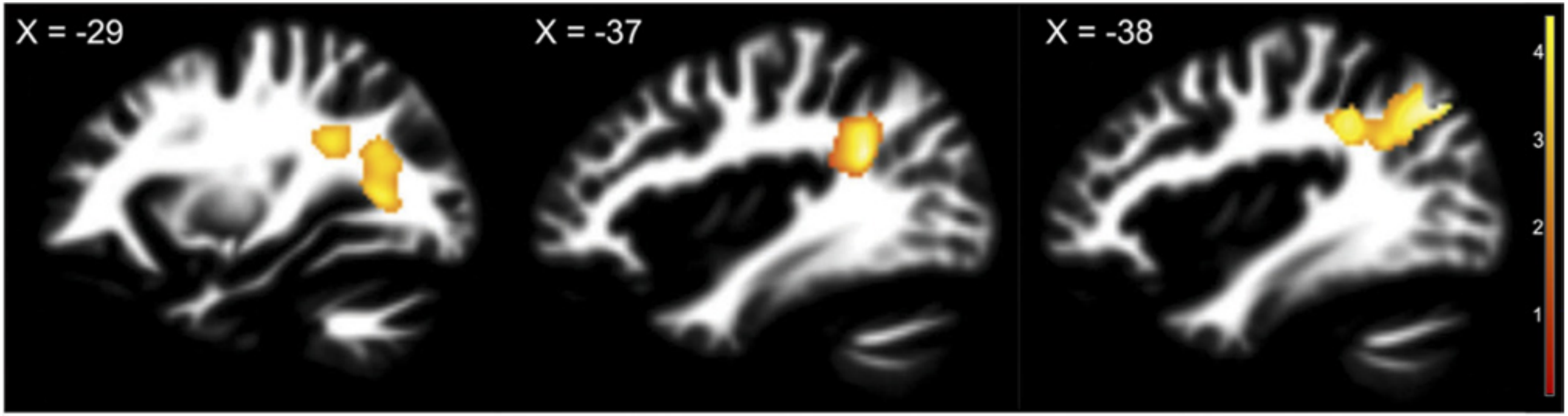
Methods: We investigated single nucleotide polymorphisms in three genes previously associated with dyslexia and implicated in neuronal migration (*DYX1C1*, *DCDC2*, *KIAA0319*) and white matter volume in a cohort of 76 children and young adults from the general population.

Results: We found that all three genes contained polymorphisms that were significantly associated with white matter volume in the left temporo-parietal region and that white matter volume influenced reading ability.

Conclusions: The identified region contained white matter pathways connecting the middle temporal gyrus with the inferior parietal lobe. The finding links previous neuroimaging and genetic results and proposes a mechanism underlying variability in reading ability in both normal and impaired readers.

E





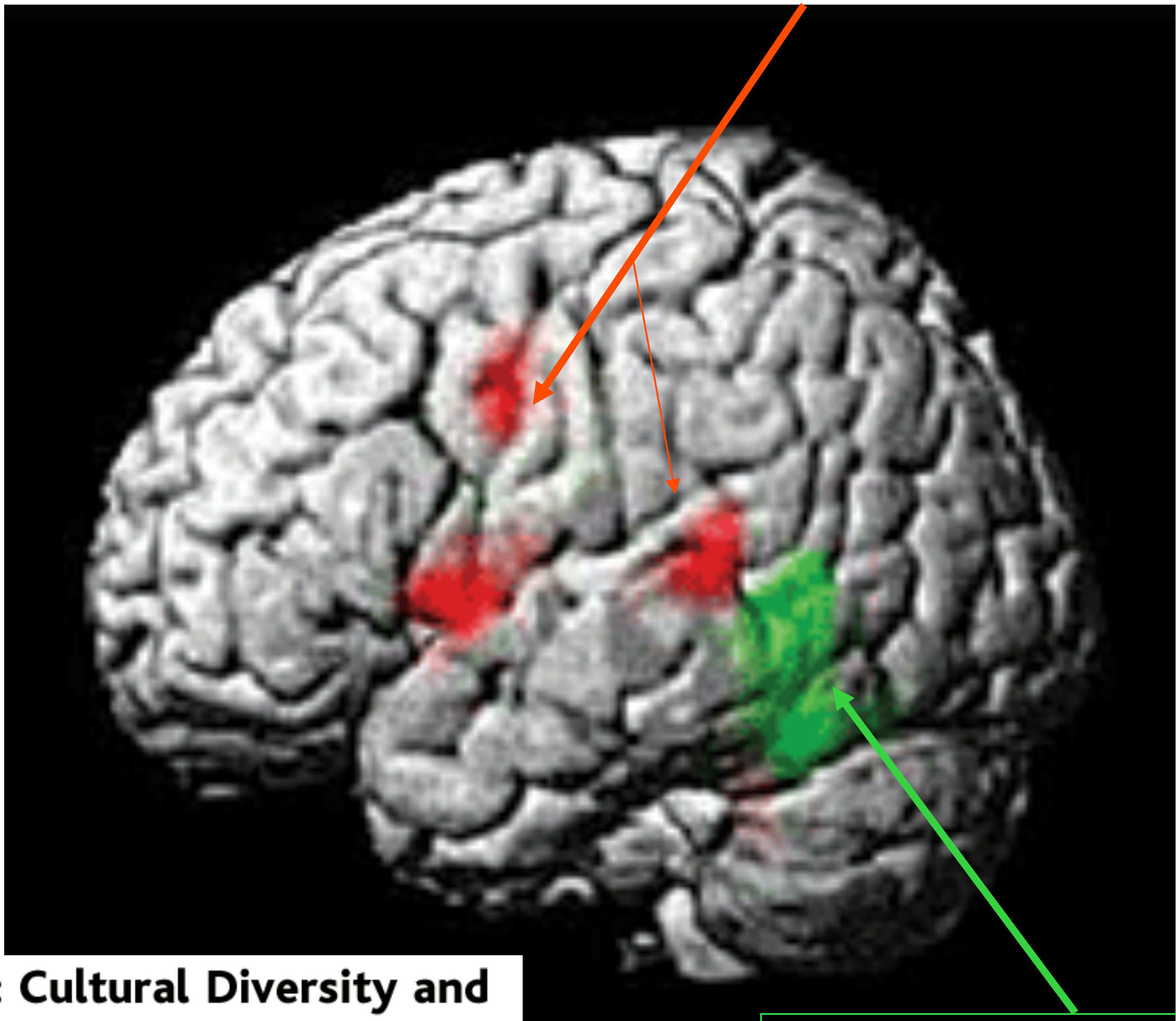
DYX1C1 DCDC2 KIAA0319

3 gènes impliqués dans la migration neuronale et liés à l'efficience en lecture

Results: We found that all three genes contained polymorphisms that were significantly associated with white matter volume in the left temporo-parietal region and that white matter volume influenced reading ability.

II/ Quelques questions sur l'activité cérébrale chez le dyslexique

également activé chez les témoins et les dyslexiques

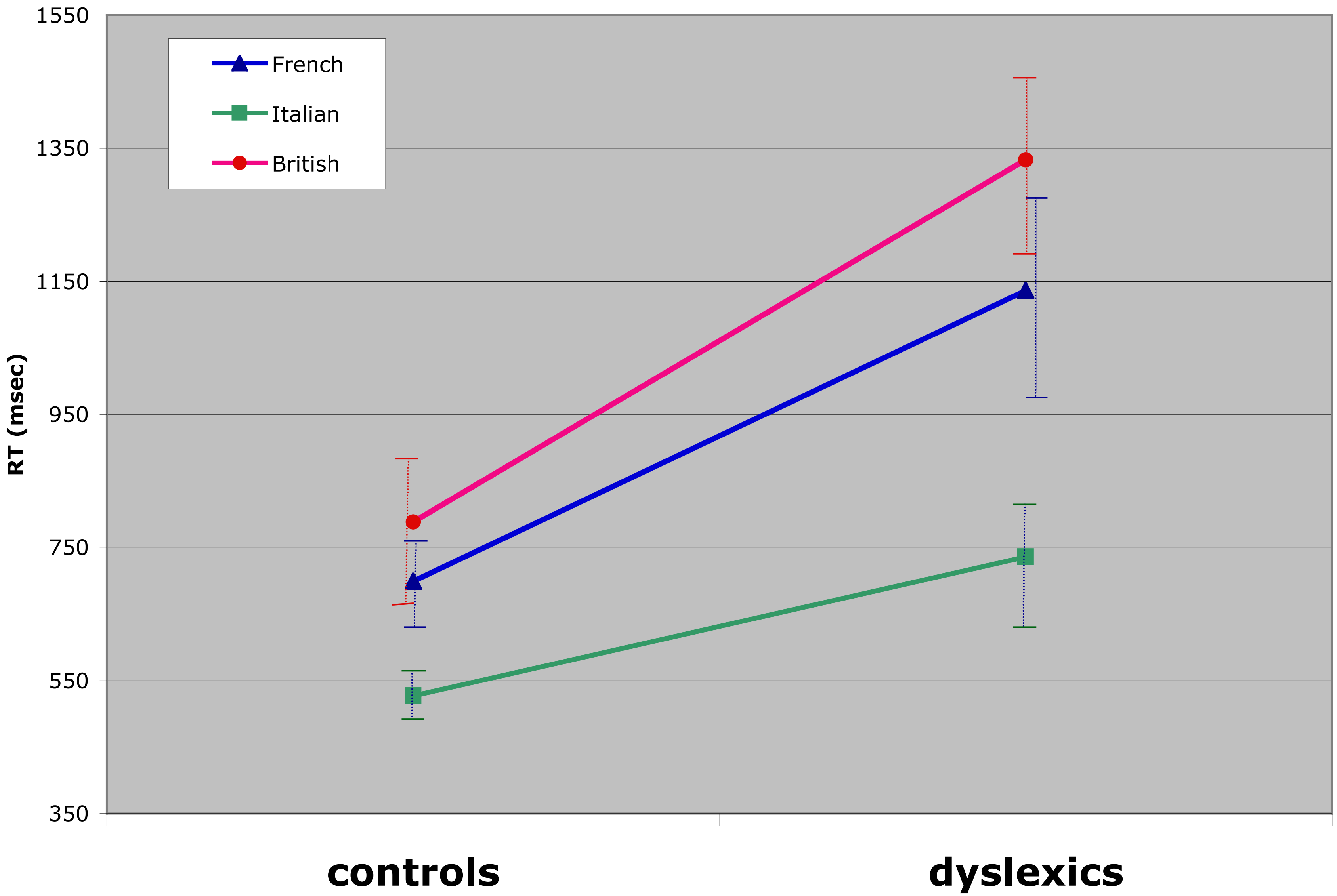


Paulesu et al., 2001

significativement moins activé chez les dyslexiques

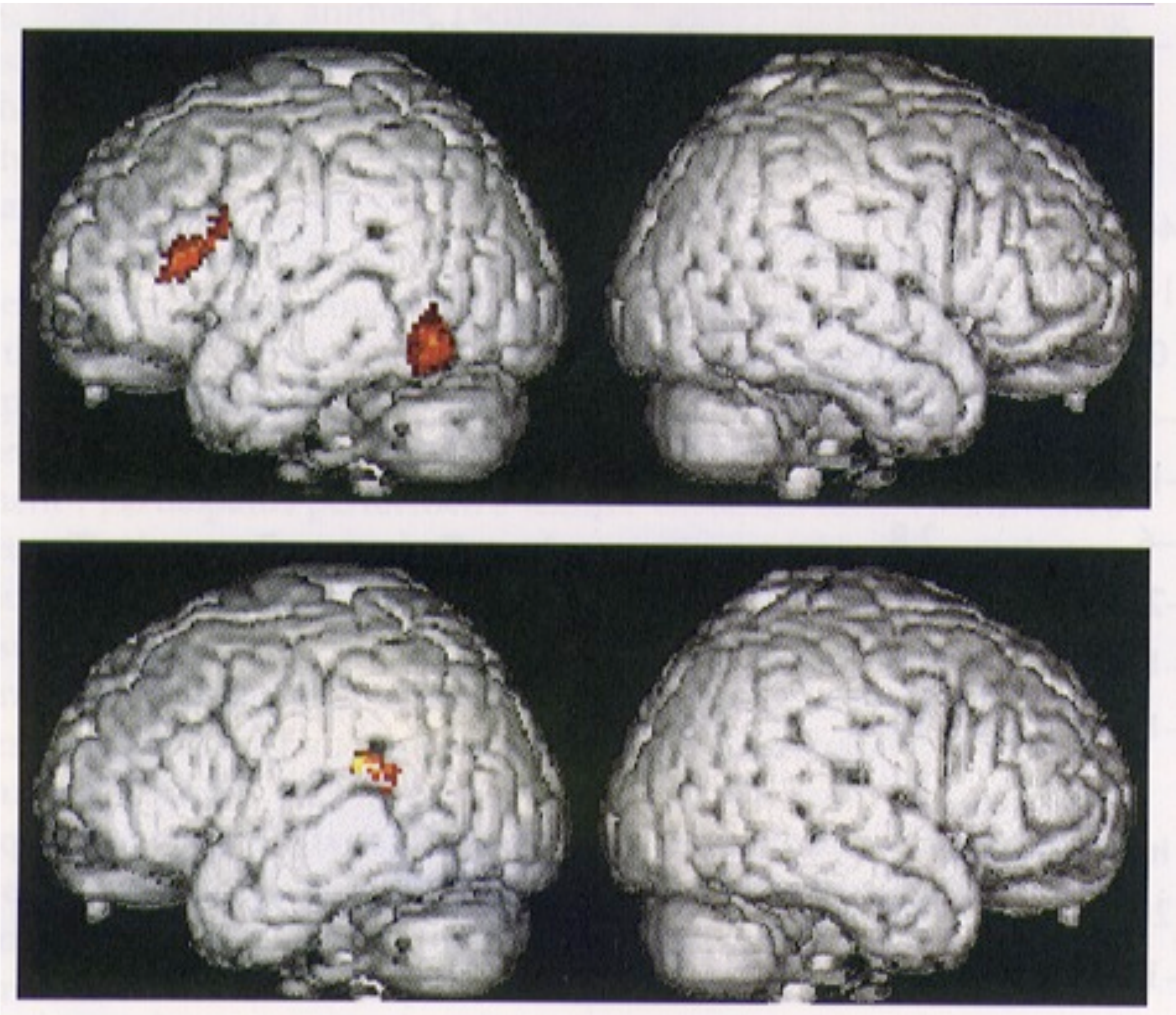
Dyslexia: Cultural Diversity and Biological Unity

E. Paulesu,[1,2*] J.-F. Démonet,[3] F. Fazio,[2,4] E. McCrory,[5] V. Chanoine,[3] N. Brunswick,[6] S. F. Cappa,[7] G. Cossu,[8] M. Habib,[9] C. D. Frith,[6] U. Frith[5]



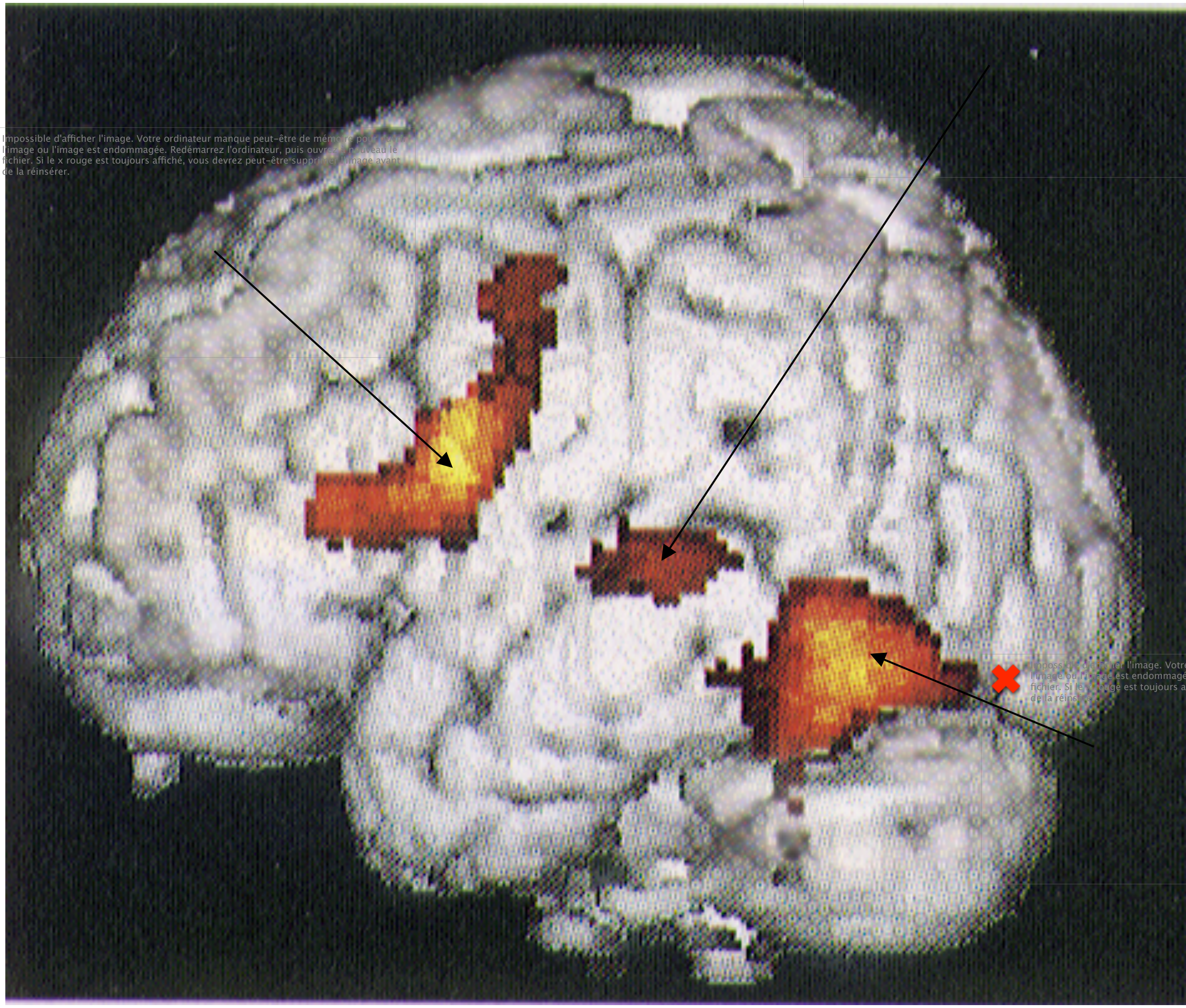
RT (msec)
1550
1350
1150
950
750
550
350
French
Italian
British
controls
dyslexics

Paulesu et al. (2000)
A cultural effect on brain function

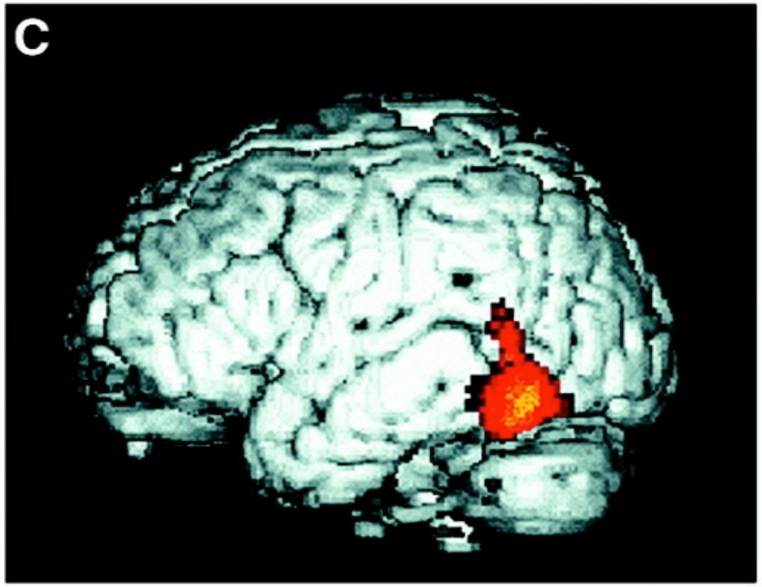


English > Italians :
(non-words)

Italians > English
(all word types)



Paulesu et al. (2000)
A cultural effect on brain function



Controls - dyslexics

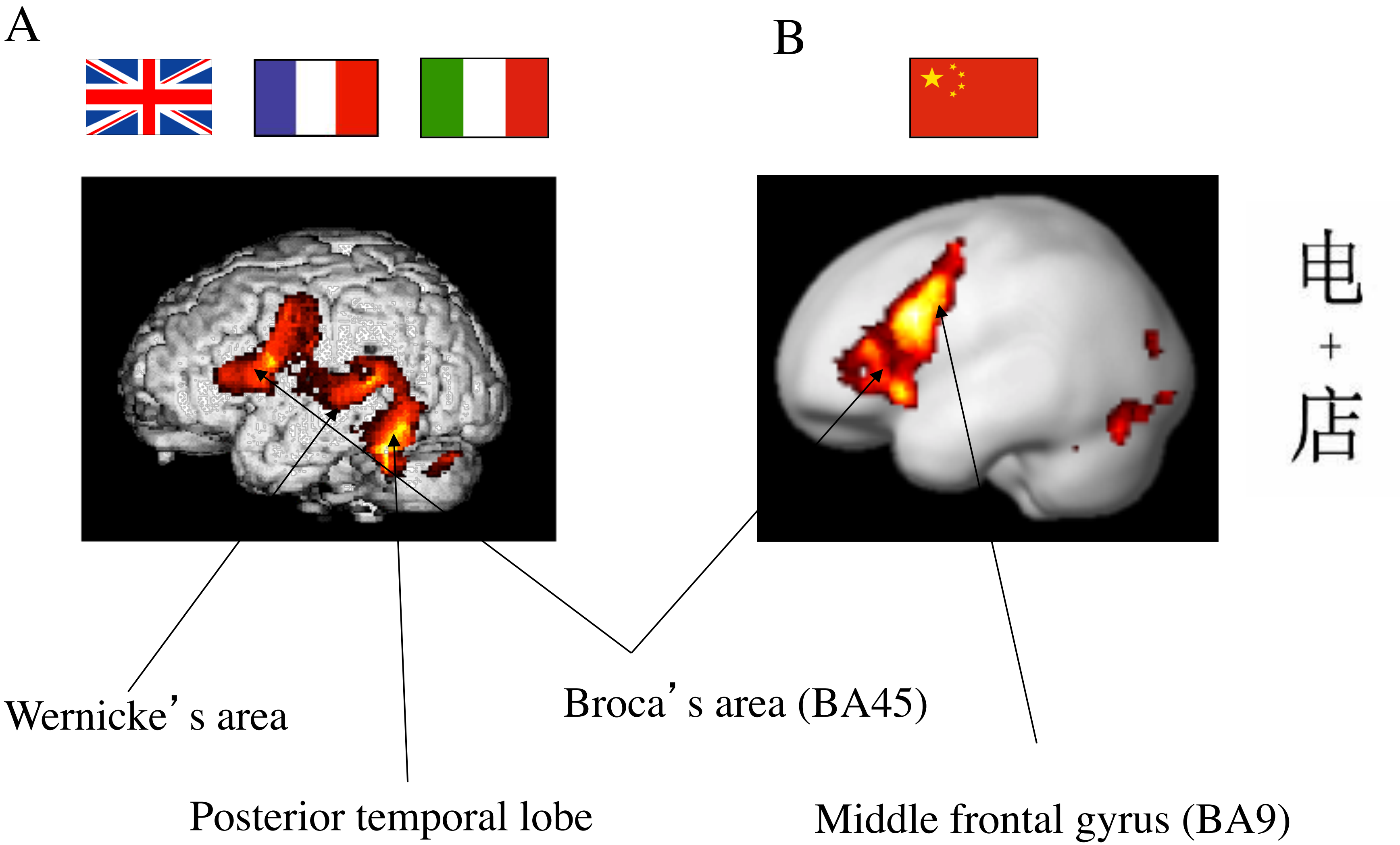
Dyslexia: Cultural Diversity and Biological Unity

E. Paulesu,[1,2*] J.-F. Démonet,[3] F. Fazio,[2,4] E. McCrory,[5] V. Chanoine,[3] N. Brunswick,[6] S. F. Cappa,[7] G. Cossu,[8] M. Habib,[9] C. D. Frith,[6] U. Frith[5]

The recognition of dyslexia as a neurodevelopmental disorder has been hampered by the belief that it is not a specific diagnostic entity because it has variable and culture-specific manifestations. In line with this belief, we found that Italian dyslexics, using a shallow orthography which facilitates reading, performed better on reading tasks than did English and French dyslexics. However, all dyslexics were equally impaired relative to their controls on reading and phonological tasks. Positron emission tomography scans during explicit and implicit reading showed the same reduced activity in a region of the left hemisphere in dyslexics from all three countries, with the maximum peak in the middle temporal gyrus and additional peaks in the inferior and superior temporal gyri and middle occipital gyrus. We conclude that there is a universal neurocognitive basis for dyslexia and that differences in reading performance among dyslexics of different countries are due to different orthographies.

[1]Psychology Department, University of Milan Bicocca, Milan, Italy. [2]INB-CNR, Scientific Institute H San Raffaele, Milan, Italy. [3]INSERM U455, Hôpital Purpan, Toulouse, France. [4]Neuroscience and Biomedical Technologies Department, University of Milan Bicocca, Milan, Italy. [5]Institute of Cognitive Neuroscience, University College London, London, UK. [6]Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK. [7]Psychology Department, University "Vita e Salute H San Raffaele", Milan, Italy. [8]Institute of Human Physiology, University of Parma, Parma, Italy. [9]Centre de Recherche Institut Universitaire de Gériatrie, Montréal, Quebec, Canada.

*To whom correspondence should be addressed at University of Milan Bicocca. E-mail: eraldo.paulesu@unimib.it



Ziegler & Habib (2005) TICS

A structural–functional basis for dyslexia in the cortex of Chinese readers

Wai Ting Siok[†‡], Zhendong Niu[§], Zhen Jin[¶], Charles A. Perfetti[‖], and Li Hai Tan[†‡††]

in and Cognitive Sciences, University of Hong Kong, Pokfulam Road, Hong Kong;
ute of Technology, Beijing 100081, China; [¶]Beijing 306 Hospital,
nent Center, University of Pittsburgh, Pittsburgh, PA 15260

of Technology, Cambridge, MA, February 25, 2008 (received for review January 1, 2008)

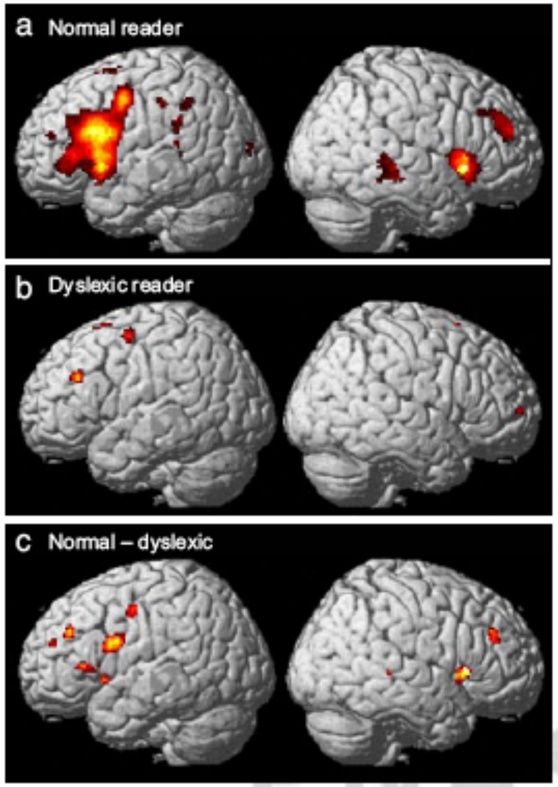


Fig. 2. Brain regions with significant activation during rhyme judgment. (*a* and *b*) Cortical activation associated with rhyme judgment contrasted with font-size decision in normal and dyslexic Chinese readers. (*c*) Brain regions showing group differences during rhyme judgment.

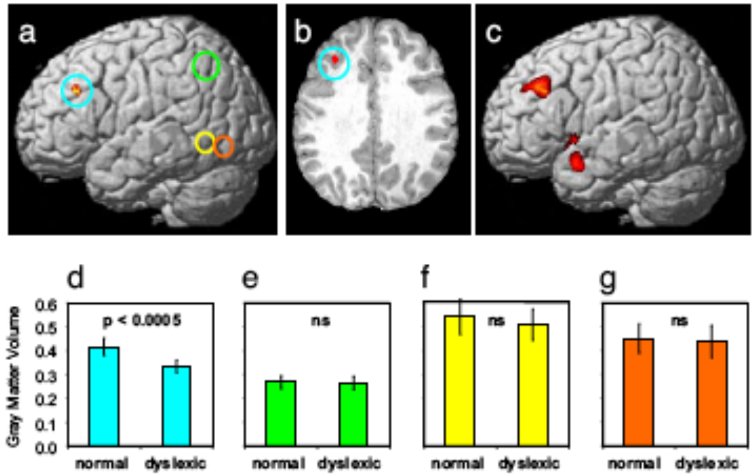


Fig. 1. Group differences in gray matter volume. (*a*, *b*, and *d*) A region in the left middle frontal gyrus (BA 9; $x = -32$, $y = 31$, $z = 28$) exhibited reduced volume in the dyslexic group, $P < 0.05$ corrected using the FWE correction for the whole brain. (*c*) At a less stringent uncorrected threshold of $P < 0.001$, reduced gray matter volume was seen in the left anterior temporal gyrus (BA 38/21) and the left Sylvian fissure, in addition to the left middle frontal gyrus. (*e*–*g*) ROI analysis of gray matter volume difference in the left posterior temporoparietal region (in green), the left middle temporal gyrus (in yellow), and the left inferior occipito-temporal cortex (in orange). No significant alteration was observed in these regions.

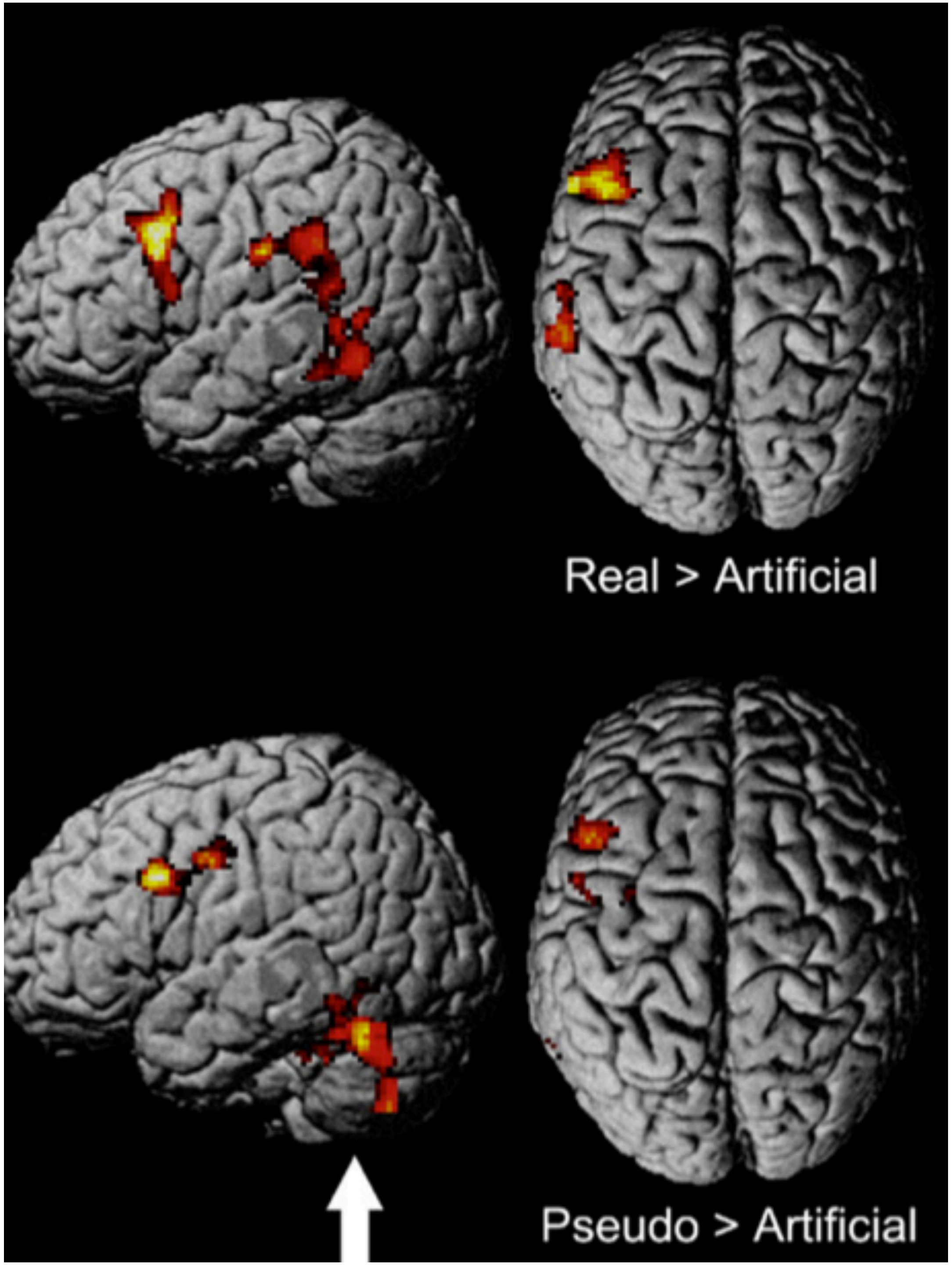
Parmi les aires sous-activées en IRMf, une région du GFMoy Gche présente une diminution significative du volume de substance grise

www.elsevier.com/locate/ynimg
NeuroImage 40 (2008) 1350–1361

The Visual Word Form Area: Evidence from an fMRI study of implicit processing of Chinese characters

Chao Liu,[a,b] Wu-Tian Zhang,[a] Yi-Yuan Tang,[a,c] Xiao-Qin Mai,[a,b,d] Hsuan-Chih Chen,[e] Twila Tardif,[b,d] and Yue-Jia Luo[a,f,*]

[a]Key Laboratory of Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, 100101, China



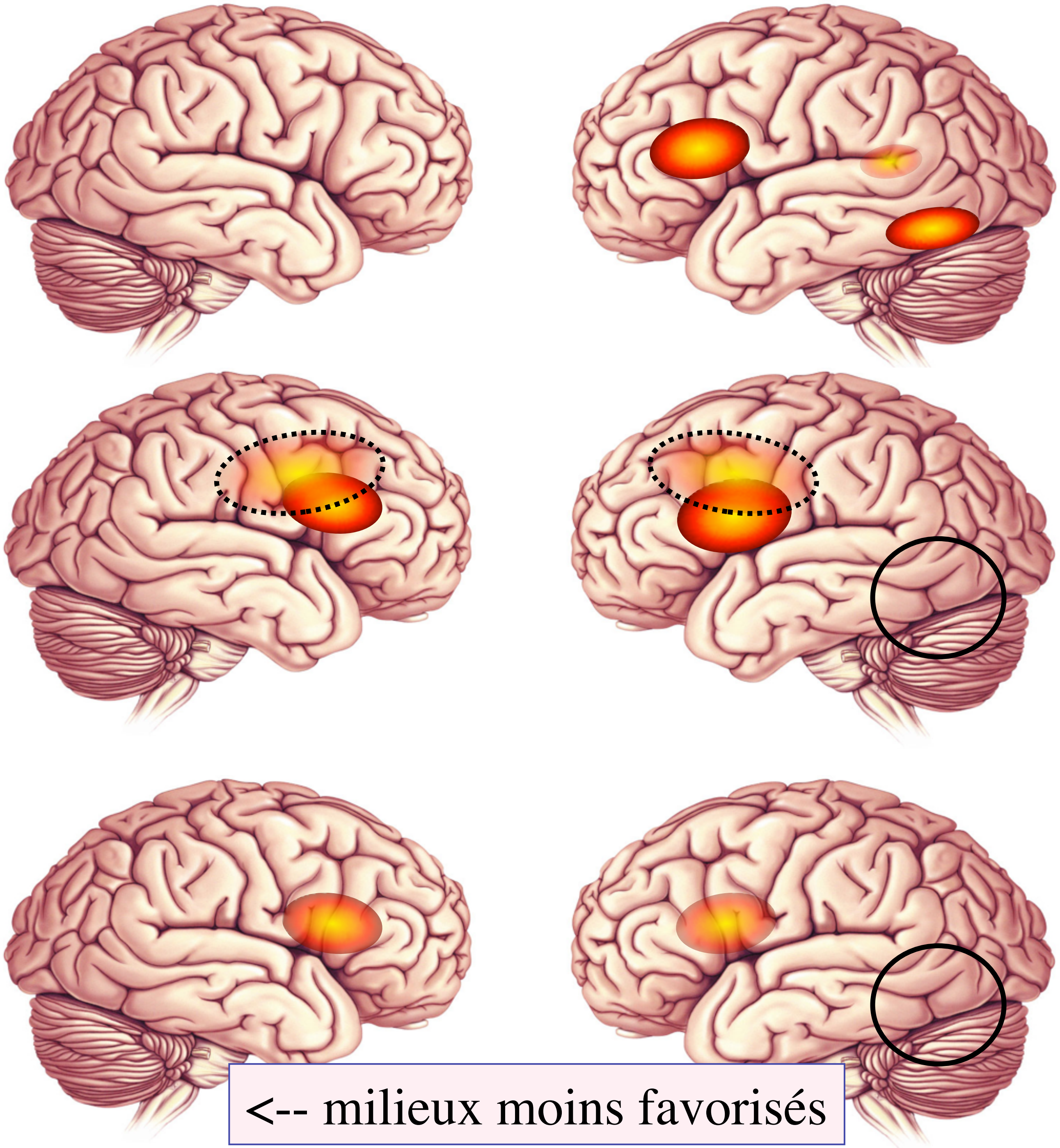
LEAT JETE

Riment?

Témoins
non dys

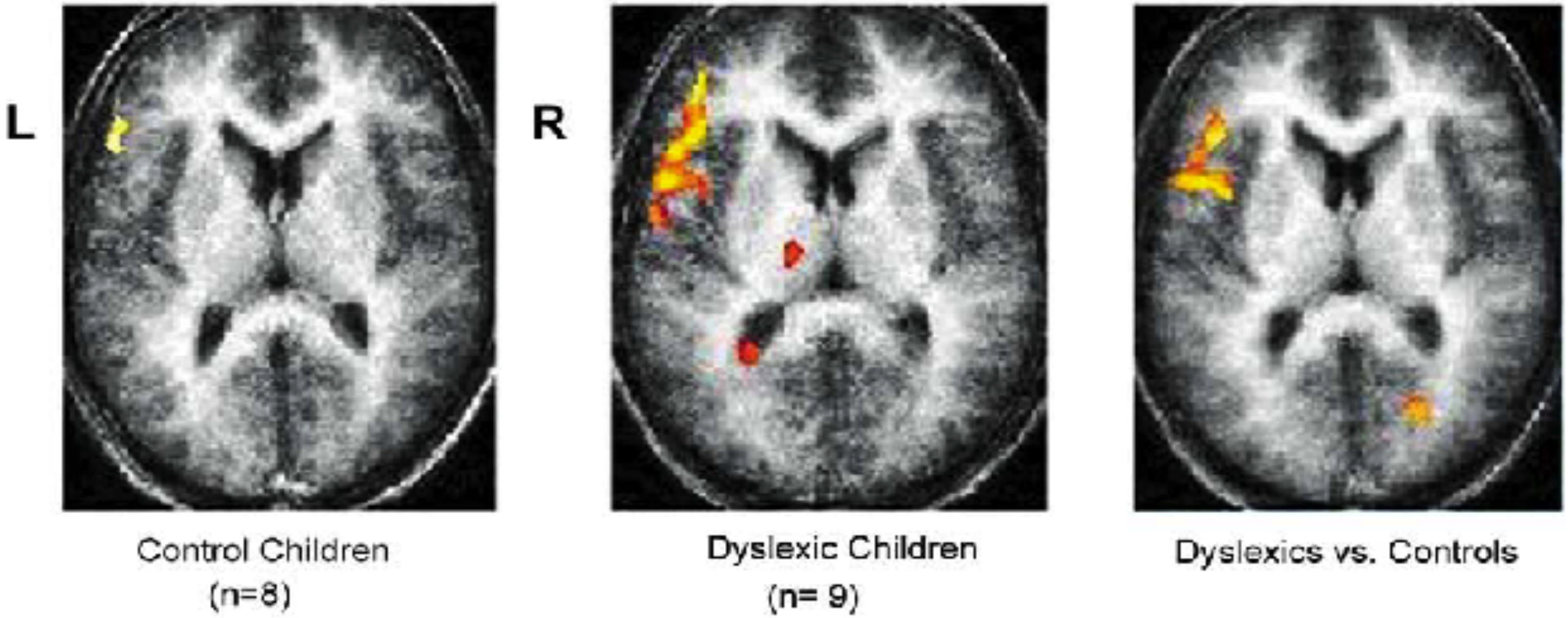
Dyslexiques
"compensés"

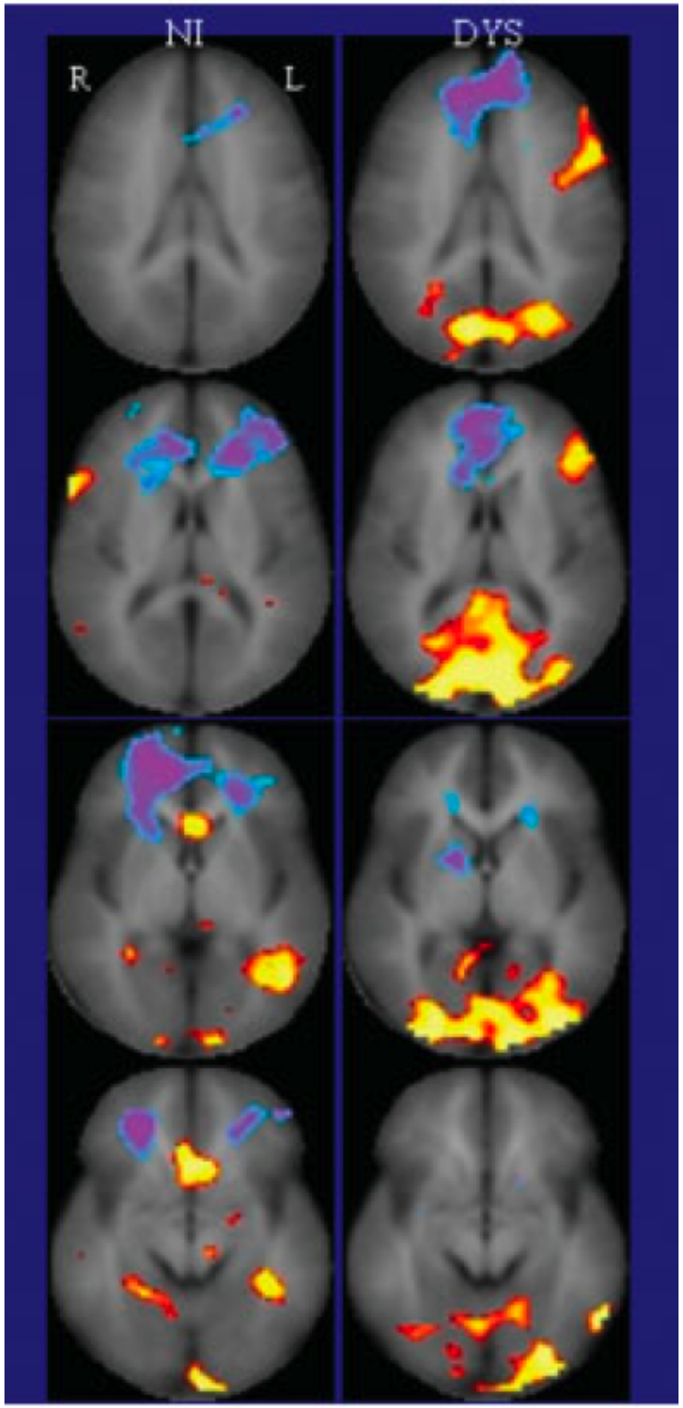
Dyslexiques
"persistants"



Shaywitz et al., Biol. Psychiatry, 2003

P. Georgiewa et al. / Neuroscience Letters 318 (2002) 5–8





35 girls, 78 boys; ages, 7–18 years; mean age, 12.7 years) and 119 nonimpaired (NI) readers

(52 girls, 67 boys; ages, 7–17 years; mean age, 11.3 years)

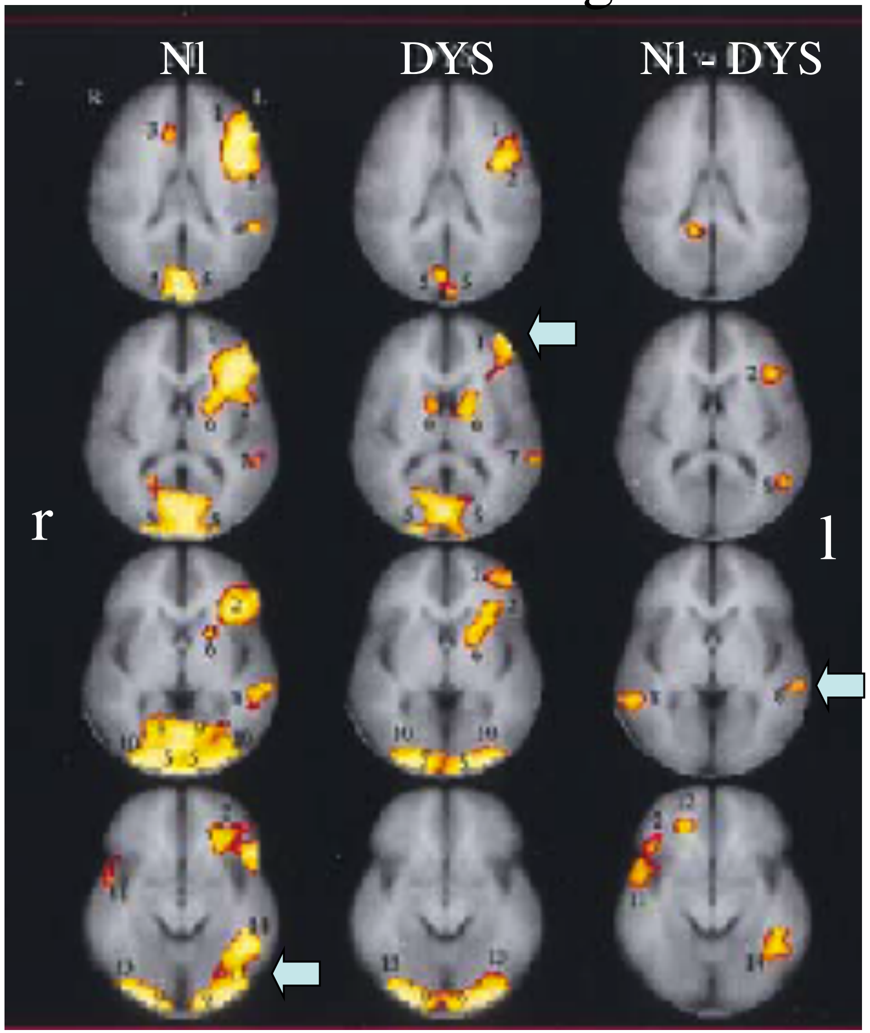
Correlation maps between age and activation for nonimpaired (NI) and dyslexic (DYS) readers during a nonword rhyming (NWR) task

Biol Psychiatry 2002;52:101–110 ©

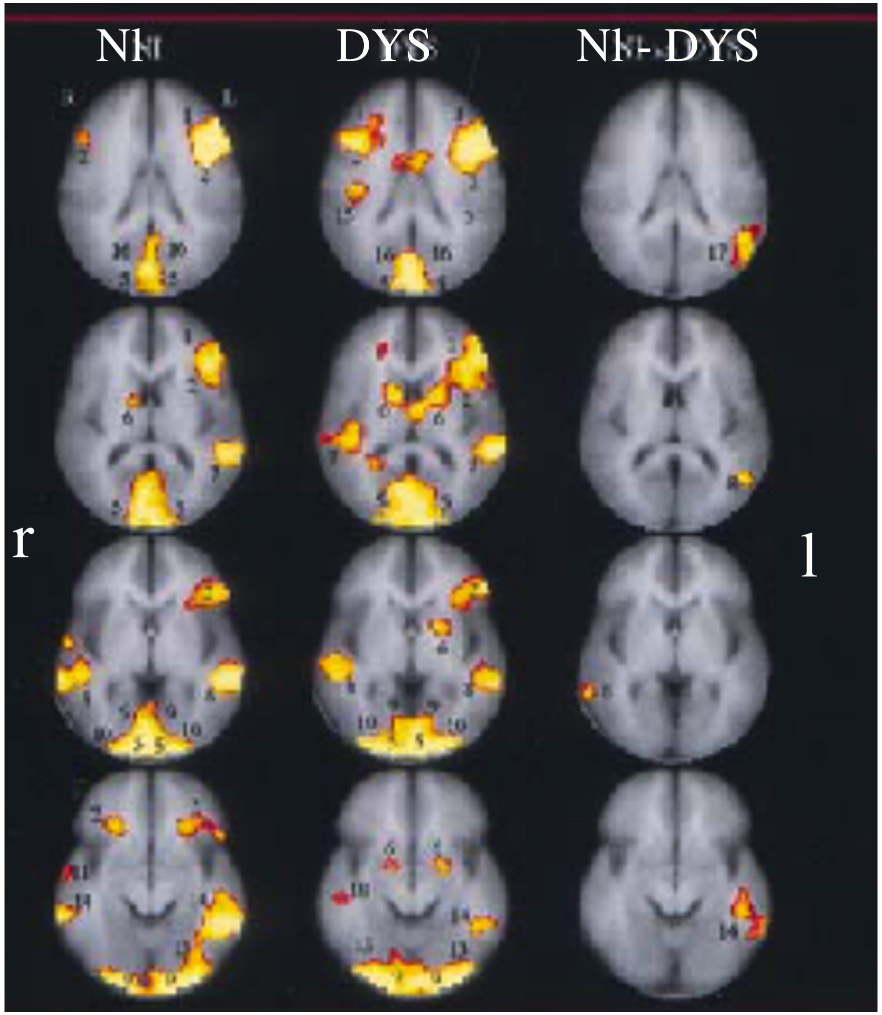
Disruption of Posterior Brain Systems for Reading in Children with Developmental Dyslexia

Bennett A. Shaywitz, Sally E. Shaywitz, Kenneth R. Pugh, W. Einar Mencl, Robert K. Fulbright, Pawel Skudlarski, R. Todd Constable, Karen E. Marchione, Jack M. Fletcher, G. Reid Lyon, and John C. Gore

Non-word reading



Semantic category judgment



Neural Systems for Compensation and Persistence: Young Adult Outcome of Childhood Reading Disability

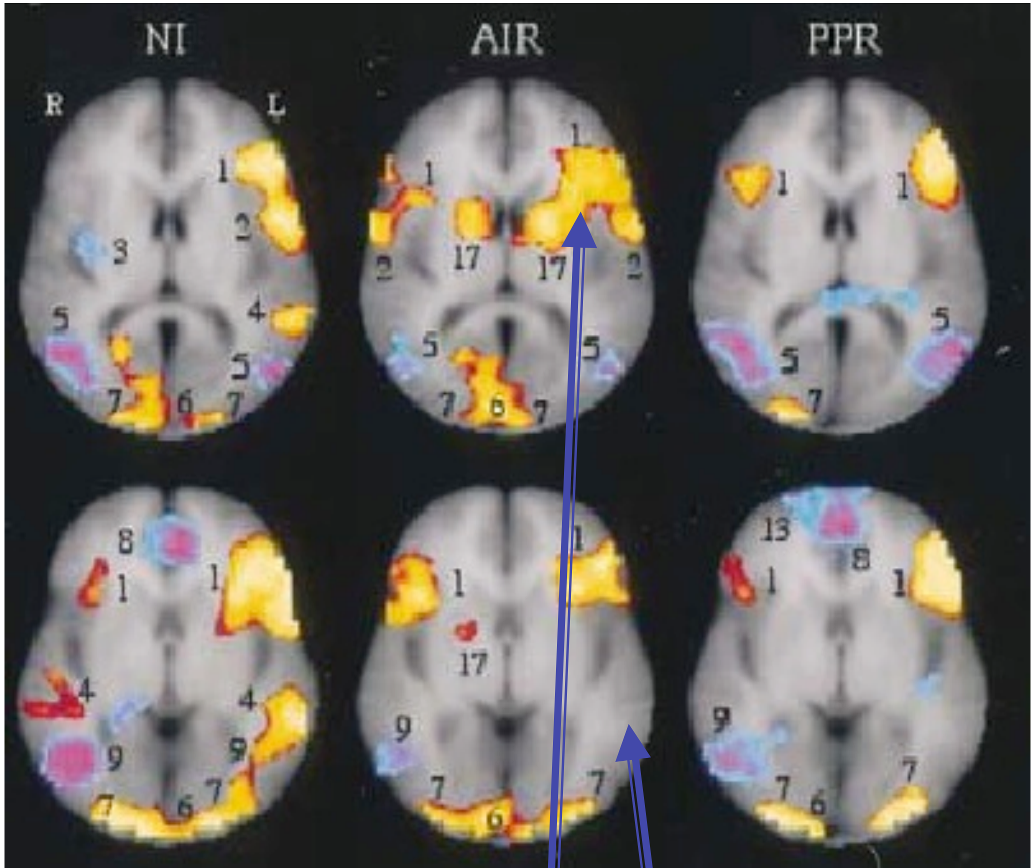
Sally E. Shaywitz, Bennett A. Shaywitz, Robert K. Fulbright, Pawel Skudlarski, W. Einar Mencl, R. Todd Constable, Kenneth R. Pugh, John M. Holahan, Karen E. Marchione, Jack M. Fletcher, G. Reid Lyon, and John C. Gore

BIOL PSYCHIATRY
2003;54:25–33

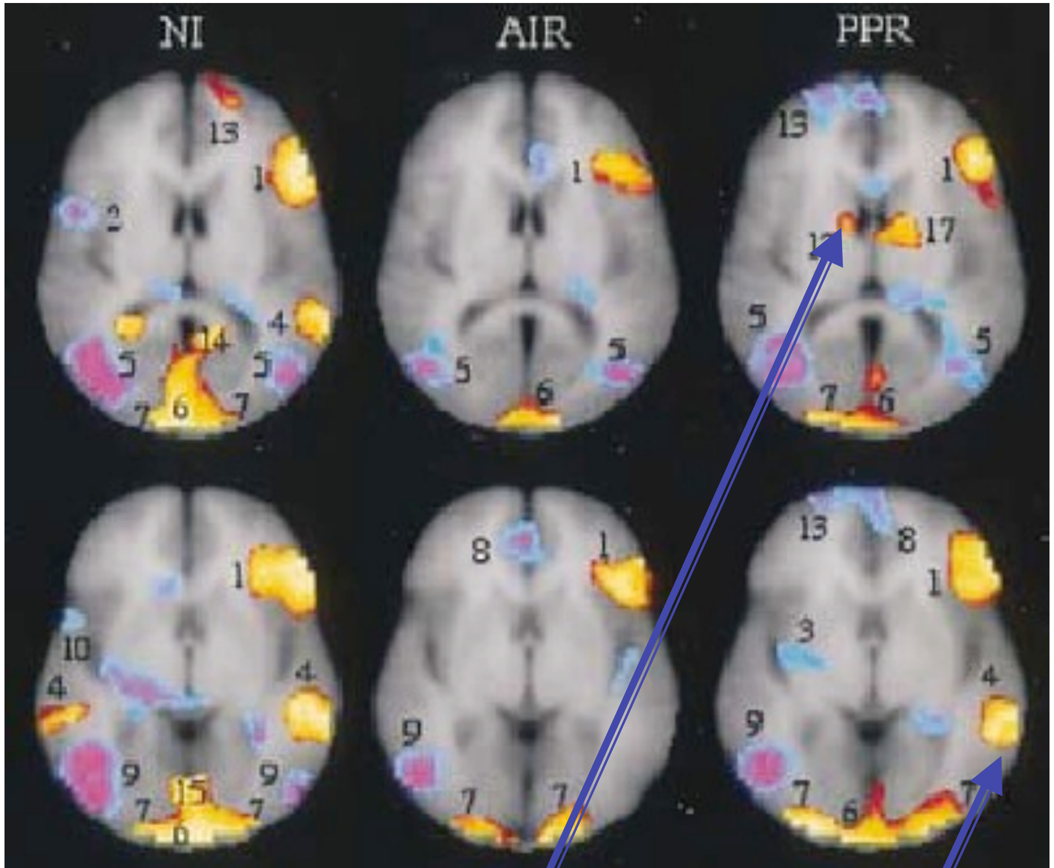
3 groups :
NI (non-impaired)
AIR (compensated)
PPR (persistent poor)

2 tasks :
NWR = « do [LEAT] and [JETE] rhyme? »
CAT = « are [CORN] and [RICE] from the same category »

Non-mots / rimes



catégorie



Compensated :

- more frontal activation (bilat)
- no sup. temp. activ.

Persistent :

- bilat. Basal gglia activation
- preserved or increased post temporal activation

Paradoxalement, le groupe persistant se rapproche plus du témoin normal que le groupe compensé.

Table 1. Early Influences and Measures as Young Adults

	Group		
	NI (n = 27)	AIR (n = 19)	PPR (n = 24)
Early Influences			
Family SES[a,f]			
High	18	6	8
Average	7	6	6
Low	2	7	10
% School Subsidized Meals[b,g]	11.2 (13.3)	15.5 (19.5)	28.4 (25.6)
Child			
WISC-R (Wechsler 1981) FSIQ—Grade 1[c]	116 (9.1)	108 (11.0)	97 (16.1)
Woodcock Johnson Reading (Woodcock and Johnson 1977)—Grade 1[a]	117 (9.4)	94.0 (11.2)	87.9 (15.1)
Measures as Young Adults			
Age (years)	20.3 (1.0)	19.9 (.9)	19.9 (1.1)
WAIS-R (Wechsler 1981) FSIQ[d]	110 (8.5)	100 (9.9)	91.2 (11.0)
Woodcock-Johnson Revised (Woodcock and Johnson 1989)			
Letter-Word Identification[d]	123 (13.0)	109 (15.0)	95.8 (3.9)
Word Attack[d]	141 (11.4)	122 (16.6)	104 (11.4)
Gray Oral Reading (Wiederholt and Bryant 1992)			
Accuracy[d]	12.2 (3.3)	5.7 (3.2)	3.1 (2.3)
Rate[d]	14.1 (1.2)	9.2 (2.1)	6.7 (2.0)
Passage[d]	13.2 (2.1)	7.6 (2.2)	4.9 (2.0)
Comprehension[e]	10.5 (3.4)	10.2 (2.8)	7.7 (3.4)
Quotient[d]	111 (12.4)	93.2 (12.9)	77.9 (13.7)
Prose Literacy[c,h]	341 (28.2)	319 (27.1)	283 (36.8)

Numbers in parentheses are SD.

NI, nonimpaired readers; AIR, accuracy improved (compensated) readers; PPR, persistently poor readers; SES, socioeconomic status; WISC-R, Wechsler Intelligence Scale for Children-Revised; FSIQ, fullscale intelligence quotient; WAIS-R, Wechsler Adult Intelligence Scale-Revised.

[a] NI > AIR, AIR = PPR, NI > PPR

[b] NI = AIR, AIR = PPR, NI < PPR

[c] NI = AIR, AIR > PPR, NI > PPR

[d] NI > AIR, AIR > PPR, NI > PPR

[e] NI = AIR, AIR = PPR, NI > PPR

Shaywitz et al., 2003 : Conclusion

- À égalité de sévérité initiale de la dyslexie
- Les deux groupes (compensé et persistant) diffèrent
  - outre l'évolution de la dyslexie
  - Par le QI de départ (compensé >persistant)
  - Par le niveau socio-culturel (non significativment différent au début)
  - Par le degré de compréhension écrite (pers.>comp.)

« PPR may represent a more environmentally influenced dyslexic reader »

Developmental Science 9:6 (2006), pp 642–654

PAPER

Brain–behavior relationships in reading acquisition are modulated by socioeconomic factors

Kimberly G. Noble,[1,2] Michael E. Wolmetz,[1] Lisa G. Ochs,[1] Martha J. Farah[2] and Bruce D. McCandliss[1]

1. Sackler Institute for Developmental Psychobiology, Weill Medical College of Cornell University, USA

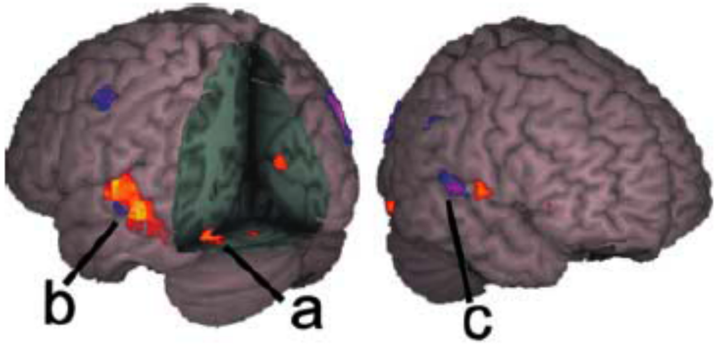
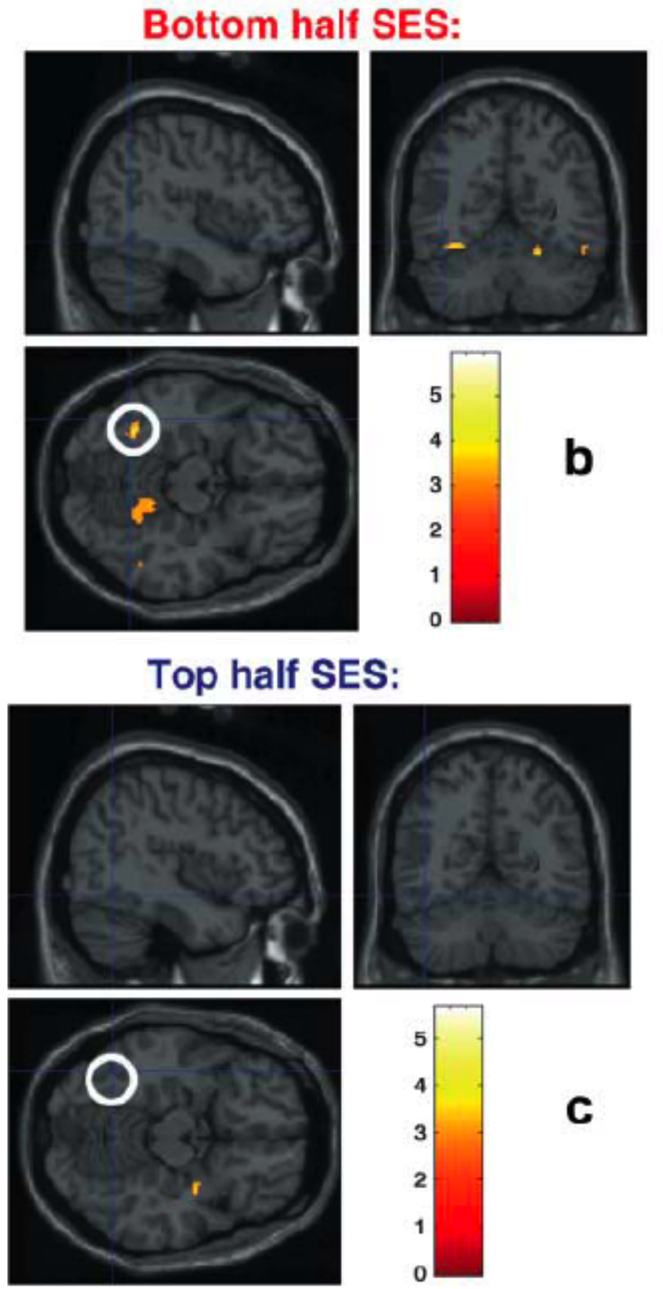


Figure 2 *Correlations of PA and activity in left fusiform and superior temporal gyrus regions, across a median split of SES. As in Figure 1, although all analyses were conducted using SES as a continuous variable, the continuum of SES has been schematically represented by dividing subjects by SES median split. Red-yellow represents correlations between PA and brain activity among children below the median SES, while blue-purple represents correlations between PA and activity among children above the median SES. Lower SES children show a positive correlation between PA and activity in (a) left fusiform (interaction cluster peak –34, –58, –16). This correlation is not observed in higher SES children. While both lower SES and higher SES children show areas of positive correlation between PA and activity in (b) left perisylvian cortex (interaction cluster peak –54, –10, 10) and (c) right perisylvian cortex (interaction cluster peak 62, –26, 6), the size of the regions exhibiting these correlations are qualitatively much larger in lower and higher SES children, respectively. Maps are depicted at p < .005 uncorrected.*

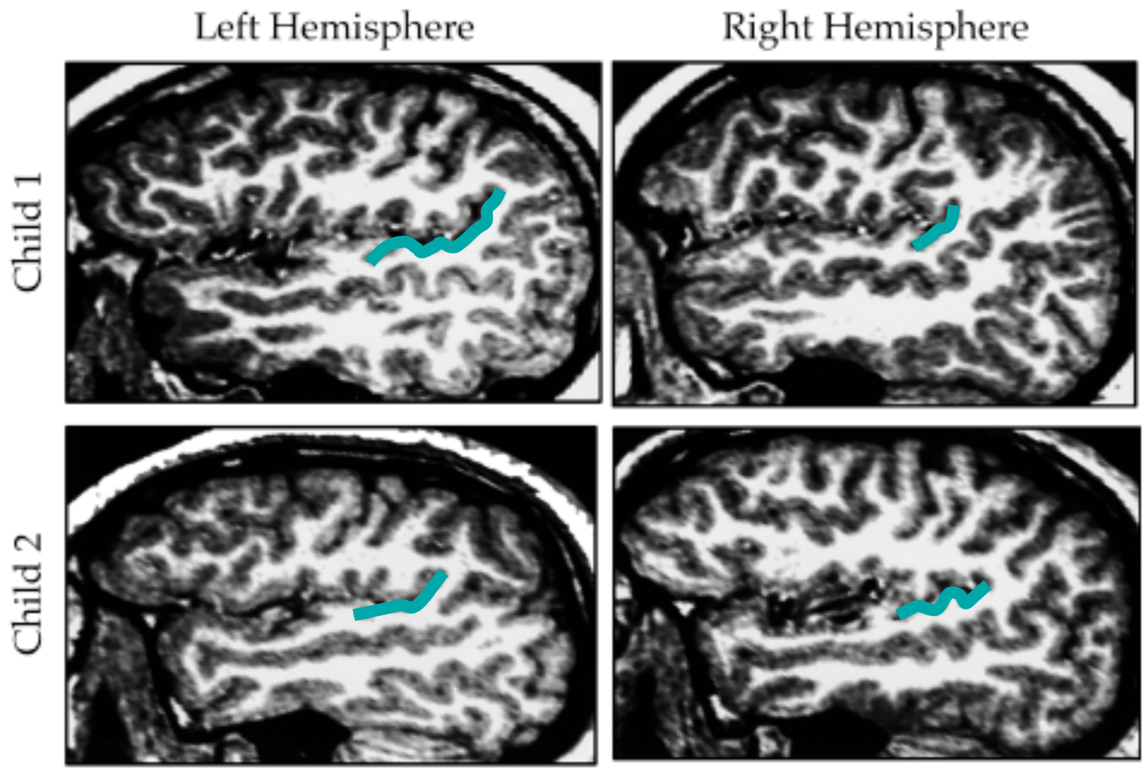
Pixels présentant une interaction entre PA (conscience phonologique) x SES (statut socio-économique)

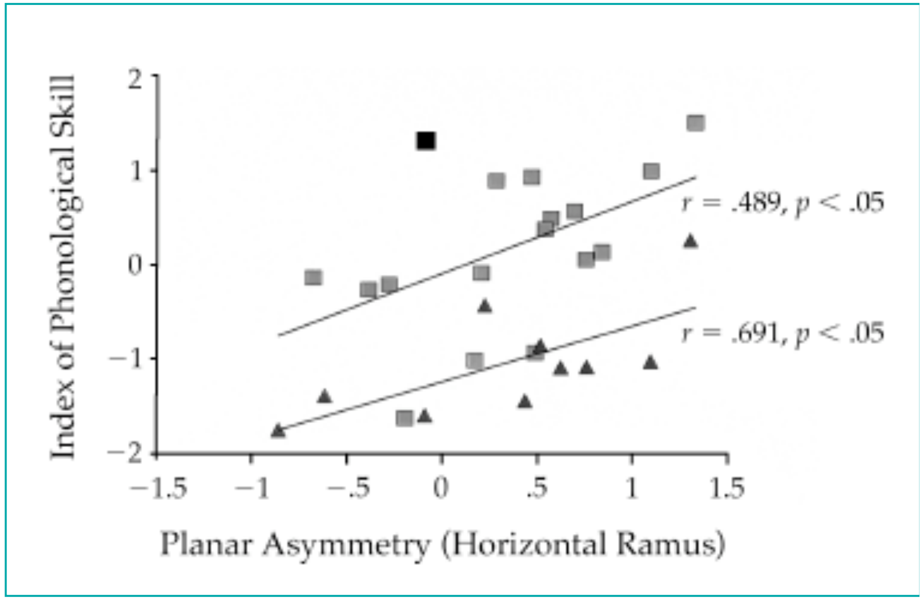


Child Development, July/August 2001, Volume 72, Number 4, Pages 988–1002

Planar Asymmetry Tips the Phonological Playground and Environment Raises the Bar

Mark A. Eckert, Linda J. Lombardino, and Christiana M. Leonard



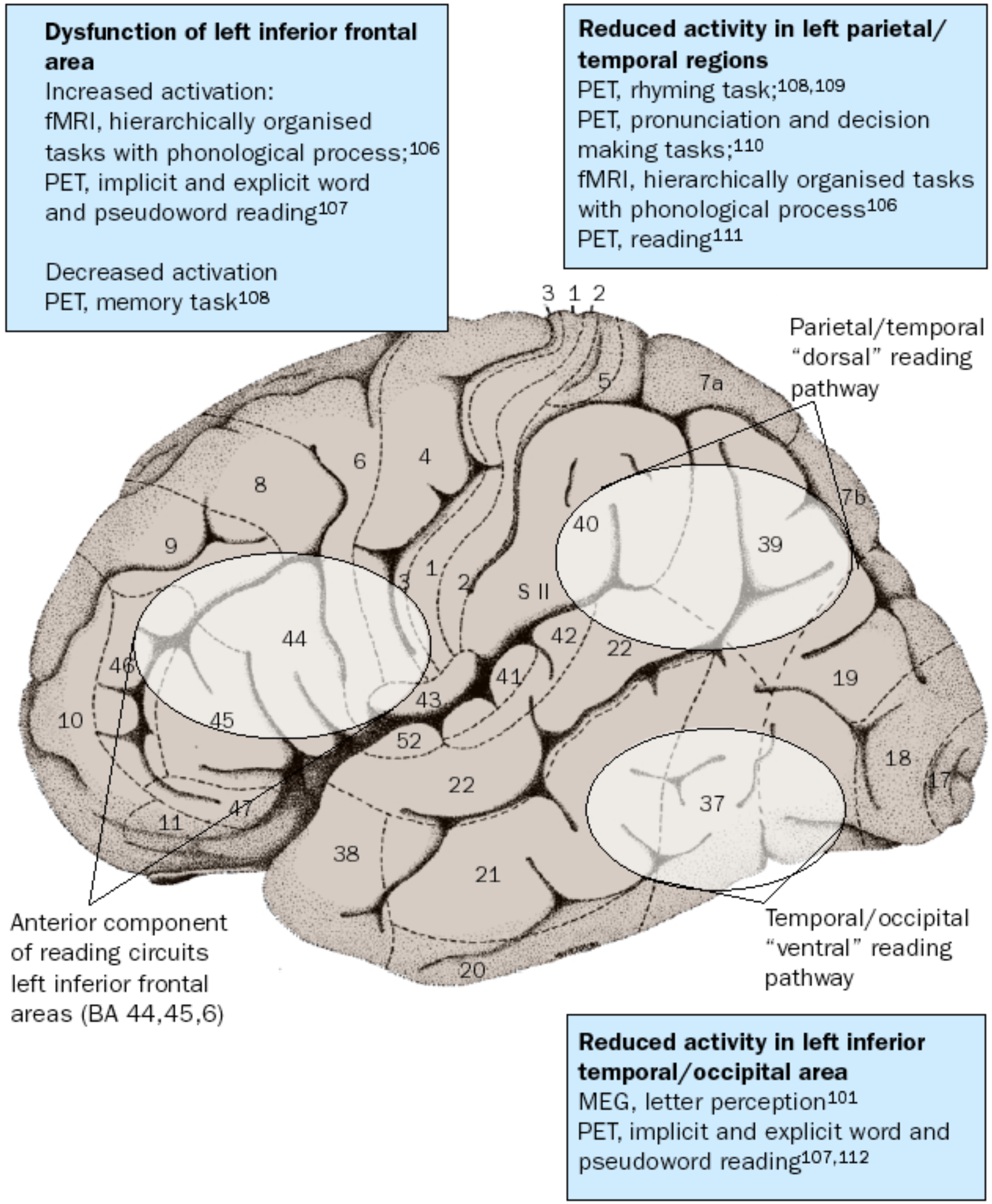


Planar asymmetry predicts phonological skill in low-SES (triangles) and high-SES (squares) right-handers

Seminar

Developmental dyslexia

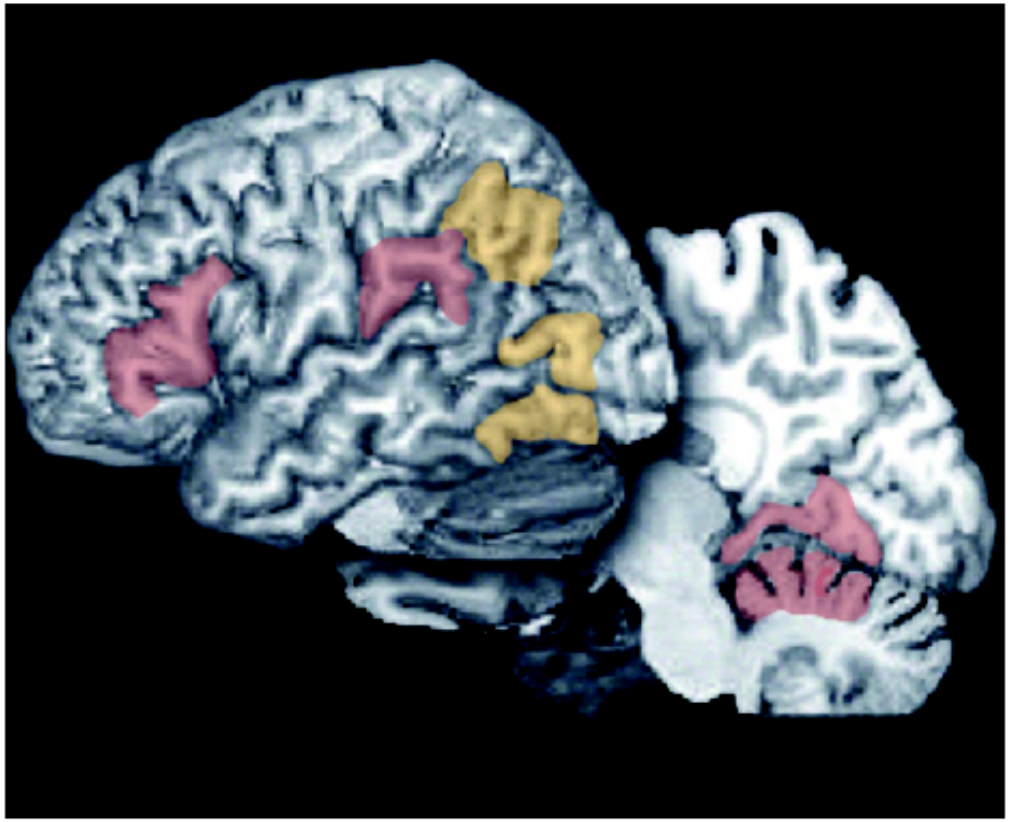
Jean-François Démonet, Margot J Taylor, Yves Chaix



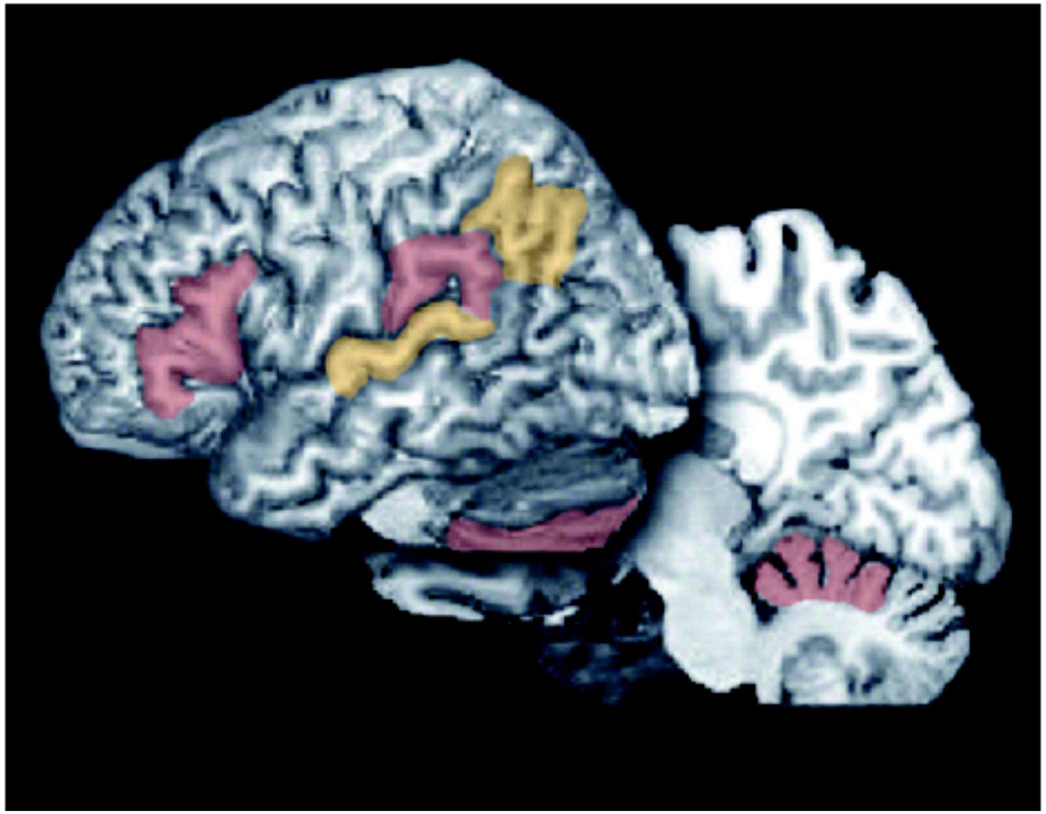
Lancet 2004; **363:** 1451–60

INSERM U455, Hôpital Purpan, IFR 96, Toulouse, France (J-F Démonet MD); **CNRS UMR 5549, Faculté de Médecine de Toulouse-Rangueil, IFR 96, Toulouse, France** (M J Taylor PhD); **and Unité de Neuro-Pédiatrie, Hôpital des Enfants, Toulouse, France** (Y Chaix MD)

Correspondence to: Dr J-F Démonet
(e-mail: demonet@toulouse.inserm.fr)



Anatomical areas activated during written language tasks and that exhibit significant differences from controls in studies of dyslexia



Anatomical areas activated during oral language tasks and that exhibit significant differences from controls in studies of dyslexia

REVIEW ■

Neuroanatomical Markers for Dyslexia: A Review of Dyslexia Structural Imaging Studies

MARK ECKERT

NEUROSCIENTIST. 10(3):000–000, 2004.

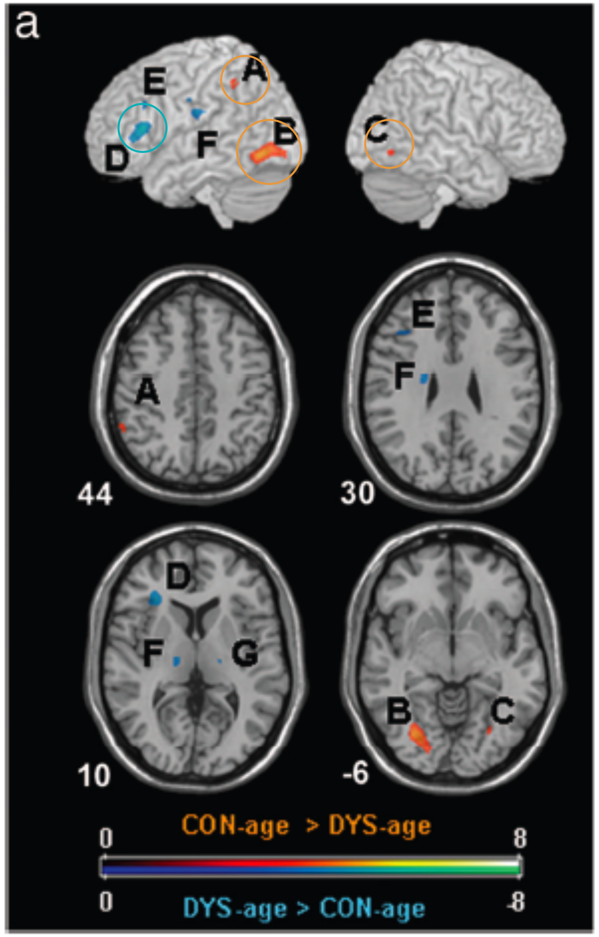
Functional and morphometric brain dissociation between dyslexia and reading ability

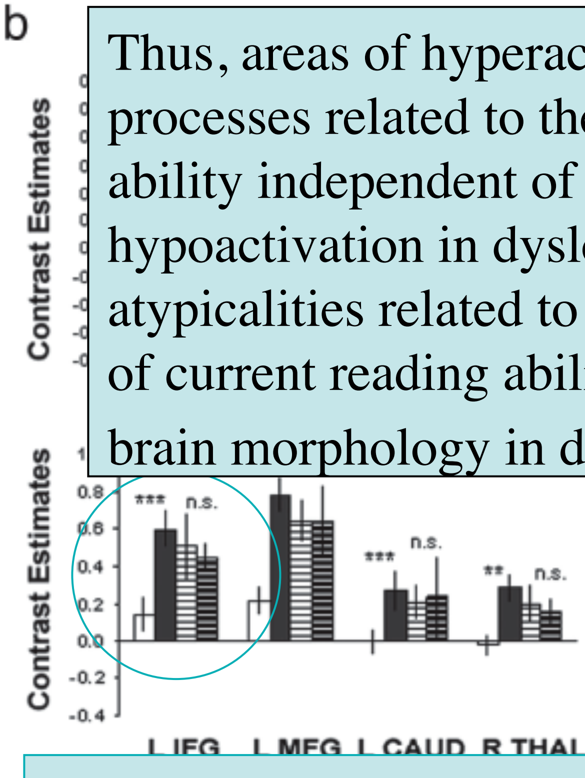
Fumiko Hoeft*[†‡], Ann Meyler[§], Arvel Hernandez*, Connie Juel[¶], Heather Taylor-Hill*, Jennifer L. Martindale*, Glenn McMillon*, Galena Kolchugina*, Jessica M. Black*[¶], Afrooz Faizi*, Gayle K. Deutsch*, Wai Ting Siok*[‖], Allan L. Reiss[†], Susan Whitfield-Gabrieli*,**, and John D. E. Gabrieli*,**

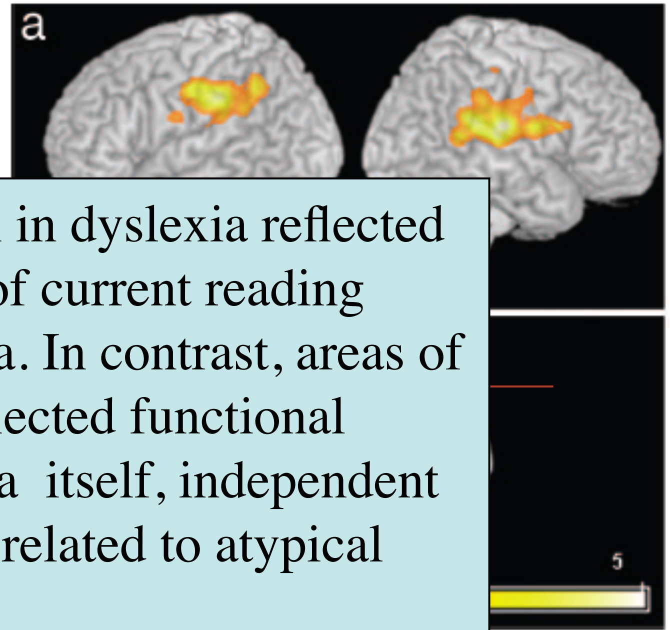
*Department of Psychology, Stanford University, Building 420, m/c 2130, Palo Alto, CA 94305-2130; [†]Center for Interdisciplinary Brain Sciences Research (CIBSR), Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine, 401 Quarry Road, Palo Alto, CA 94305-5795; [§]Department of Psychology, Carnegie Mellon University, Baker Hall, Pittsburgh, PA 15213-3890; [¶]School of Education, Stanford University, 485 Lausen Mall, Palo Alto, CA 94305-3096

Edited by Michael M. Merzenich, University of California School of Medicine, San Francisco, CA, and approved December 27, 2006 (received for review October 26, 2006)

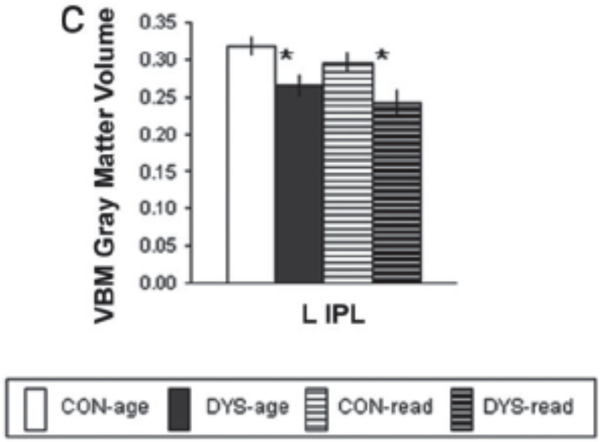
a) régions de diminution de volume
b) idem pour zones d'activation réduite en fMRI (L IPL)







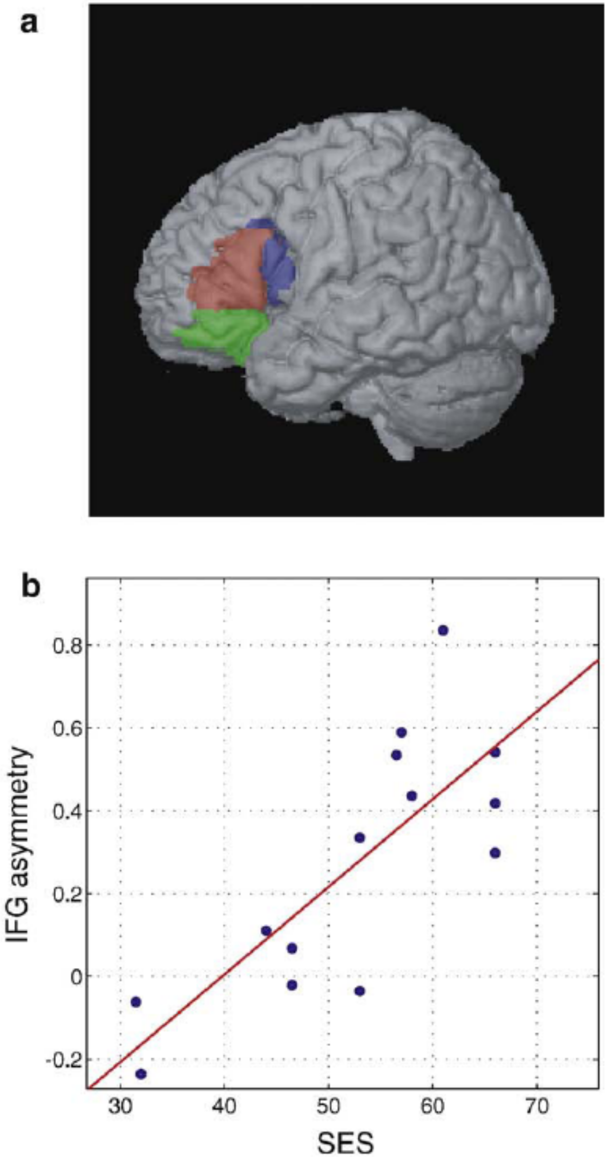
Thus, areas of hyperactivation in dyslexia reflected processes related to the level of current reading ability independent of dyslexia. In contrast, areas of hypoactivation in dyslexia reflected functional atypicalities related to dyslexia itself, independent of current reading ability, and related to atypical brain morphology in dyslexia.



Hypoactivation significative pour les régions postérieures. Hyperactivation significative pour les régions antérieures, seulement par rapport aux témoins d'âge chronologique

I/ IRMf

II/ VBM



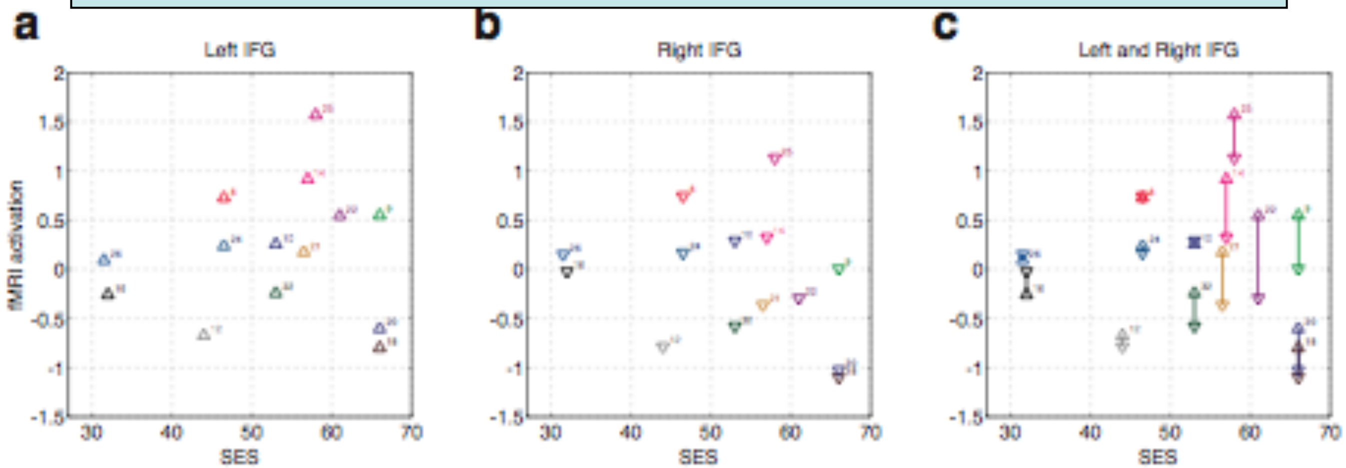
Corrélation entre le degré d'asymétrie de l'aire de Broca dans une tâche d'activation (dire si deux mots entendus riment) et le statut socio-économique

Socioeconomic status predicts hemispheric specialisation of the left inferior frontal gyrus in young children

Rajeev D.S. Raizada,[a,*] Todd L. Richards,[b] Andrew Meltzoff,[a] and Patricia K. Kuhl[a]

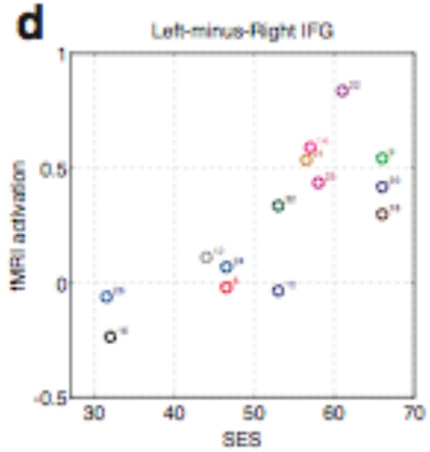
[a]Institute for Learning and Brain Sciences, University of Washington, Box 357988, Seattle, WA 98195, USA
[b]Department of Radiology, University of Washington Medical School, Seattle, WA 98195, USA

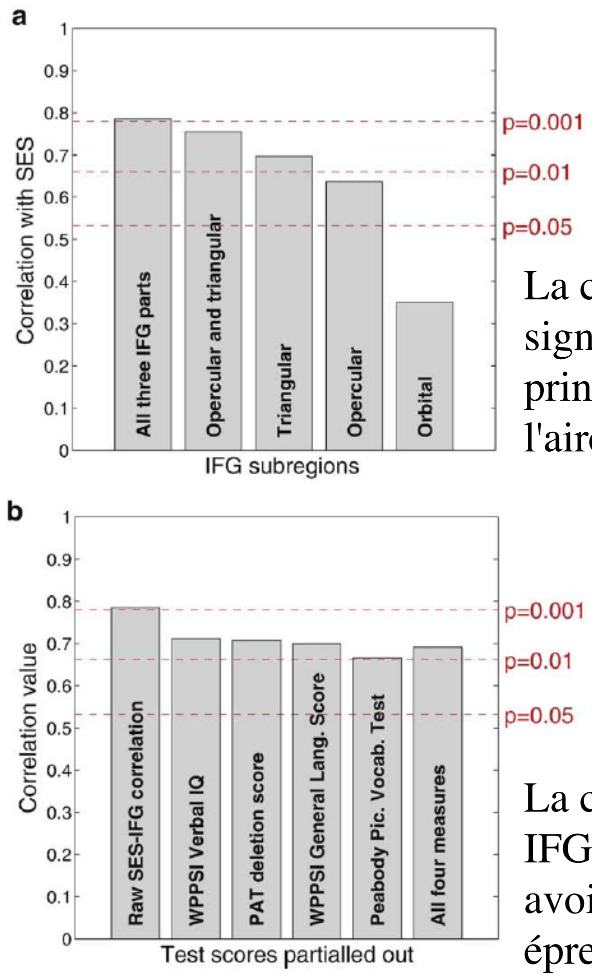
14 enfants de 5 ans, en "pre-school", de milieux socio-économiques moyen-faibles à aisés. fMRI sur tâche de rimes auditive + neuroanatomie en VBM (segmentation SG/SB).



La corrélation concerne principalement l'asymétrie d'activation (et non chaque côté pris séparément)

Le statut socio-économique détermine donc le degré de latéralisation de la fonction étudiée

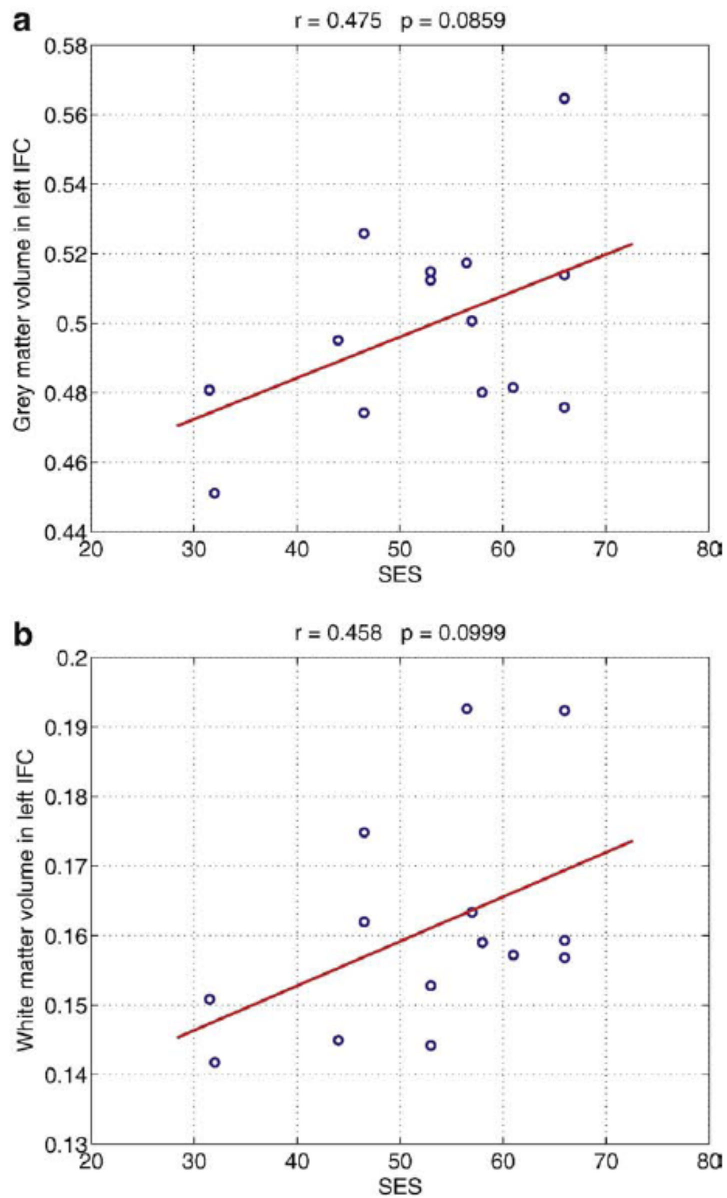




La corrélation est significative pour les deux principales régions de l'aire de Broca

La corrélation entre SES et IFG reste significative après avoir éliminé les scores aux épreuves verbales

Fig. 3. (a) The correlations of the different subparts of the IFG with socioeconomic status. (b) The partial correlations between SES and IFG asymmetry, after removing the effects of various standardised test scores. The test that was partialled out is marked on each bar, with the leftmost bar showing the correlation without any partialling and the rightmost bar showing the effect of partialling out the four test scores simultaneously.



Il existe également une corrélation du point de vue neuroanatomique entre les volumes de SG et de SB et le SES

Conclusion : le niveau socio-économique détermine en partie non seulement le degré de latéralisation de la fonction, mais la taille même des structures sous-jacentes.

Neuropsychologia 47 (2009) 1972–1977

Contents lists available at ScienceDirect

Neuropsychologia

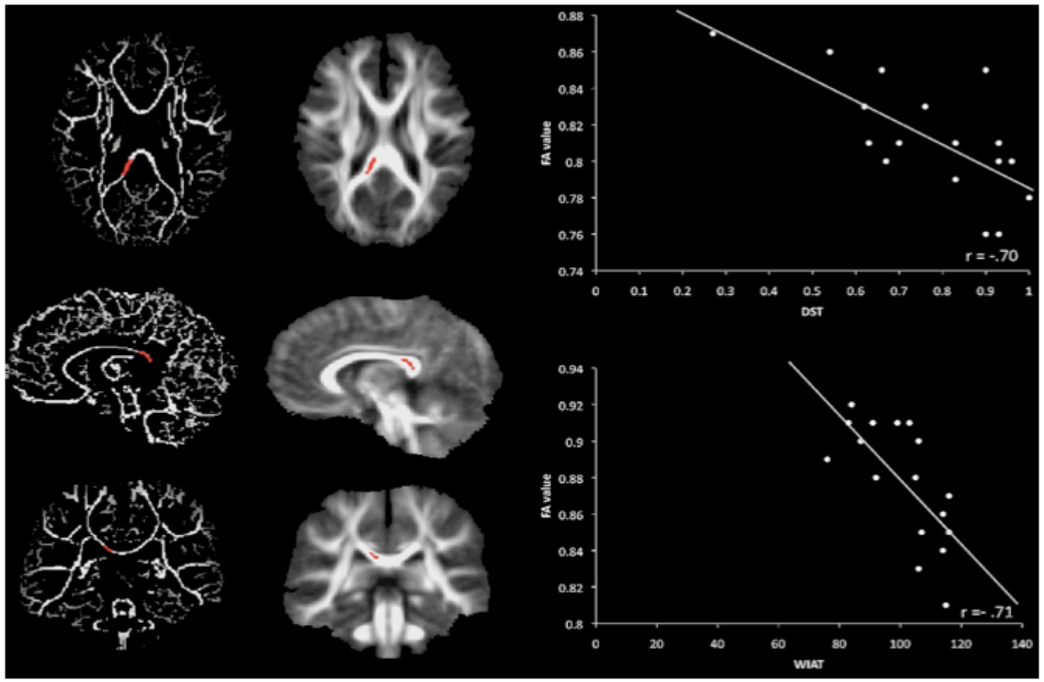
journal homepage: www.elsevier.com/locate/neuropsychologia

Brain connectivity in non-reading impaired children and children diagnosed with developmental dyslexia

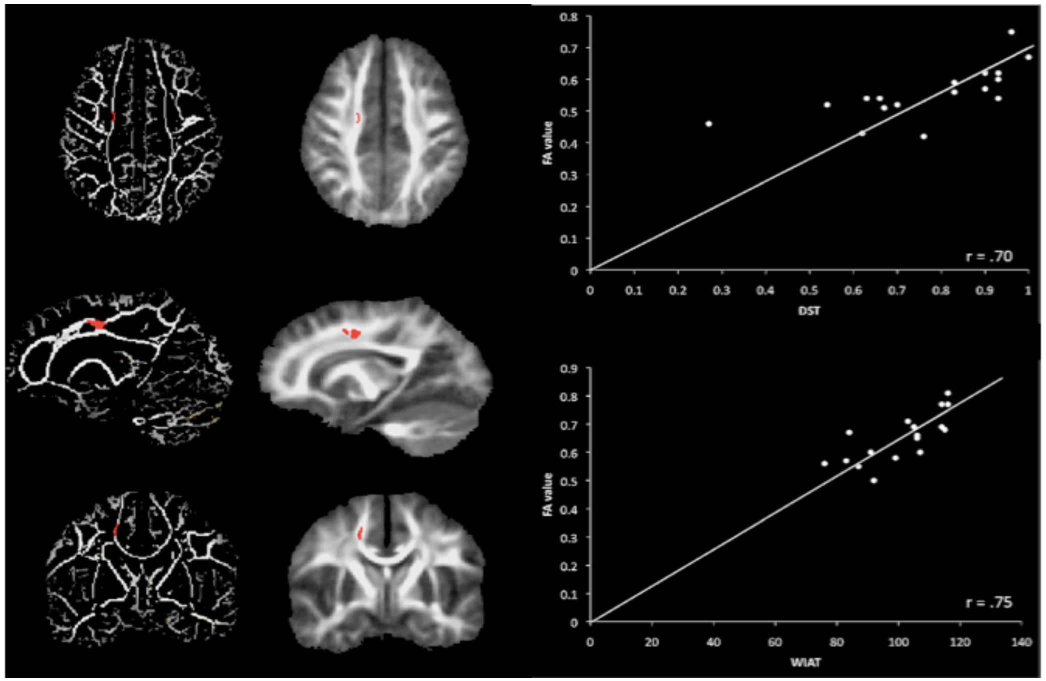
Timothy N. Odegard [a,c,*], Emily A. Farris [a], Jeremiah Ring [b], Roderick McColl [c], Jeffrey Black [b,c]

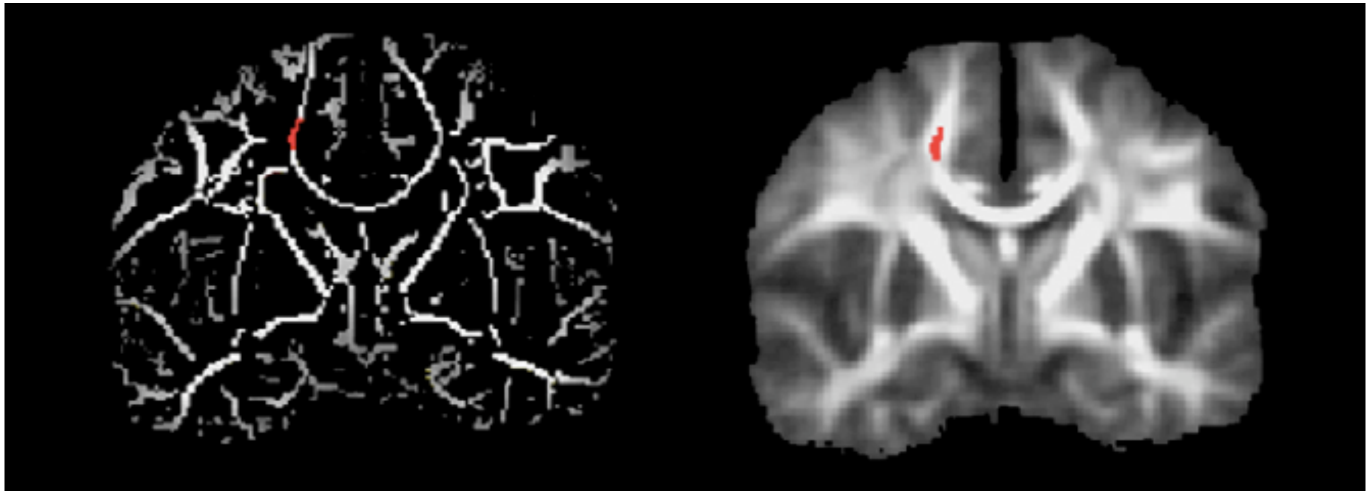
[a] University of Texas Arlington, United States

Corrélations entre F.A. et décodage en lecture pour des voxels situés dans le corps calleux postérieur gauche



Corrélations entre F.A. et décodage en lecture pour des voxels situés dans la corona radiata supérieure gauche





these data replicate the positive correlations observed between reading ability and FA values in left hemisphere white matter tracts that project along the superior–inferior axis opposed to the anterior–posterior axis (Beaulieu et al., 2005; Dougherty et al., 2007; Niogi & McCandliss, 2006). The main areas observed to be positively correlated with reading ability in the present study were located on the left superior corona radiata, which is a white matter tract that projects from the thalamus to the sensory cortices

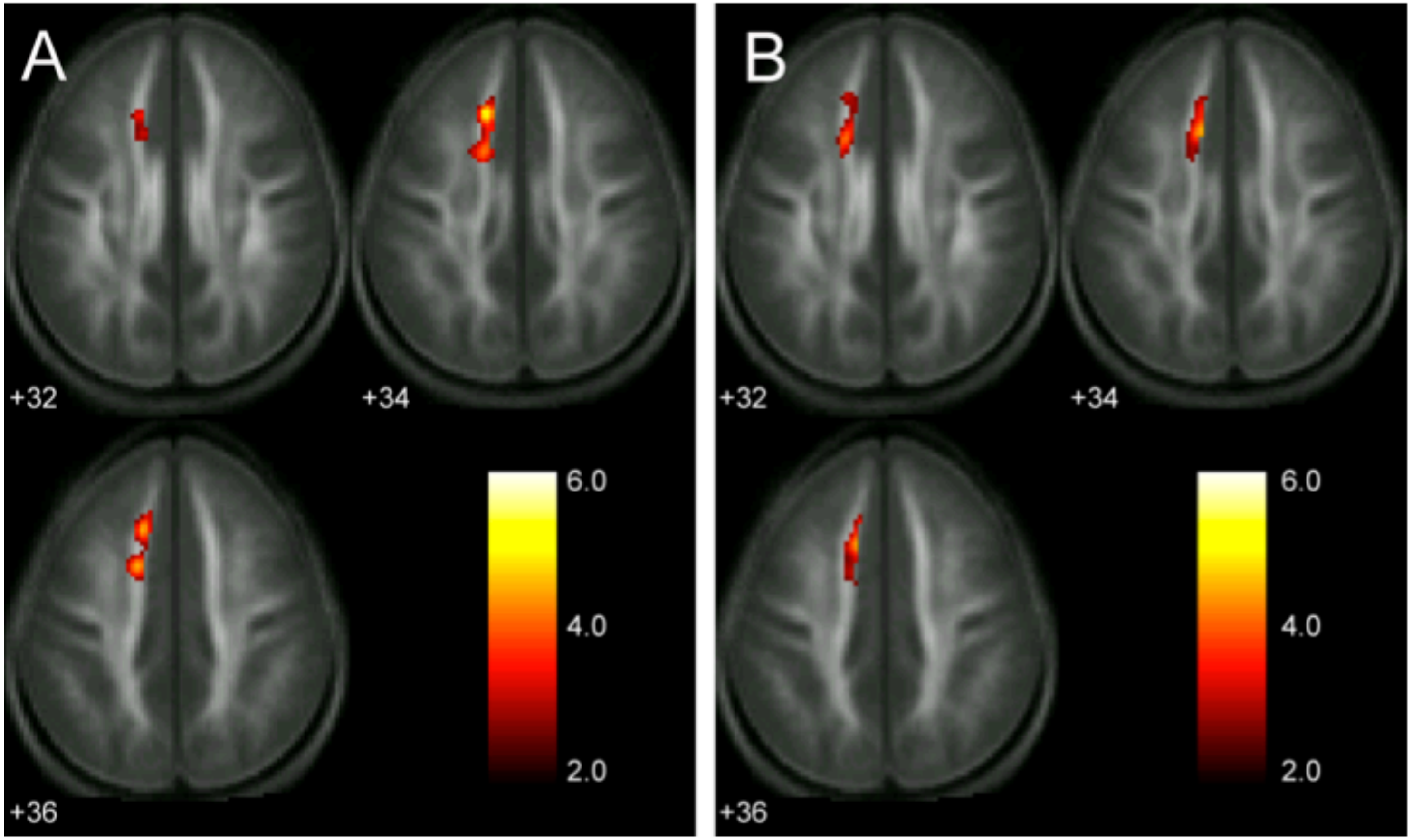
Published in final edited form as:
Neuron. 2009 December 10; 64(5): 624–631. doi:10.1016/j.neuron.2009.10.018.

Altering cortical connectivity: Remediation-induced changes in the white matter of poor readers

Timothy A. Keller[1] and **Marcel Adam Just**[1]
[1]Center for Cognitive Brain Imaging, Department of Psychology, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA

72 participants : 35 poor readers that received the treatment, 12 poor readers that did not receive the treatment, and 25 good readers that did not receive the treatment

Treatment : 100 hours of intensive reading instruction (one of 4 classical reading remediation programmes)



(A) Region where the poor reader group showed an increase in FA between the pre- remediation and post-remediation scans (peak $t(34) = 5.12$, at Montreal Neurological Institute (MNI) coordinates −2 28 36, spatial extent = 450 voxels, $p < .05$ corrected for multiple comparisons). There were no areas where poor readers showed a decrease in FA between phases, nor were there any areas where the control group of good readers or the control group of unremediated poor readers showed either an increase or decrease in FA. (B) Region showing a significant difference in FA between good readers and all poor readers at the first scan (peak $t(70) = 4.66$, at MNI coordinates −0 20 38, spatial extent = 418 voxels, $p < .05$ corrected for multiple comparisons).

NeuroImage xxx (2010) xxx–xxx

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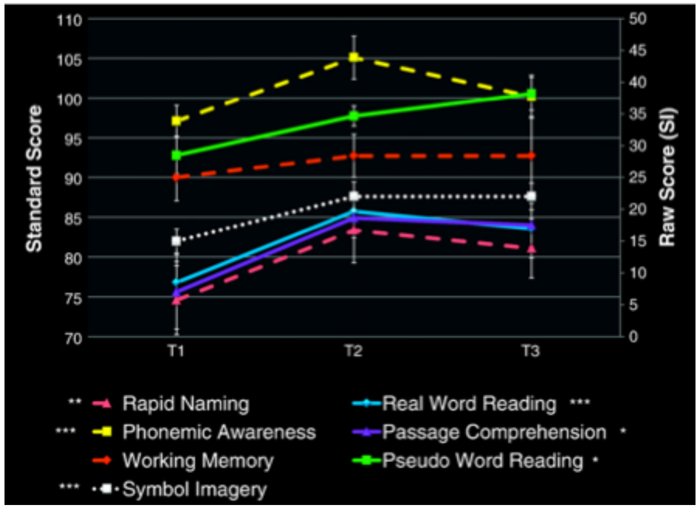
Gray matter volume changes following reading intervention in dyslexic children

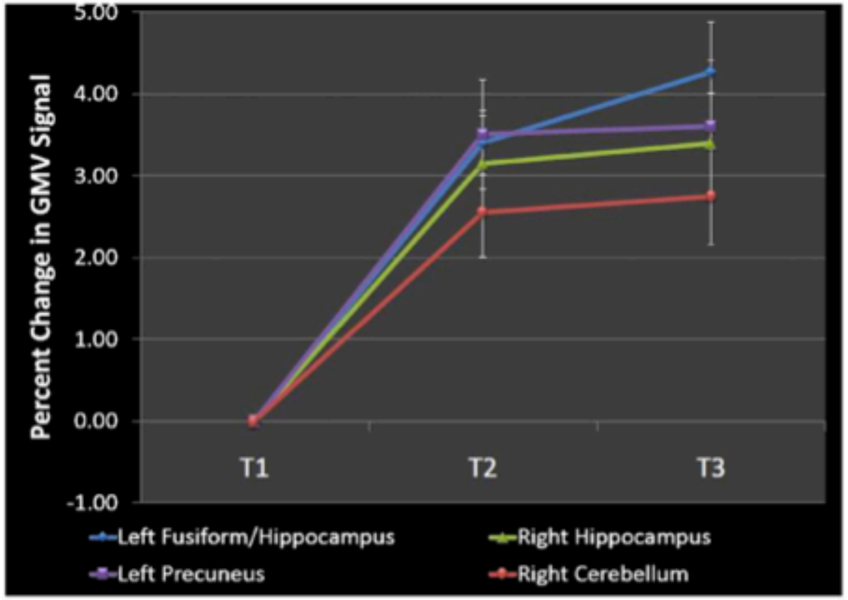
Anthony J. Krafnick [a], D. Lynn Flowers [a,b], Eileen M. Napoliello [a], Guinevere F. Eden [a,*]

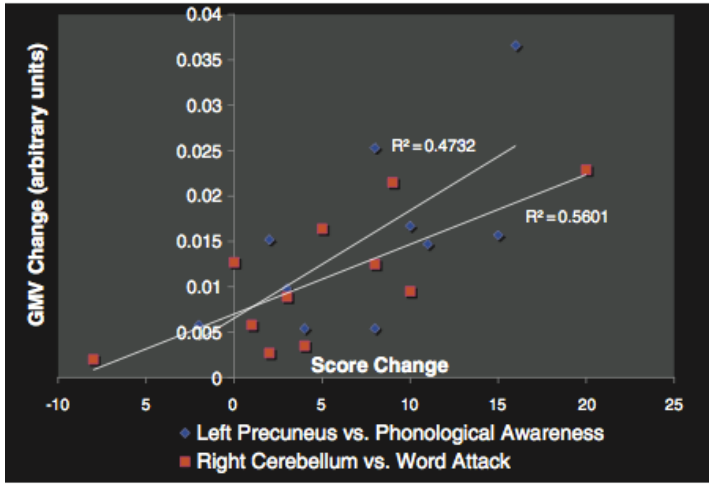
[a] Center for the Study of Learning, Georgetown University Medical Center, 4000 Reservoir Road, Building D Suite 150, Washington, DC 20057, USA
[b] Wake Forest University Baptist Medical Center, Winston Salem, NC, 27157

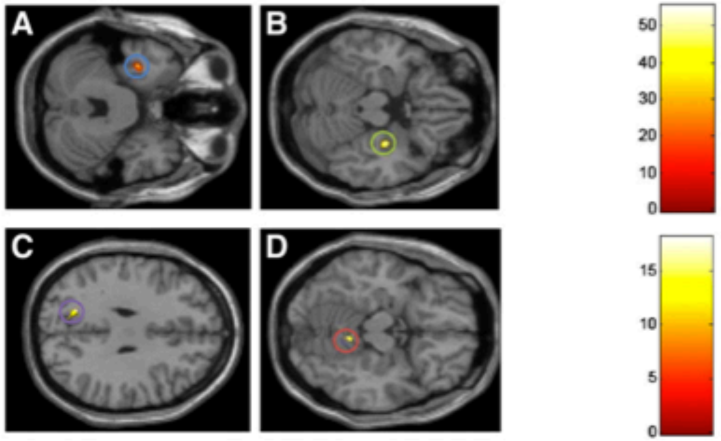
11 children, mean age 9,5y, 8 week reading intervention, Seeing Stars (Lindamood-Bell Learning Processes ©), focuses heavily on imaging/visualization starting with single letters and increasing in difficulty to image one syllable and up to two and three syllable words. Then 8 week : no intervention



3 scans : before the reading intervention (T1), after the reading intervention (T2) and after the period of no intervention (T3)







Neural systems predicting long-term outcome in dyslexia

Fumiko Hoeft[a,b,1], Bruce D. McCandliss[c], Jessica M. Black[a,d], Alexander Gantman[a], Nahal Zakerani[a], Charles Hulme[e], Heikki Lyytinen[f], Susan Whitfield-Gabrieli[g], Gary H. Glover[h], Allan L. Reiss[a,b,h], and John D. E. Gabrieli[h]

[a]Center for Interdisciplinary Brain Sciences Research, and [b]Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine, Stanford, CA 94129; [c]Department of Psychology and Human Development, Vanderbilt University, Nashville, TN 37203; [d]Graduate School of Social Work, Boston College, Chestnut Hill, MA 02467; [e]Department of Psychology, University of York, York Y010 5DD, United Kingdom; [f]Department of Psychology, University of Jyväskylä, 40351 Jyväskylä, Finland; [g]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139; and [h]Department of Radiology, Stanford University School of Medicine, Stanford, CA 94305

Edited by Marcus E. Raichle, Washington University of St. Louis, St. Louis, MO, and approved November 2, 2010 (received for review June 24, 2010)

Utilisent une double méthodologie d'imagerie fonctionnelle et morphologique (DTI) pour prédire l'évolution à long terme du trouble de la lecture chez des pré-adolescents dyslexiques. Deux mesures particulières (activation du lobe frontal inférieur droit en IRMf et anisotropie du faisceau arqué droit en DTI) prédisent à elles seules 72% de la variance en termes d'évolution de la lecture sur 2,5 ans faisant suite au premier examen. Ces mesures sont des meilleurs prédicteurs de l'évolution que n'importe quelle combinaison de tests cognitifs réalisés sur la même période.

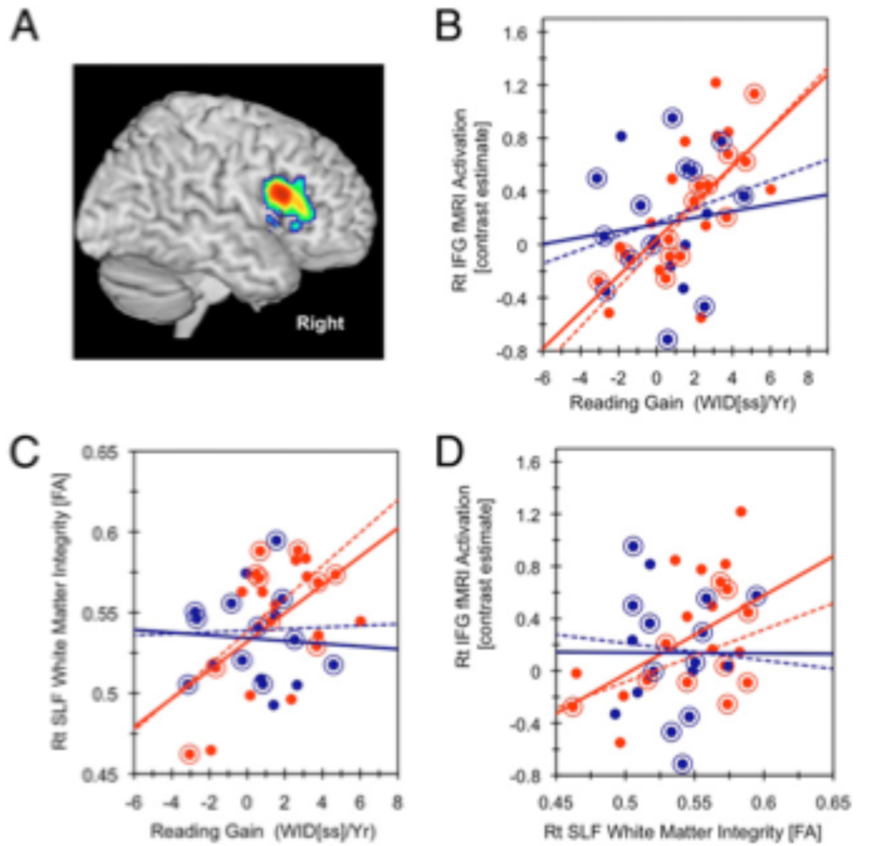


Fig. 2. fMRI and DTI predictors of reading gains in dyslexia. (*A*) Association between brain activation (rhyme > rest) and future reading improvement.

NeuroImage xxx (2010) xxx–xxx

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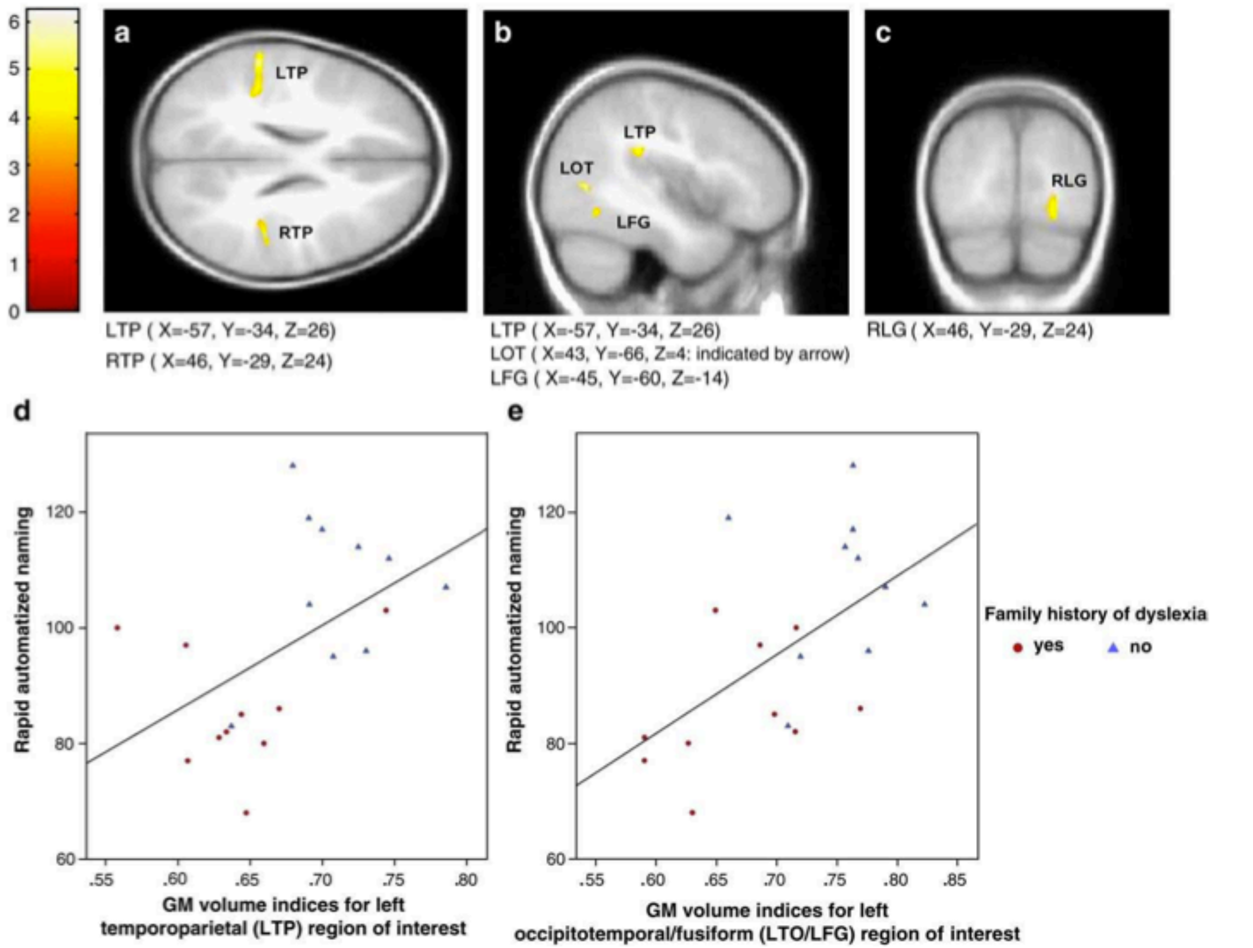
Structural brain alterations associated with dyslexia predate reading onset

Nora Maria Raschle, Maria Chang, Nadine Gaab *

Children's Hospital Boston, Department of Medicine, Division of Developmental Medicine, Laboratories of Cognitive Neuroscience, 1 Autumn Street, Mailbox # 713, Boston, MA 02115, USA

Twenty healthy, native English speaking children with (FHD+/ n = 10) and without (FHD–/n = 10) a family-history of developmental dyslexia, (mean age 5 years and 11 months)

Voxel-based morphometry revealed significantly reduced gray matter volume indices for pre-reading children with, compared to children without, a family-history of developmental dyslexia in left occipitotemporal, bilateral parietotemporal regions, left fusiform gyrus and right lingual gyrus. Gray matter volume indices in left hemispheric occipitotemporal and parietotemporal regions of interest also correlated positively with rapid automatized naming.



ig. 1. [a–c] Statistical parametric maps showing brain areas with significant decreased gray matter volume indices in pre-reading FHD+ compared to FHD– children (a = axial, = sagittal, c = coronal view). [d–e] Correlations between gray matter volume indices in the left parietotemporal (d) and left occipitotemporal (e) ROI and rapid automatized naming.

Functional characteristics of developmental dyslexia in left-hemispheric posterior brain regions predate reading onset

Nora Maria Raschle[a,b], Jennifer Zuk[a], and Nadine Gaab[a,b,c,1]

[a]Laboratories of Cognitive Neuroscience, Division of Developmental Medicine, Department of Medicine, Children's Hospital Boston, and [b]Harvard Medical School, Boston, MA 02115; and [c]Harvard Graduate School of Education, Cambridge, MA 02138

Activation d'un réseau occipito-temporo-frontal chez des enfants pré-lecteurs (moyenne âge 5ans 8mois) avec (FHD+) ou sans (FHD-) une histoire familiale de dyslexie avérée, dans une tâche de décision de similitude du premier phonème de deux mots représentés sur des dessins

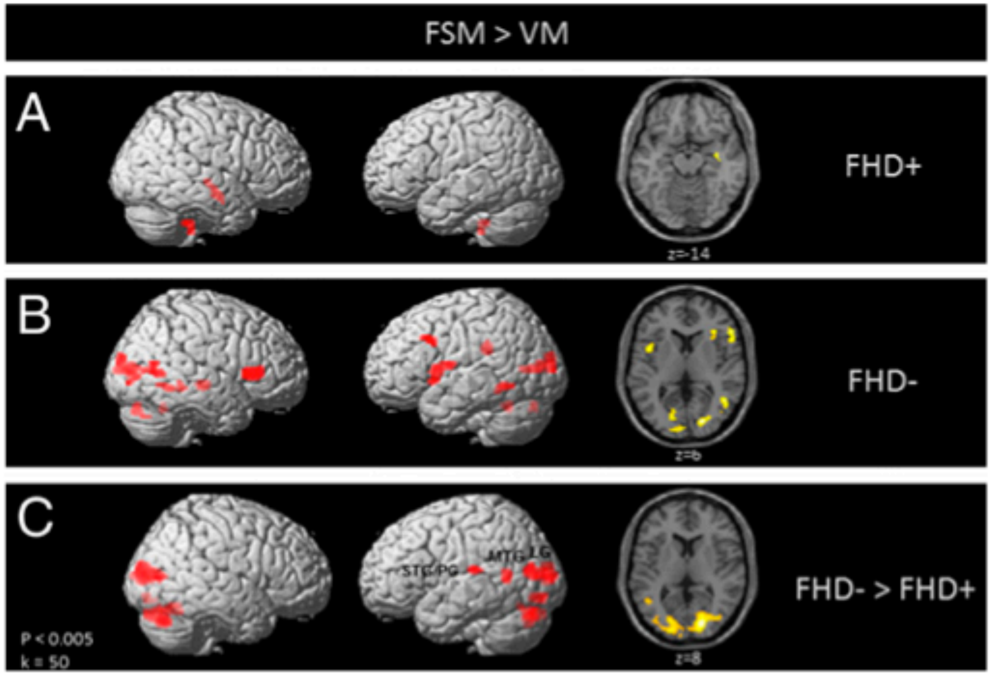


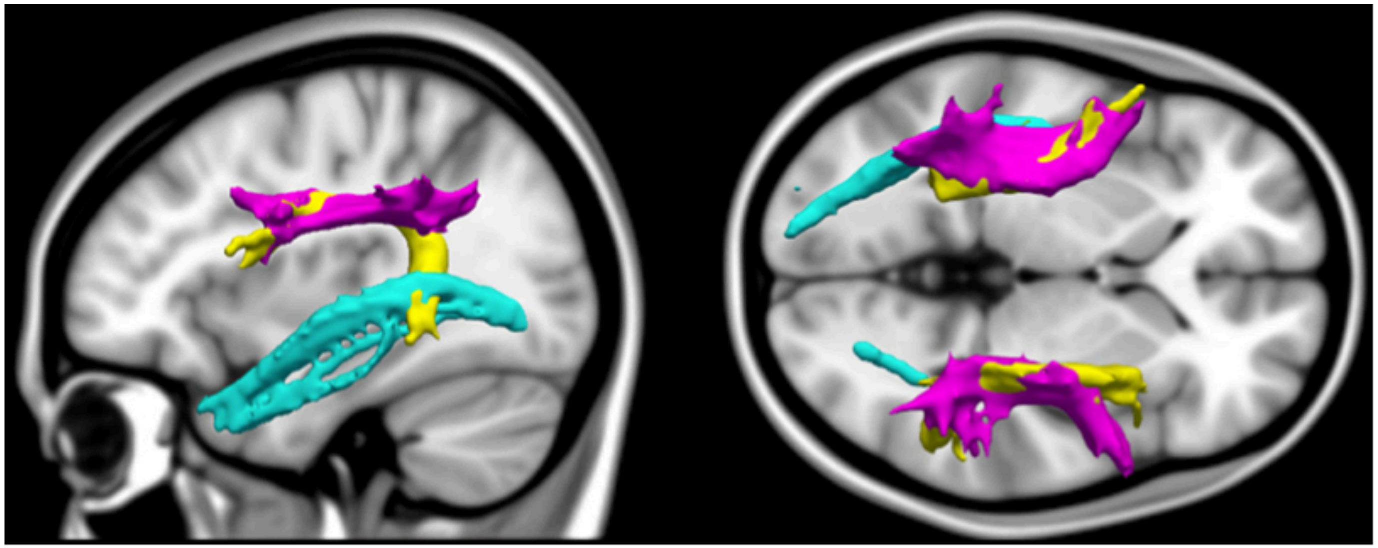
Fig. 1. Statistical parametric maps showing brain activation during phonological processing (FSM > VM) for children with (*A*) and without (*B*) a familial risk for DD, as well as group differences between children with compared to without ($FHD^- > FHD^+$) a familial risk for DD (*C*). FHD^- show significantly greater activation compared to FHD^+ children in bilateral occipitotemporal and left temporoparietal brain regions, as well as left and right cerebellar regions.

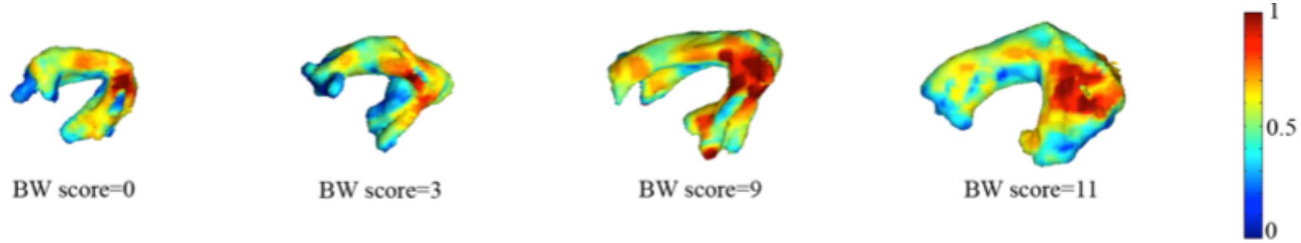
The Journal of Neuroscience, August 14, 2013 • 33(33):13251–13258 • 13251

Behavioral/Cognitive

Tracking the Roots of Reading Ability: White Matter Volume and Integrity Correlate with Phonological Awareness in Prereading and Early-Reading Kindergarten Children

Zeynep M. Saygin,[1]* Elizabeth S. Norton,[1]* David E. Osher,[1] Sara D. Beach,[1] Abigail B. Cyr,[1] Ola Ozernov-Palchik,[3] Anastasia Yendiki,[4] Bruce Fischl,[2,4] Nadine Gaab,[3] and John D.E. Gabrieli[1]
[1]McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences and [2]Computer Science and Artificial Intelligence Laboratory





40 enfants de différents niveaux de capacités de conscience phonologique en première moitié de maternelle et 18 pré-lecteurs. Corrélation avec l'organisation (taille et anisotropie) du faisceau arqué dans les deux populations :

→les différences d'organisation du FA ne sont pas la conséquence de l'acquisition de la lecture.

→Pas de telle corrélation avec les

Corrélation entre le score de conscience phonologique en maternelle et la morphologie du faisceau arqué (volume et anisotropie)

NeuroImage 56 (2011) 1735–1742

Meta-analyzing brain dysfunctions in dyslexic children and adults

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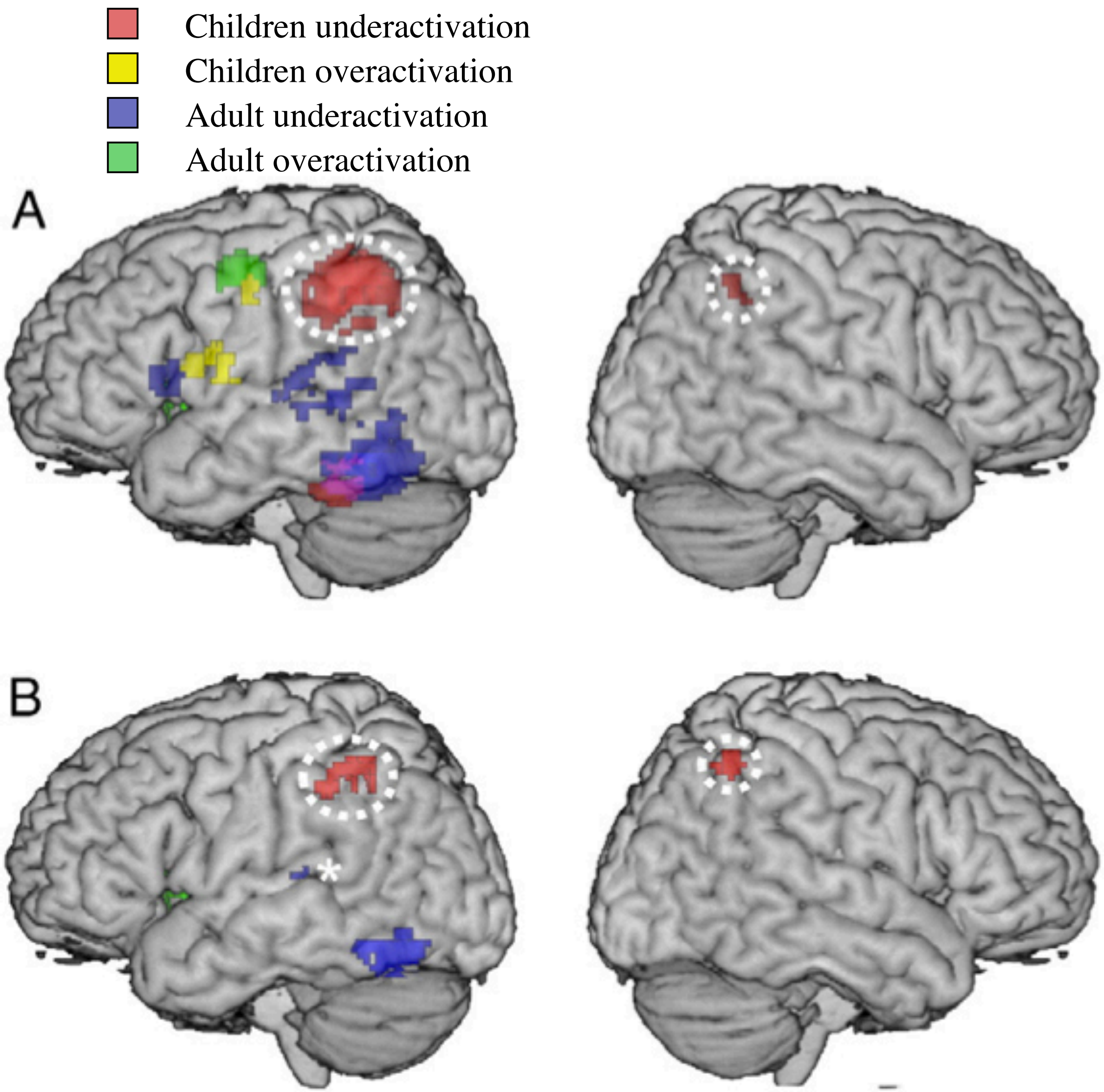
[b] Neuroscience Institut and Department of Neurology, Christian Doppler Clinic, Paracelsus Private Medical University, Ignaz-Harrer-Str. 79, 5020 Salzburg, Austria



We examined the evidence from functional imaging studies for predominance of a phonological left temporo- parietal (TP) dysfunction in dyslexic children and predominance of a visual-orthographic left occipito-temporal (OT) dysfunction in dyslexic adults. Separate meta-analyses of **9 studies with children (age means: 9-11 years) and of 9 studies with adults (age means: 18-30 years)** and statistical comparison of these meta-analytic maps did find support for a dysfunction of a left ventral OT region in both children and adults. The findings on a possible predominance of a left TP dysfunction in children were inconclusive. Contrary to expectation, underactivation in superior temporal regions was only found for adults, but not for children. For children, underactivation was found in bilateral inferior parietal regions, but this abnormality was no longer present when foci identified by higher dyslexic task-negative activation (i.e., deactivation in response to reading compared to baseline) were excluded. These meta-analytic results are consistent with recent findings speaking for an early engagement of left OT regions in reading development and for an early failure of such an engagement in dyslexia.

Grey Matter Alterations Co-Localize with Functional Abnormalities in Developmental Dyslexia: An ALE Meta-Analysis

Janosch Linkersdörfer[1,2]*, Jan Lonnemann[2,3], Sven Lindberg[1,2], Marcus Hasselhorn[1,2,3], Christian J. Fiebach[1,3,4]

1 Center for Individual Development and Adaptive Education of Children at Risk, Frankfurt, Germany, **2** German Institute for International Educational Research, Frankfurt, Germany, **3** Institute for Psychology, Goethe-University Frankfurt, Germany, **4** Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, The Netherlands

Abstract

The neural correlates of developmental dyslexia have been investigated intensively over the last two decades and reliable evidence for a dysfunction of left-hemispheric reading systems in dyslexic readers has been found in functional neuroimaging studies. In addition, structural imaging studies using voxel-based morphometry (VBM) demonstrated grey matter reductions in dyslexics in several brain regions. To objectively assess the consistency of these findings, we performed activation likelihood estimation (ALE) meta-analysis on nine published VBM studies reporting 62 foci of grey matter reduction in dyslexic readers. We found six significant clusters of convergence in bilateral temporo-parietal and left occipito-temporal cortical regions and in the cerebellum bilaterally. To identify possible overlaps between structural and functional deviations in dyslexic readers, we conducted additional ALE meta-analyses of imaging studies reporting functional underactivations (125 foci from 24 studies) or overactivations (95 foci from 11 studies) in dyslexics. Subsequent conjunction analyses revealed overlaps between the results of the VBM meta-analysis and the meta-analysis of functional underactivations in the fusiform and supramarginal gyri of the left hemisphere. An overlap between VBM results and the meta-analysis of functional overactivations was found in the left cerebellum. The results of our study provide evidence for consistent grey matter variations bilaterally in the dyslexic brain and substantial overlap of these structural variations with functional abnormalities in left hemispheric regions.

Double méta-analyse :

- 9 études en VBM=62 foyers de réduction de SG chez dyslexiques
- 24 études en IRMf =125 foyers d'hypoactivation et 11 études=95 foyers de sur-activation

Résultats:

- VBM : clusters de convergence dans G bilatéral, GTInf Gche et cervelet bilatéral
- superposition entre hypoactivation fonctionnelle et foyer de réduction VBM temporal inférieur gauche
- superposition entre hyperactivation et foyer de réduction VBM cervelet

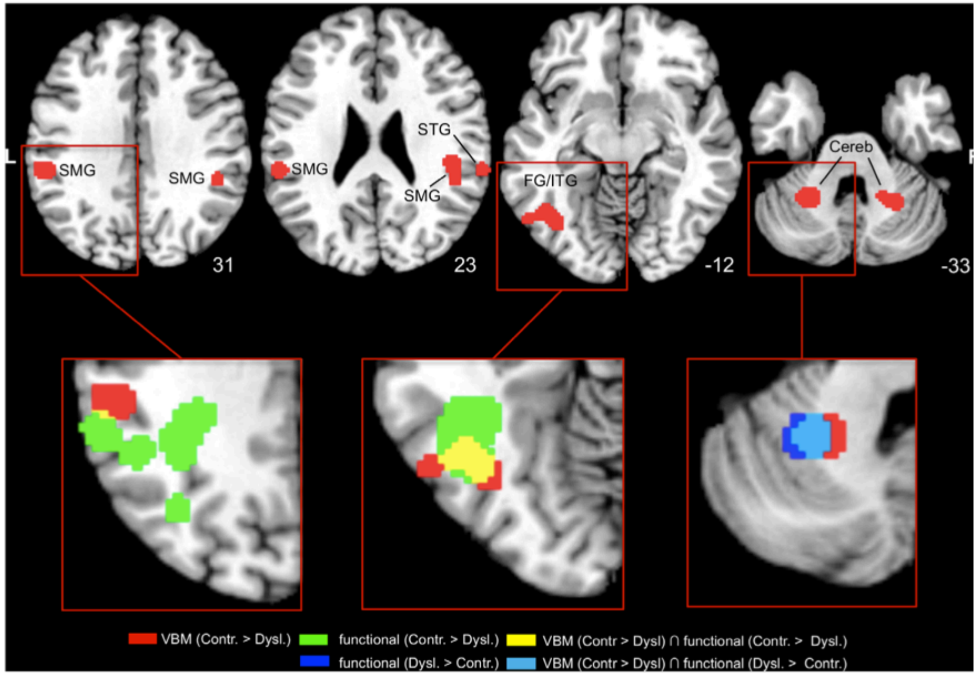


Figure 1. Results of the ALE meta-analysis of VBM studies and the conjunction analyses. Upper row–2D axial slices depicting t thresholded and binarized ALE map for the VBM meta-analysis (red) projected onto the Colin T1-template in MNI space. Images are presented neurological convention (i.e., left = left) and MNI coordinates in the inferior-superior (Z) plane are provided with each slice. Lower row – cut-outs the axial slices display overlaps (yellow) of the VBM meta-analysis (red) with the thresholded and binarized ALE map for the meta-analysis functional underactivations (green) and overlaps (light blue) with the thresholded and binarized ALE map for the meta-analysis of functior overactivations (dark blue). SMG = supramarginal gyrus; STG = superior temporal gyrus; FG/ITG = fusiform gyrus/inferior temporal gyr Cereb = cerebellum.
doi:10.1371/journal.pone.0043122.g001

En résumé : neurobiologie de la dyslexie

- Les découvertes initiales de Galaburda sur le cortex d'humains dyslexiques ont été ravivées par les études génétiques montrant des altérations de gènes impliqués dans le développement cérébral précoce.
- Les techniques modernes de traitement du signal IRM ont montré de façon convergente une anomalie structurale fine de la connectivité entre diverses régions cérébrales, en particulier hémisphériques gauches
- Il reste que ces anomalies, aussi robustes soient-elles, ne peuvent être tenues comme à coup sûr responsables du trouble de la fonction (e.g. lecture) dont elles peuvent tout aussi bien représenter la conséquence (plutôt que la cause)

Dyslexie : du cerveau à la dysfonction

- Approche centrée sur l'explication du trouble de la lecture
  - Causes proximales : phonologique et visuelle
  - Causes distales : multiples
- Approche prenant en compte les co-occurrences
  - Trouble du traitement temporel
  - Trouble cérébelleux
  - Trouble du transcodage intermodalitaire

Coltheart’s notion of proximal and distal causes:

– Proximal: “the particular abnormality of a child’s reading system that is responsible for that child’s poor reading”

E.g. imperfect acquisition of the nonlexical route

– Distal: the underlying causes of the proximal difficulties

Proximal Causes

Developmental phonological dyslexia:

– Specific difficulty in acquiring the nonlexical route

Developmental surface dyslexia:

– Specific difficulty in acquiring the lexical route (orthographic lexicon)

Distal causes

- Crossed laterality
- Visual perception deficit
- Eye-movement deficit
- Attentional deficit
- Eye focusing deficit
- Short term memory limitations
- Sequencing (temporal and/or spatial) deficit
- Maturational lag
- Deficiency in metalinguistic abilities
- Incompatibility of teaching and learning styles
- Perceptual-motor deficit

DOI: 10.1093/brain/awg076 *Brain* (2003), **126,** 841–865

Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults

Franck Ramus,[1,5] Stuart Rosen,[2] Steven C. Dakin,[3] Brian L. Day,[4] Juan M. Castellote,[4,6] Sarah White[1] and Uta Frith[1]

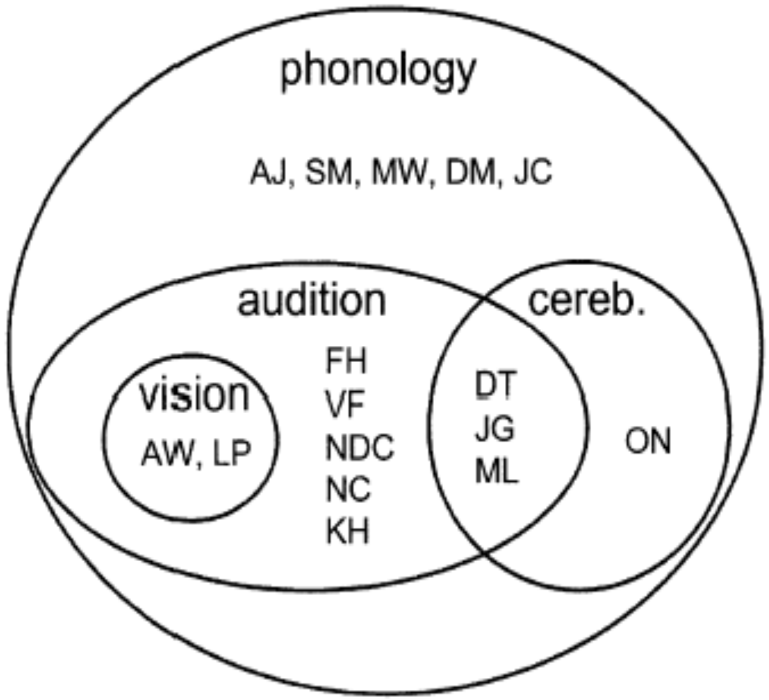
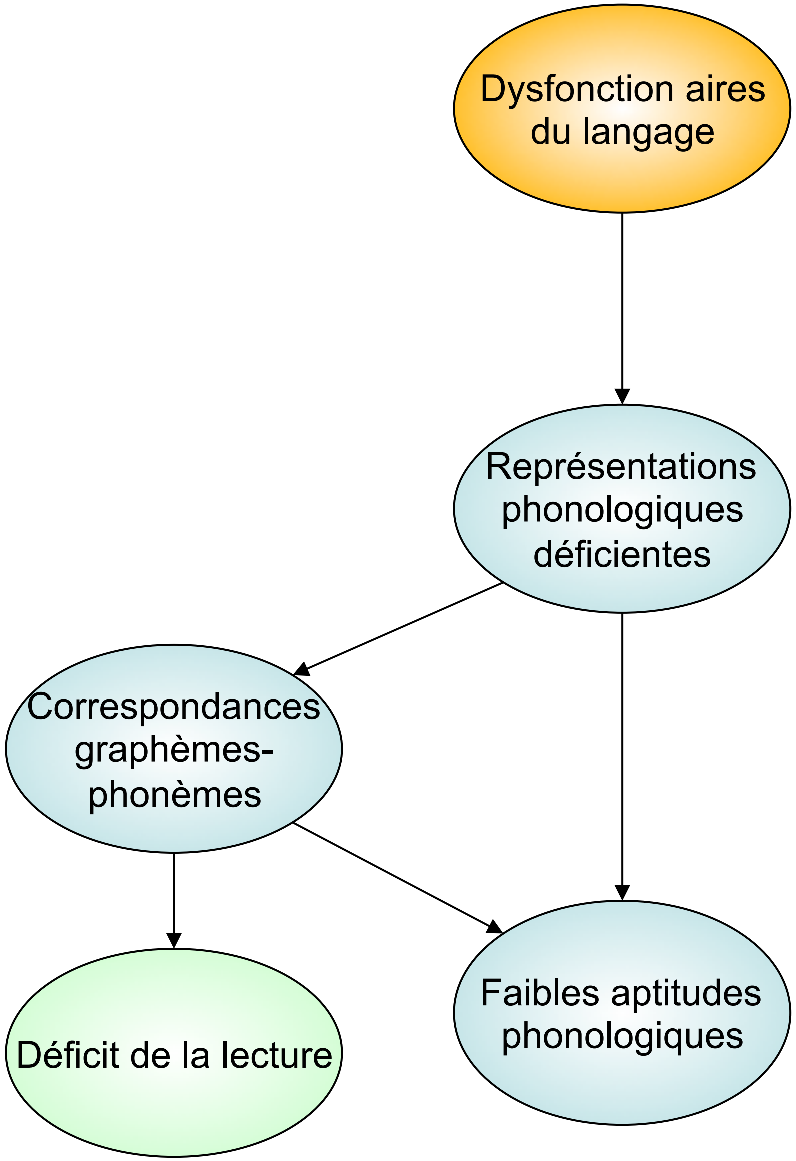
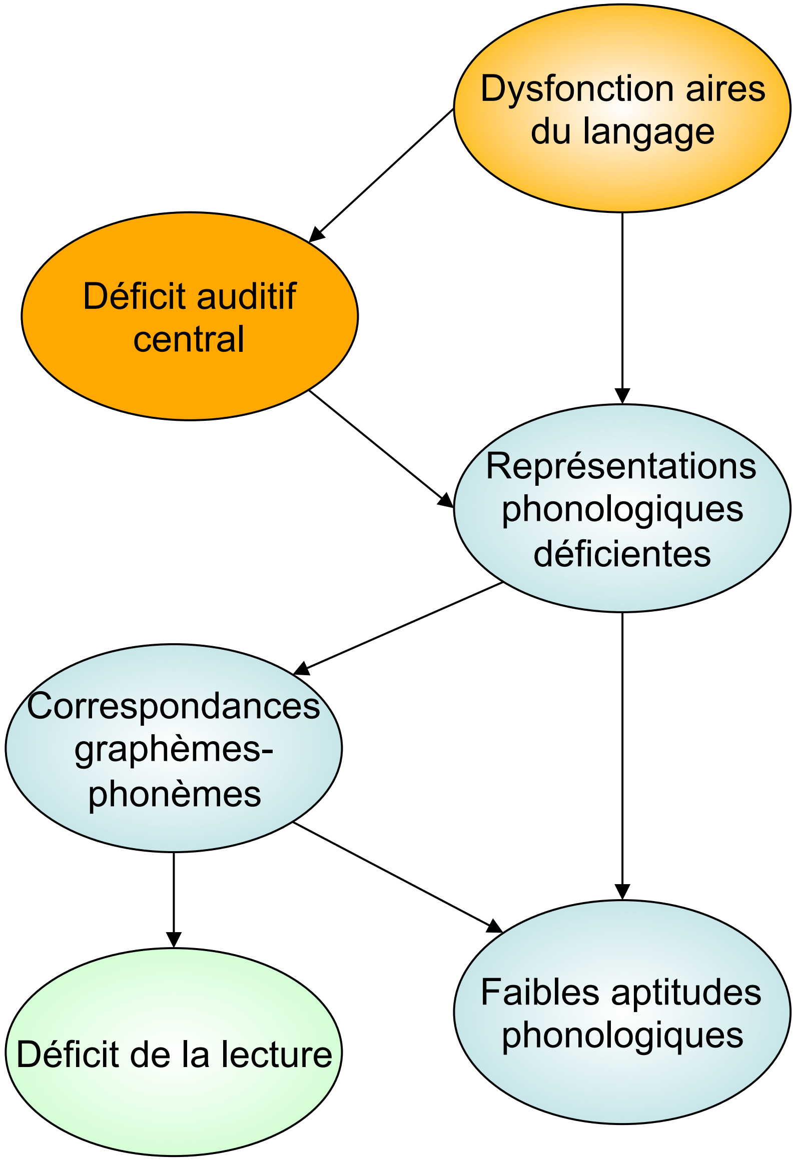


Fig. 4 Distribution of phonological, auditory, visual and cerebellar disorders in the sample of 16 dyslexic adults. Initials refer to individual dyslexic subjects.

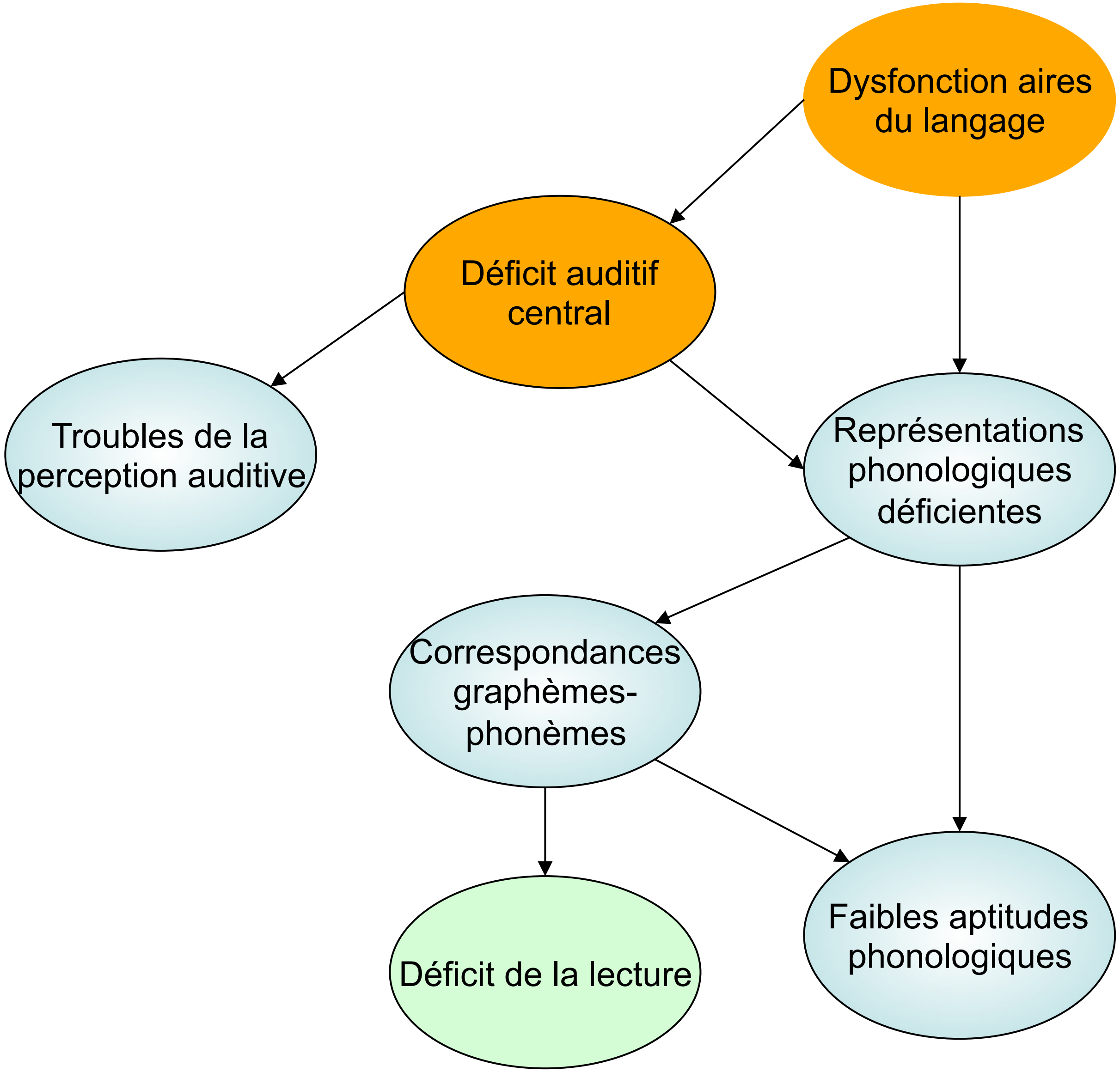
- Principaux résultats :
  - –16/16 déficit phonologique
  - –10/16 déficit traitement auditif [speech, nonspeech, slow and rapid]
  - –4/16 déficit moteur
  - –2/16 déficit visuel



théorie dominante : la théorie du déficit phonologique



déficit auditivo-perceptif



déficit auditivo-perceptif

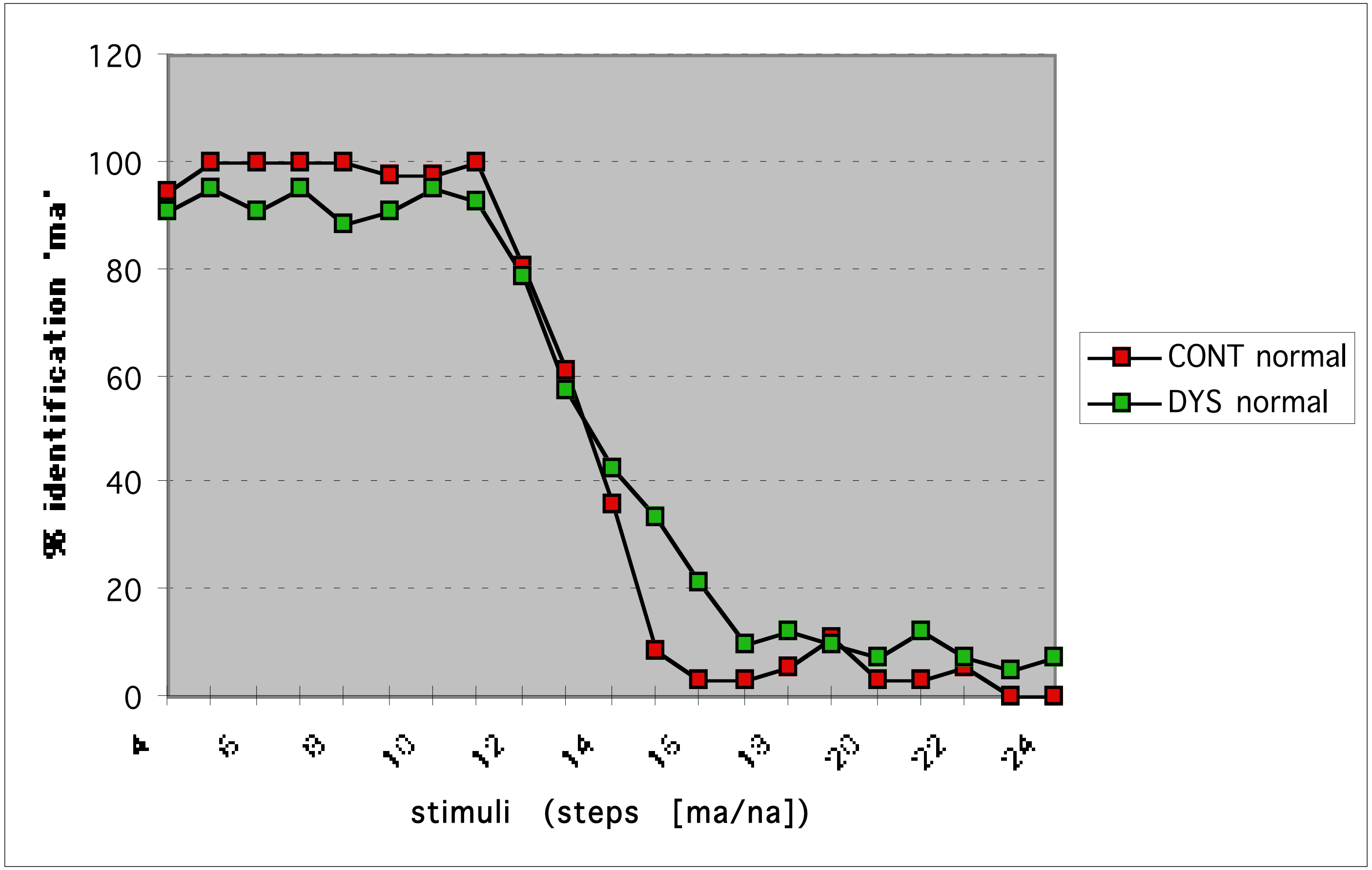
Perceptual Discrimination of Speech Sounds in Developmental Dyslexia

Willy Serniclaes
Laboratoire de Statistique Médicale
Ecole de Santé Publique
Université Libre de Bruxelles
Brussels, Belgium

Liliane Sprenger-Charolles
CNRS - LEAPLE
and
Université René Descartes
Paris, France

Experiments previously reported in the literature suggest that people with dyslexia have a deficit in categorical perception. However, it is still unclear whether the deficit is specific to the perception of speech sounds or whether it more generally affects auditory function. In order to investigate the relationship between categorical perception and dyslexia, as well as the nature of this categorization deficit, speech specific or not, the discrimination responses of children who have dyslexia and those of average readers to sinewave analogues of speech sounds were compared. These analogues were presented in two different conditions, either as nonspeech whistles or as speech sounds. Results showed that children with dyslexia are less categorical than average readers in the speech condition, mainly because they are *better* at discriminating acoustic differences between stimuli

Sujets témoins et dyslexiques: continuum [ma/na]



Allophonic perception (Serniclaes et al., 2001; 2004)

categorical perception in dyslexics is underdeveloped

by contrast: dyslexics are better at detecting the differences between allophones

allophonic perception mode

In other words: dyslexics suffer from a "developmental arrest": they perceive speech just as babies younger than 8 months do.

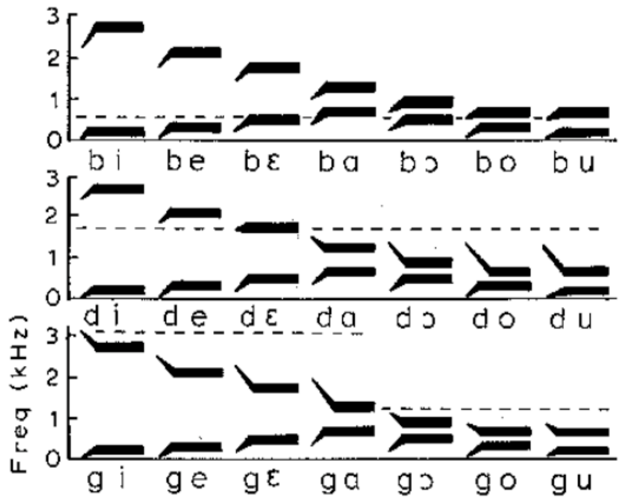
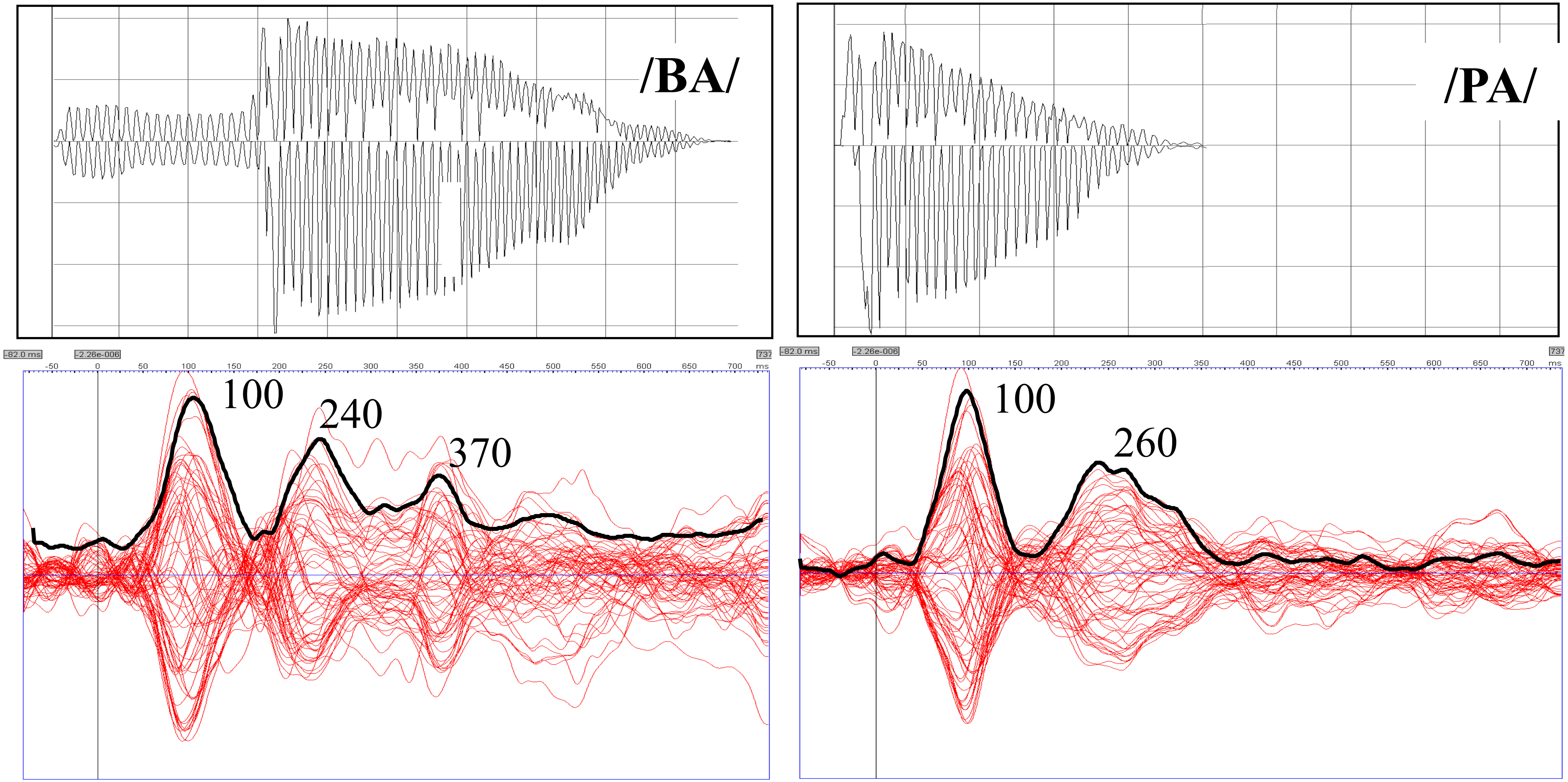


Figure 4 Dans la coarticulation, la réalisation des sons affecte celles des sons voisinants. Ici, les consonnes occlusives voisées bilabiales (/b/), alvéodentales (/d/), et vélaires (/g/) commencent à des fréquences différentes selon la voyelle suivante et ont des effets différentes sur la positionnement des formants caractérisant chaque voyelle. Le décours temporel des « transitions formantiques » contenant toute l'information critique à l'identification de ces sons se déroule dans une fenêtre temporelle de seulement quelques dizaines de millisecondes (d'après Delattre et al., 1955).

Serniclaes, W., Van Heghe, S., Mousty, Ph., Carré, R., & Sprenger-Charolles, L. (2004). Allophonic mode of speech perception in dyslexia. Journal of Experimental Child Psychology, 87, 336-361

Corrélats électrophysiologiques du déficit de discrimination dans la dyslexie
K. Giraud et al., 2005



Giraud K, Trébuchon A, Demonet JF, Habib M, Liégeois-Chauvel C. Asymmetry of voice onset time (VOT) processing in adult developmental dyslexics. Cerebral Cortex October 2005;15:1524—1534

Neuron 72, 1080–1090, December 22, 2011

Neuron
Article

Altered Low-Gamma Sampling in Auditory Cortex Accounts for the Three Main Facets of Dyslexia

Katia Lehongre,[1] Franck Ramus,[2] Nadège Villiermet,[2] Denis Schwartz,[3] and Anne-Lise Giraud[1,*]
[1]Inserm U960 - Ecole Normale Supérieure, 75005 Paris, France

Using magnetoencephalography and behavioral tests, we show in dyslexic subjects a reduced left- hemisphere bias for phonemic processing, reflected in less entrainment to z30 Hz acoustic modulations in left auditory cortex. This deficit correlates with measures of phonological processing and rapid naming. We further observed enhanced cortical entrainment at rates beyond 40 Hz in dyslexics and show that this particularity is associated with a verbal memory deficit.

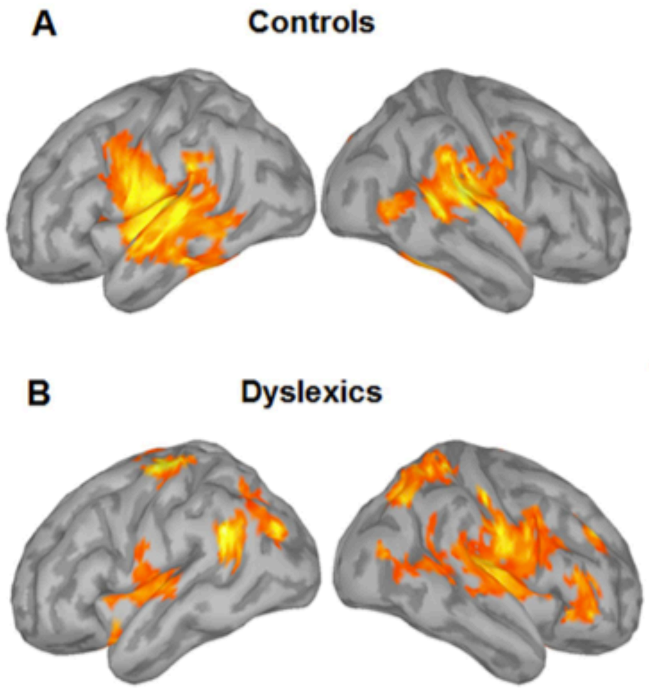
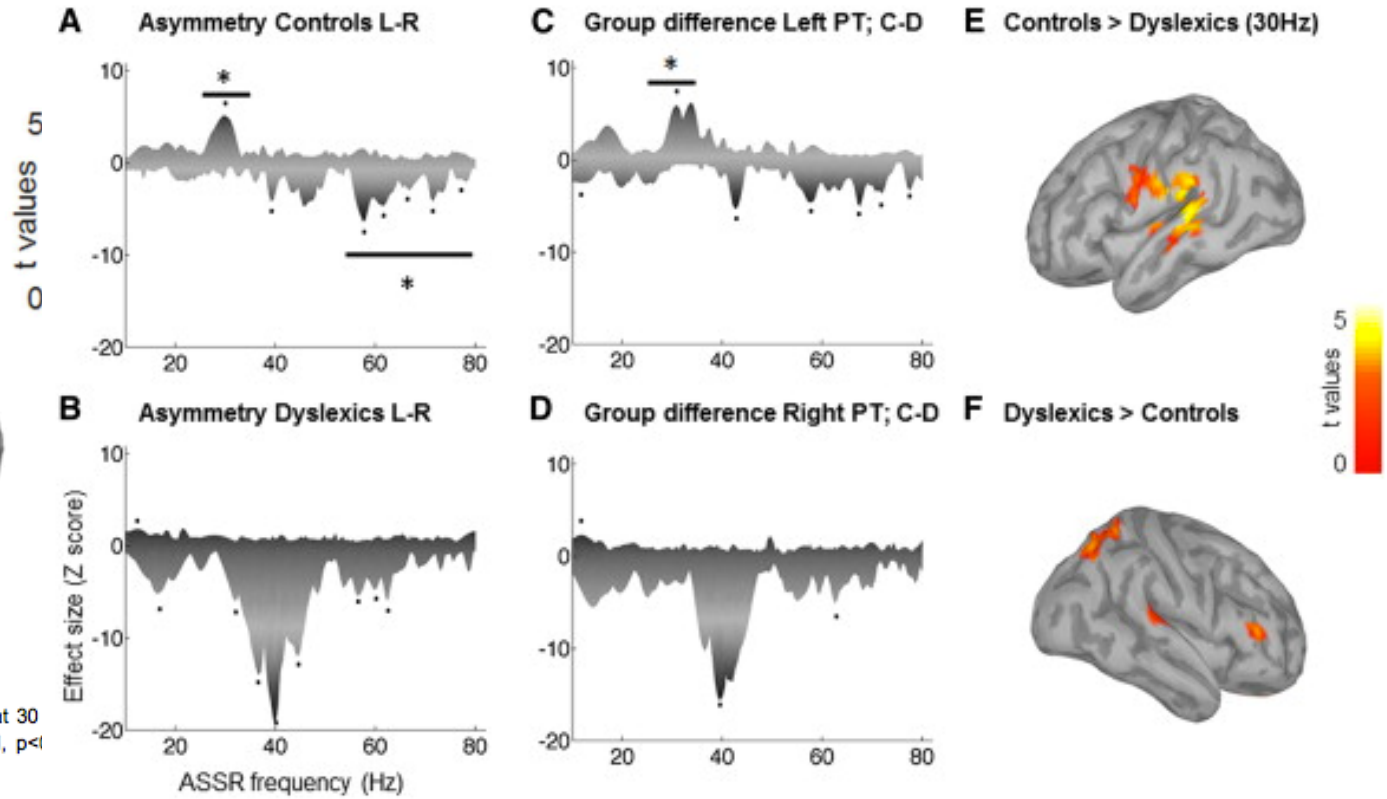


Figure S3, related to Figure 3: Cortical surface rendering of the ASSR at 30 controls (A) and in dyslexics (B), representation of t values (one tailed, p<
minimum cluster size=40).



Opinion

A temporal sampling framework for developmental dyslexia

Usha Goswami

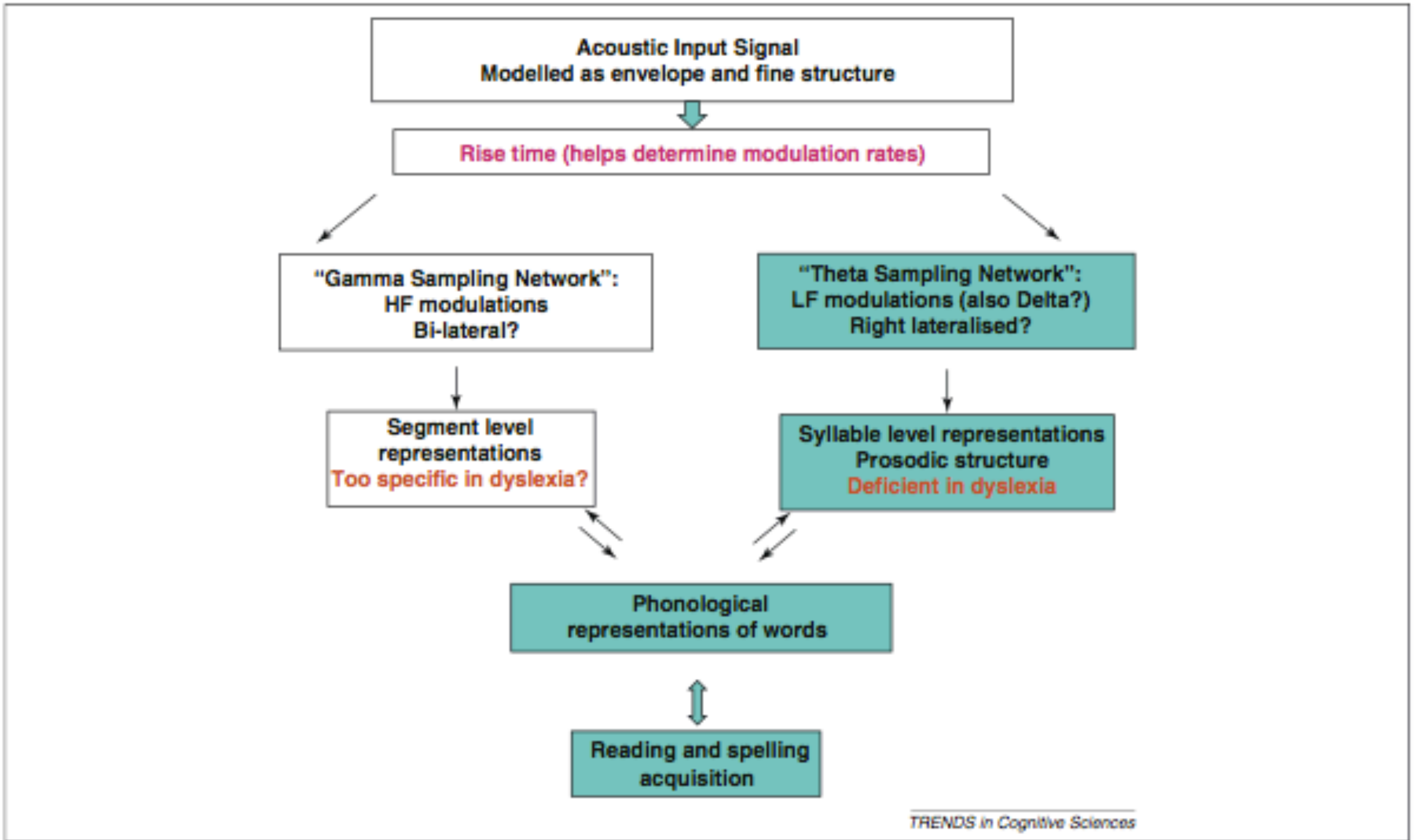


Figure 1. The temporal sampling framework. The TSF assumes a specific dyslexic difficulty with slower temporal modulations, as rise-time perception difficulties in dyslexia involve more extended rise times. As slower modulations are preferentially processed by the right hemisphere, the TSF assumes a right-lateralised impairment in Theta and Delta oscillators. The proposed range of low-frequency modulations processed by the Theta oscillators varies across published studies, but is proposed by Poeppel *et al.* [6] to yield a temporal integration window of ~100–300 ms (approximating the syllable rate). The proposed range for high-frequency modulations also varies across studies, but in [6] yields a temporal integration window of 20– 50 ms, approximating the phonetic rate. According to the TSF, the proposed temporal integration window for syllabic parsing in the right hemisphere might function atypically in dyslexia, yielding the auditory basis of the associated phonological and language deficits (deficits indicated by blue shading).

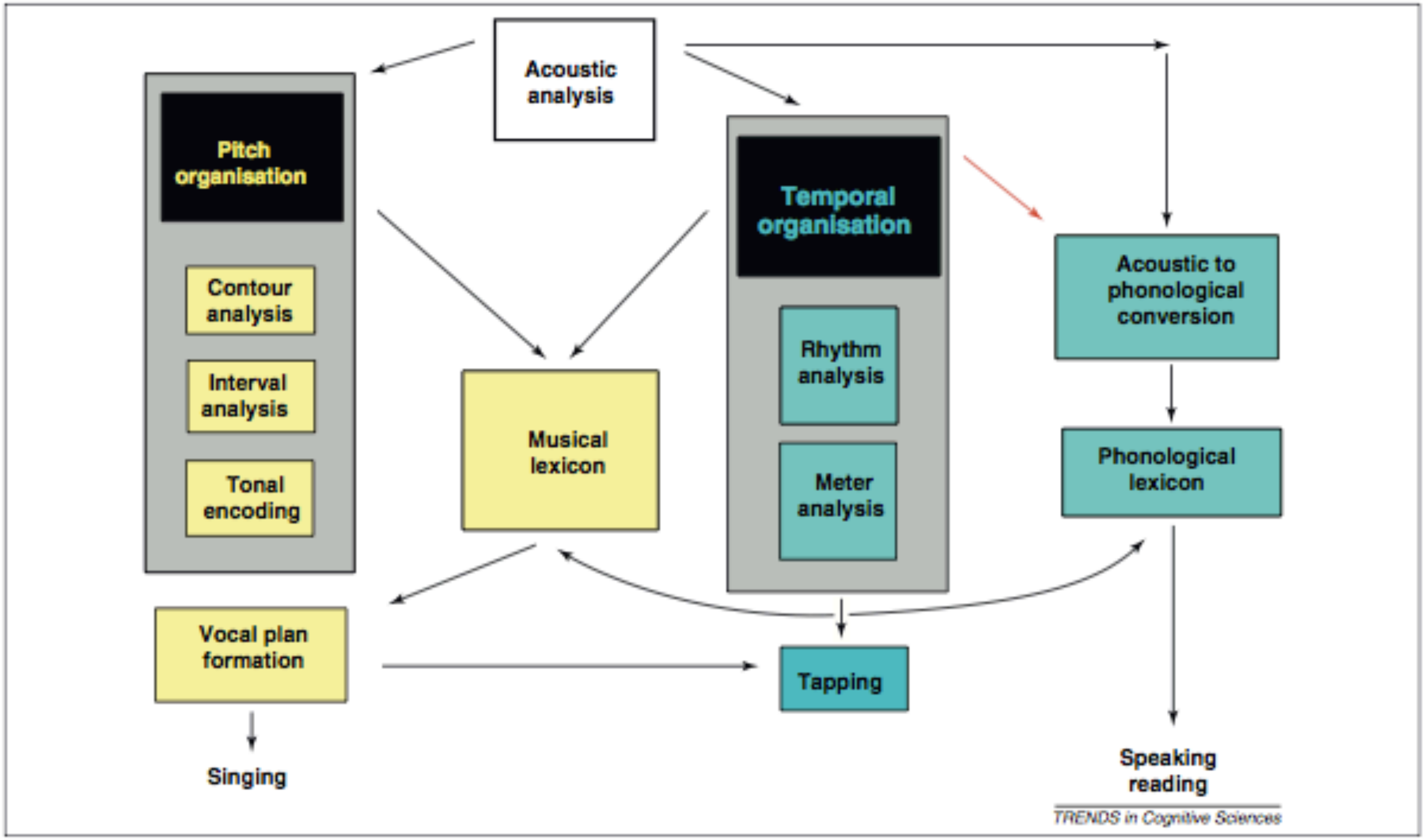
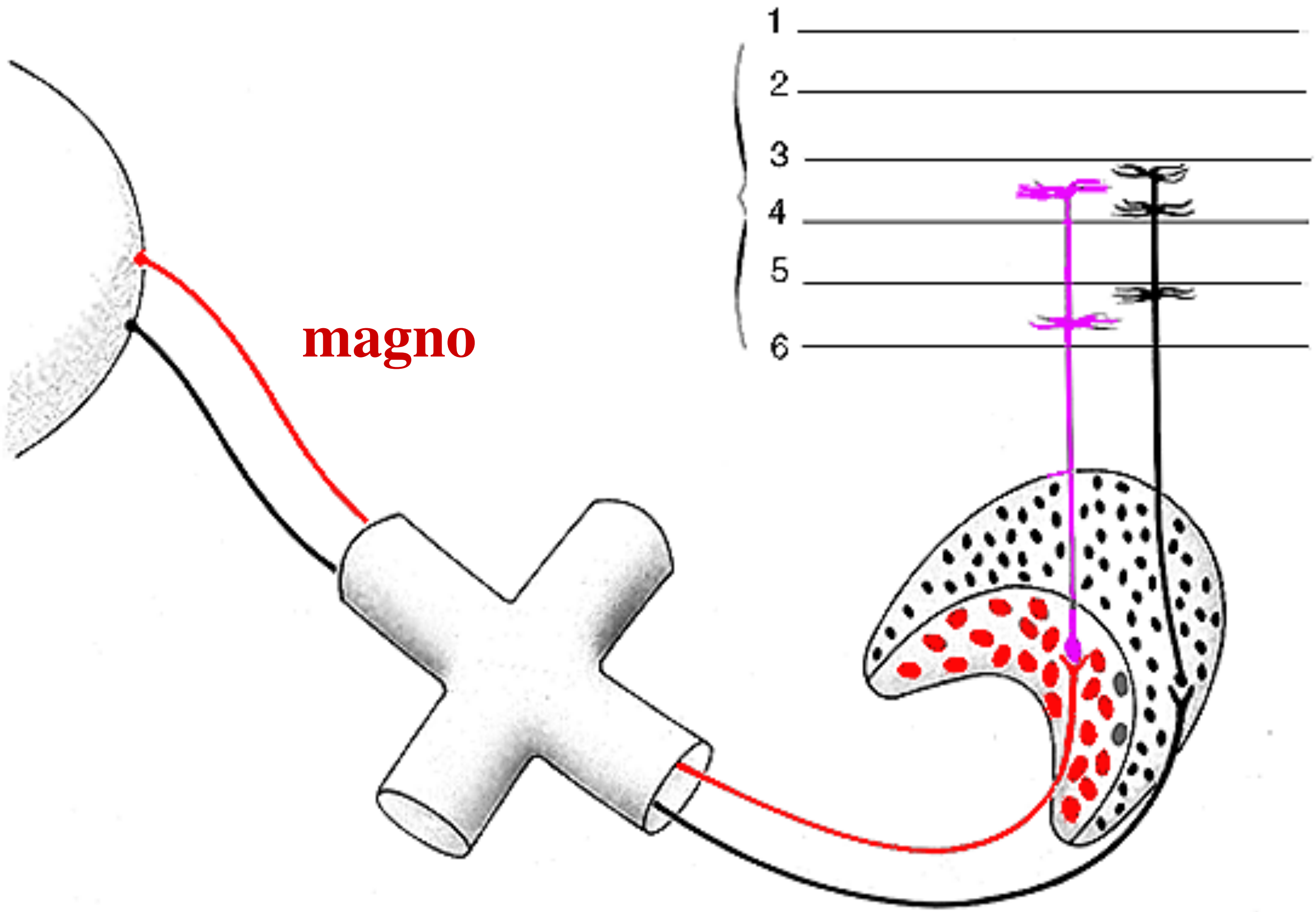
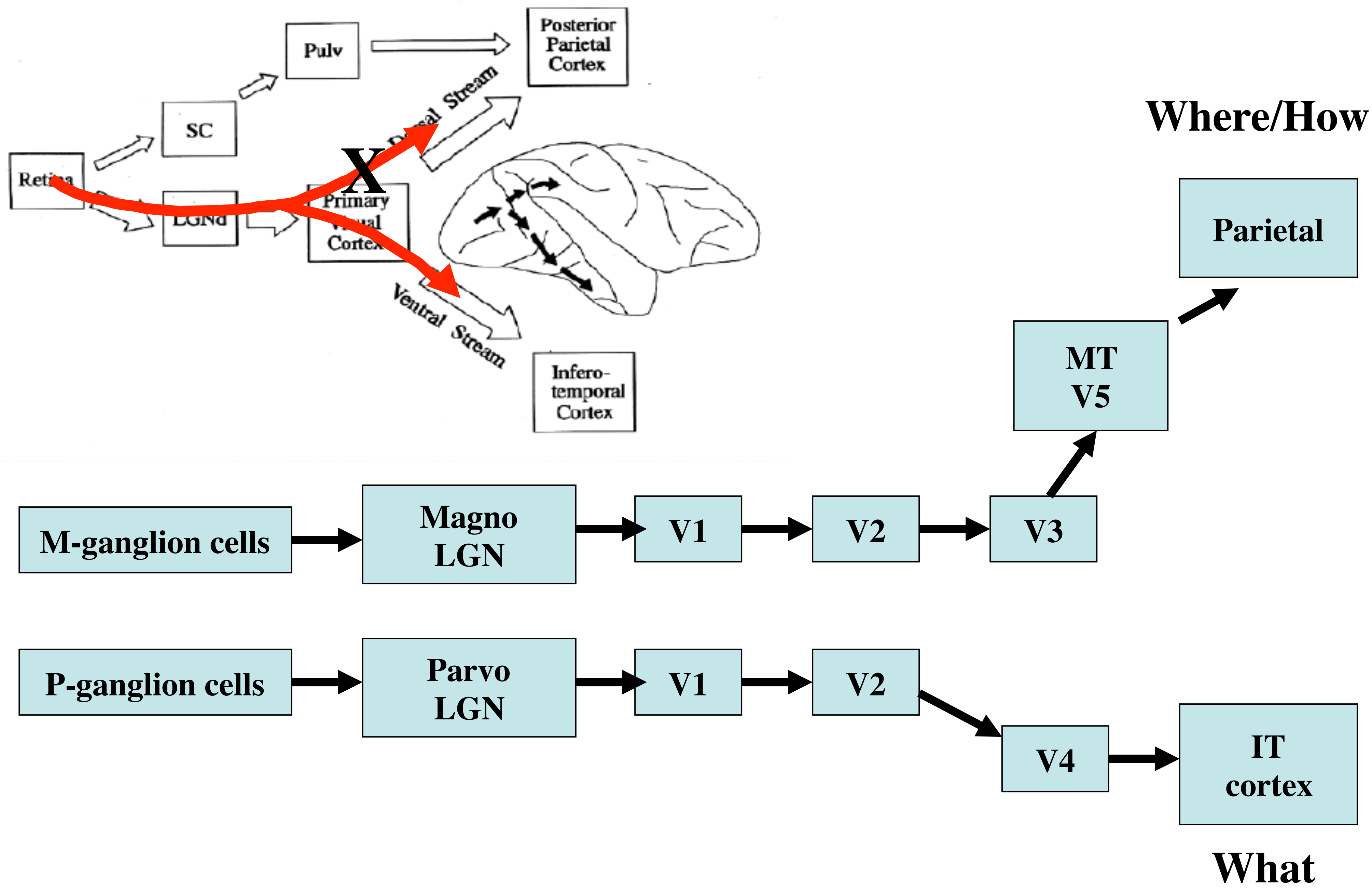


Figure 2. Components of music and language processing. A model of how acoustic analysis of pitch versus rhythm might contribute to language versus musical processing, based on the modular framework of Peretz and Coltheart [69]. The skills preserved in amusia yet impaired in dyslexia are shown in blue. The skills impaired in amusia are shown in yellow. Although developmental disorders of learning are not modular, the framework is useful for supporting the view that musical remediation of dyslexia via training in rhythm and meter might improve phonological development and processing of low-frequency modulations.

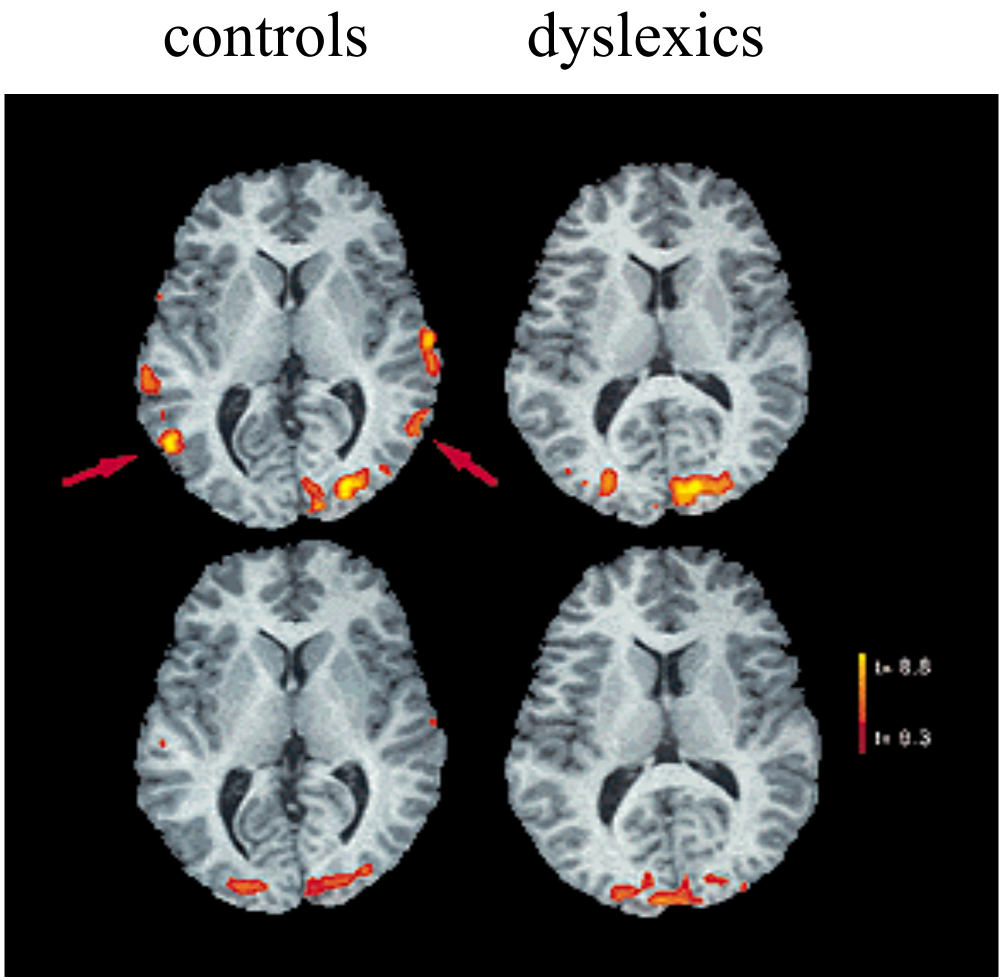


Défaut du système magno-cellulaire :

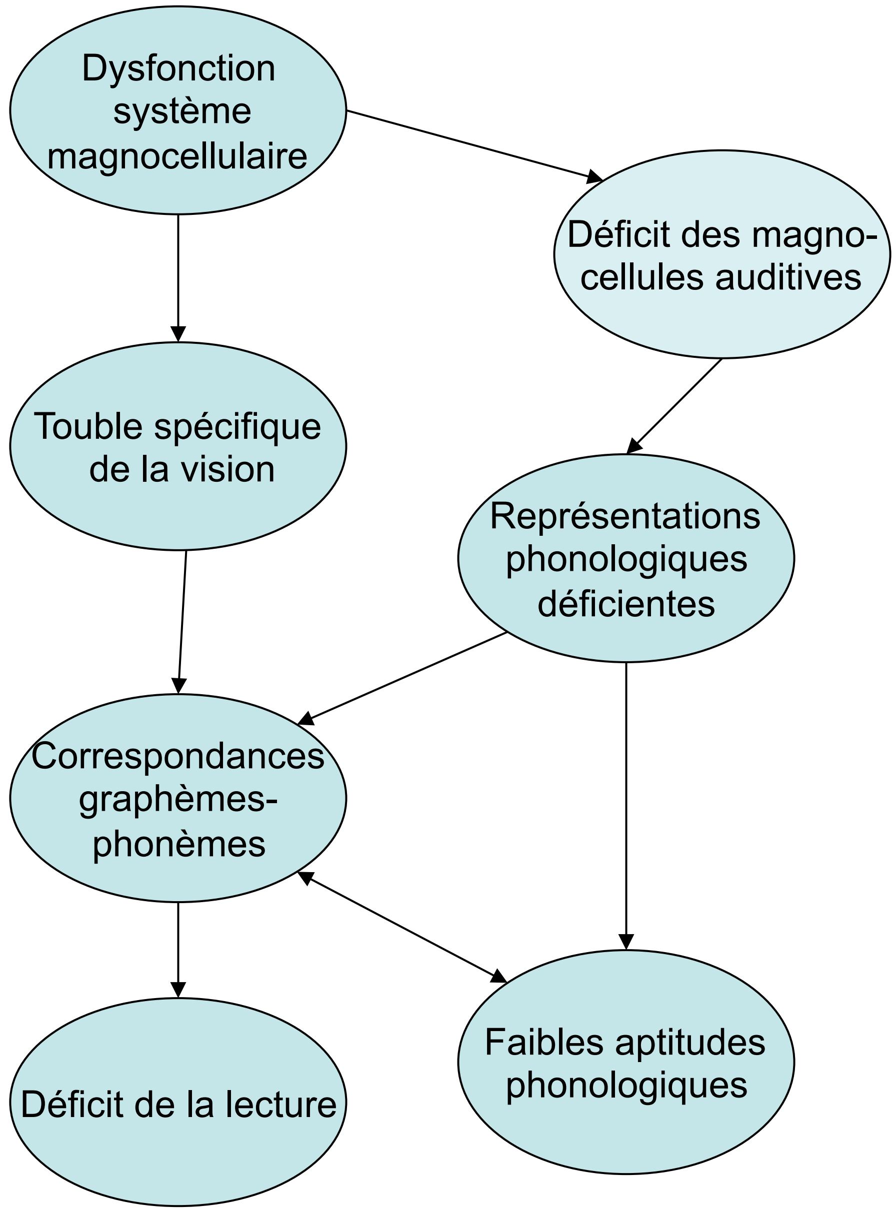
- sensibilité aux contrastes
- persistance visuelle excessive



Pulv
Posterior Parietal Cortex
SC
Stream
X
Primary
Cortex
Ventral Stream
Infero-temporal Cortex
Where/How
Parietal
MT
V5
M-ganglion cells
Magno LGN
V1
V2
V3
P-ganglion cells
Parvo LGN
V1
V2
V4
IT cortex
What



Dyslexics : failure to activate V5/MT « motion area »
(Eden et al., 1996)



dysfonction système magnocellulaire (J. Stein)

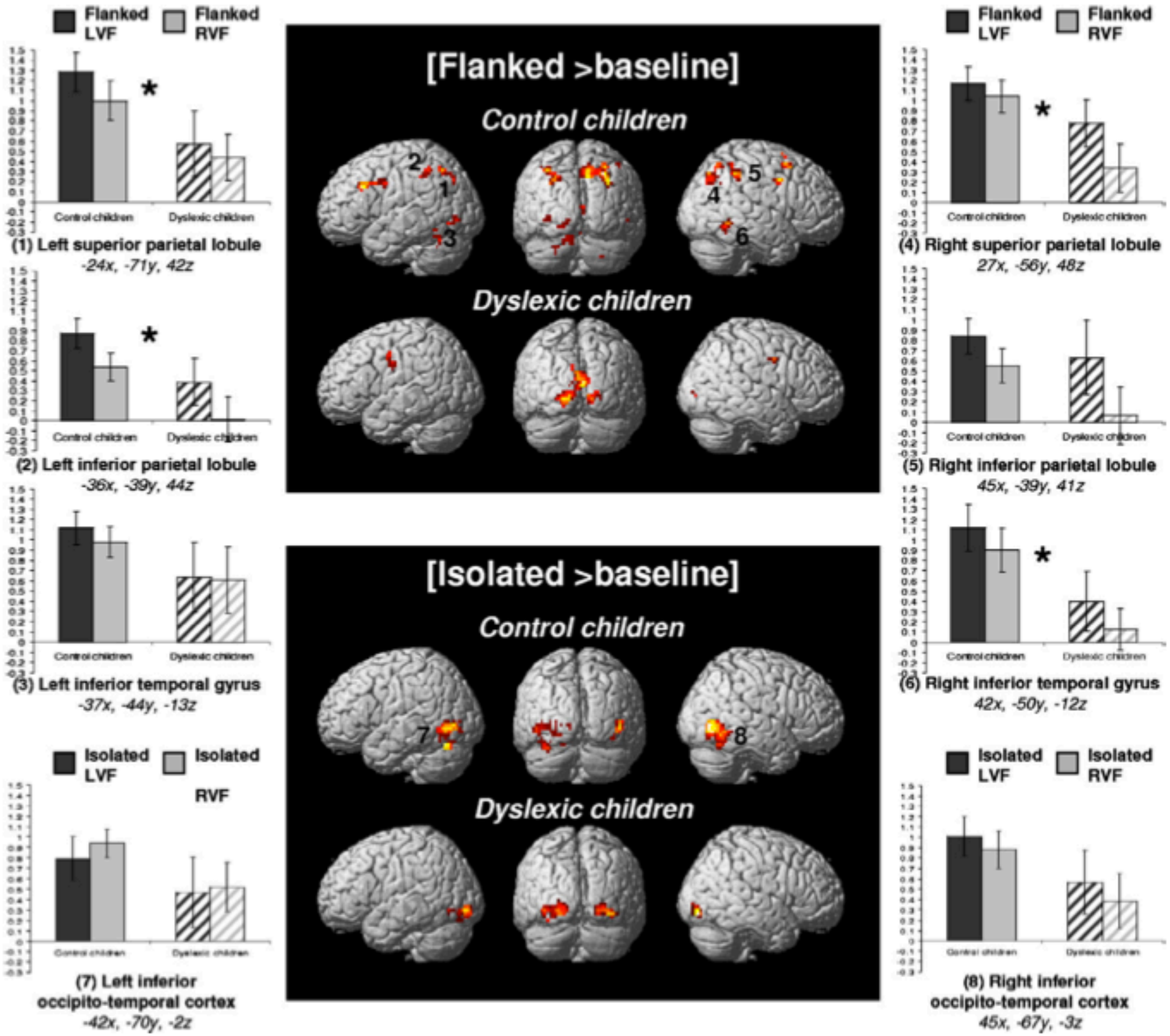
Les théories "attentionnelles"

- Mini-héminégligence gauche (Hari et Renvall, 2001) : : difficultés liées à l'orientation dans le champ visuel gauche
- « viscosité du déplacement attentionnel » (SAS="sluggish attentional shifting", Hari & Renvall, 2001) : difficultés que rencontrent les dyslexiques pour se désengager d'un stimulus lorsqu'il doivent traiter une série de stimuli en succession rapide.
- trouble de l'ajustement de la fenêtre attentionnelle (Valdois et al., 2004) : les dyslexiques seraient limités dans le nombre d'éléments visuels qu'ils peuvent traiter simultanément, en parallèle.

Dysfonction des systèmes attentionnels pariétaux

Superior parietal lobule dysfunction in a homogeneous group of dyslexic children with a visual attention span disorder

C. Peyrin [a], J.F. Démonet [b], M.A. N'Guyen-Morel [c], J.F. Le Bas [d], S. Valdois [a,*]



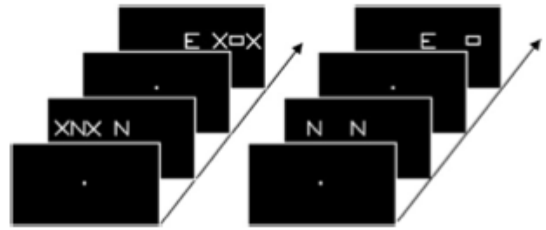


Fig. 1. Example of stimuli used in the categorisation task. Participants have to decide whether the stimuli of a pair were identical or not. Parafoveal stimuli were lateralized in either the right or left visual field, masked by two X in the flanked condition (left side of the figure) and displayed alone in the isolated condition (right side).

With respect to controls, the dyslexic children showed significantly reduced activation within bilateral parietal and temporal areas during flanked processing, but no difference during the isolated condition.

10.1016/j.bandl.2010.06.005

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

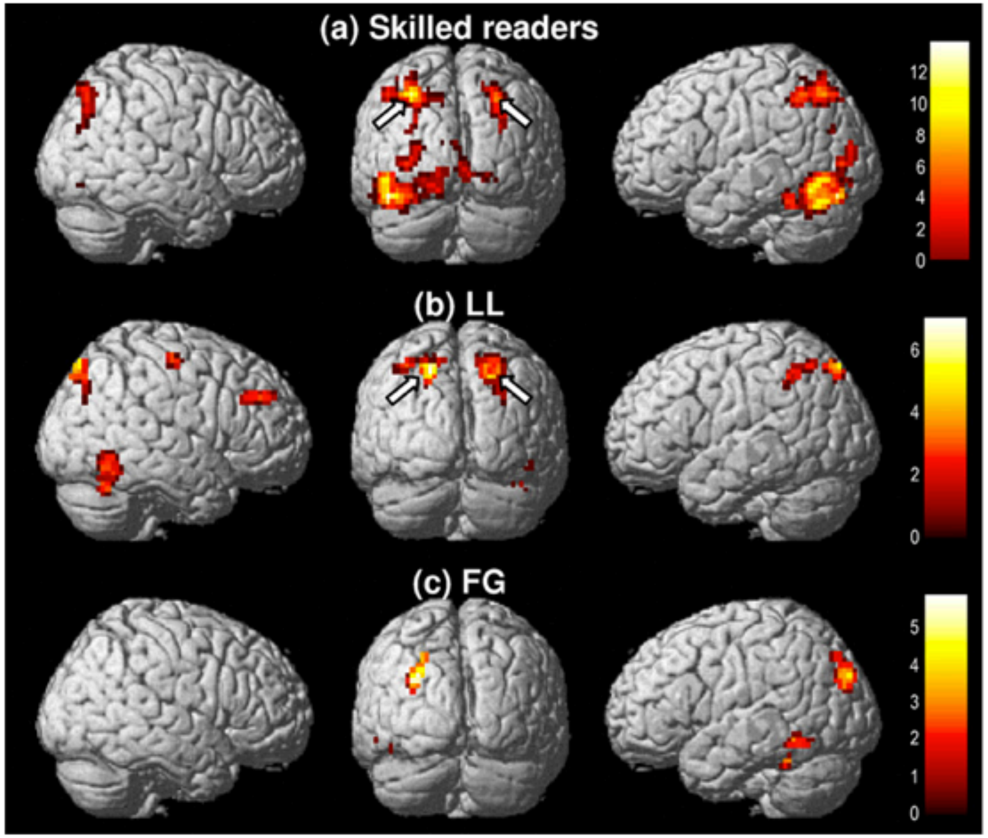
Neural dissociation of phonological and visual attention span disorders in developmental dyslexia: FMRI evidence from two case reports

C. Peyrin [a,b,*], M. Lallier [b,c], J.F. Démonet [d], C. Pernet [e], M. Baciu [a,f], J.F. Le Bas [g], S. Valdois [a,b]

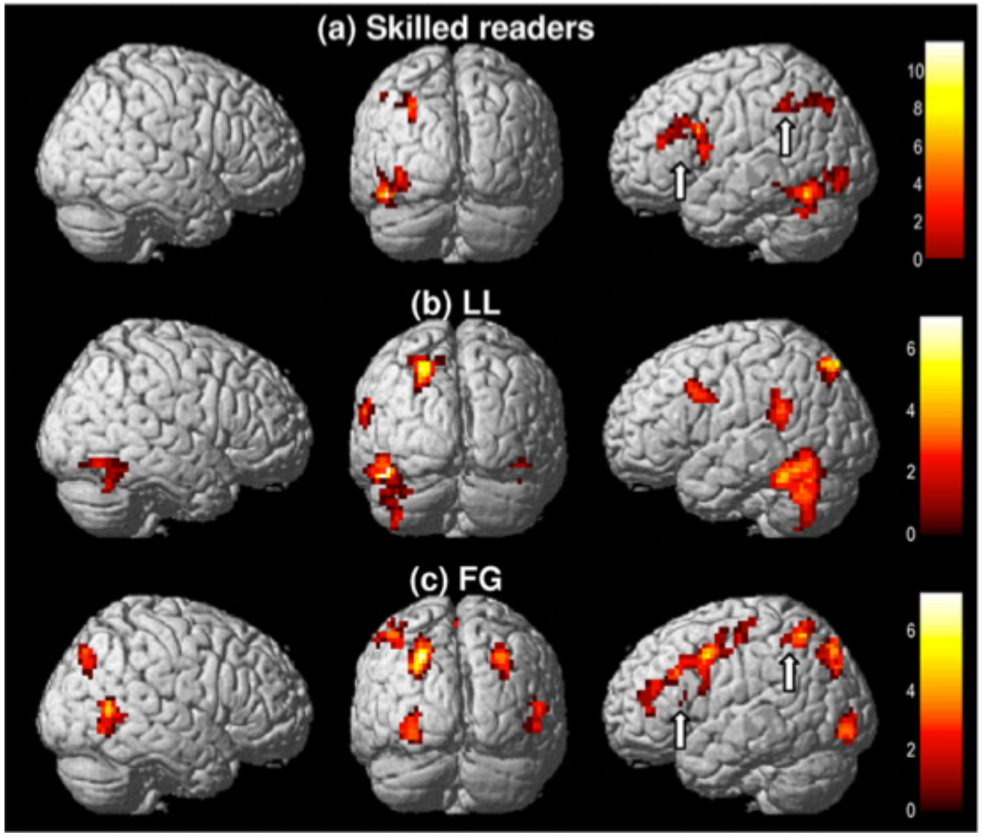
Performance of the two dyslexic young adults, LL and FG, in reading and spelling, and in phonological and visual attention tasks as compared to 20 chronological age controls.

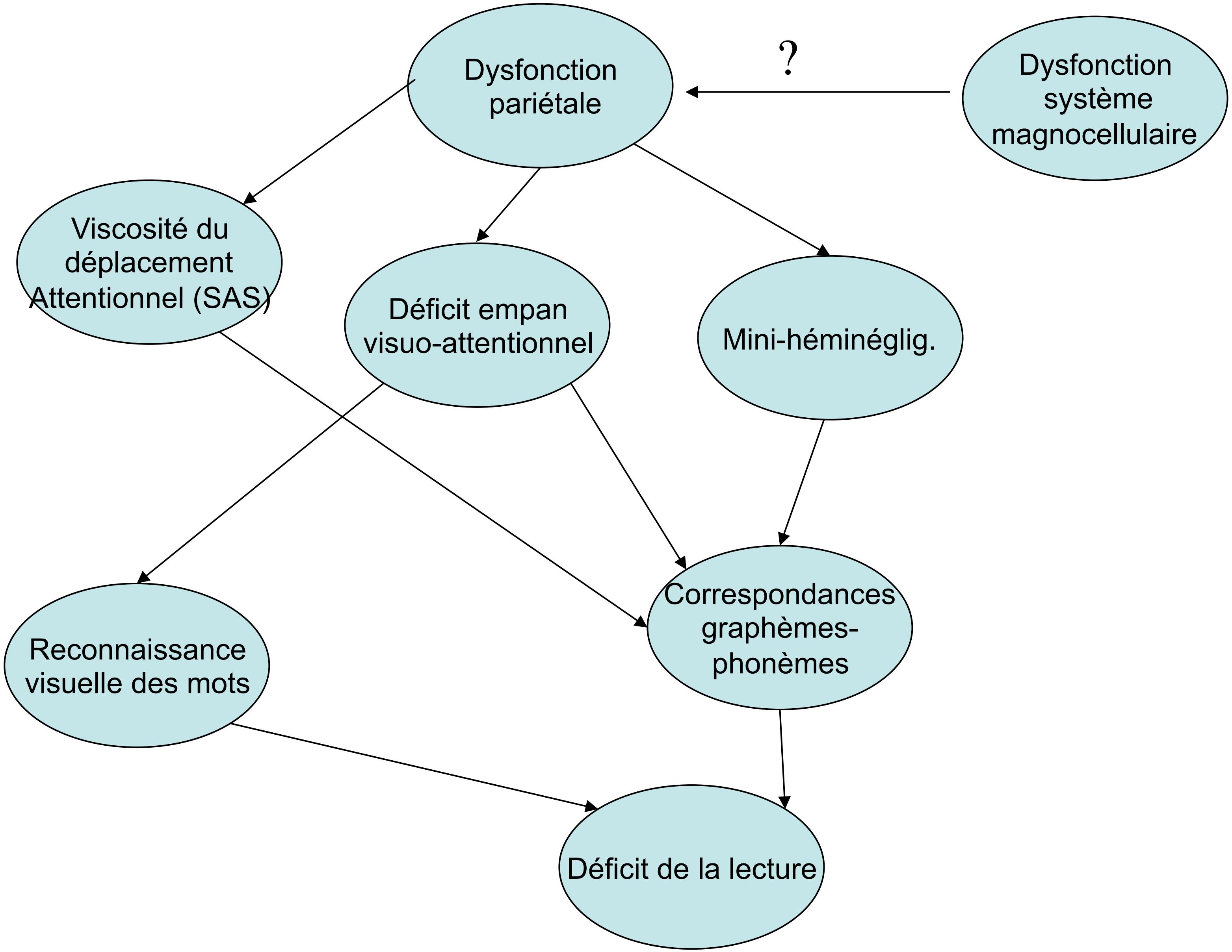
	LL		FG		Controls ($N = 20$)
	Performance	$t(19)^a$	Performance	$t(19)^a$	Mean (SD)
Reading					
Irregular words (/40)					
Accuracy	38	+0.60	33	-1.90^{*}	36.80 (1.94)
Rate	32	−1.30	49	-3.97^{***}	23.75 (6.20)
Pseudo-words (/40)					
Accuracy	38	+0.06	25	-7.77^{***}	37.90 (1.62)
Rate	56	-2.33^{*}	61	-2.97^{**}	37.75 (7.64)
Regularisations	1/2(50%)		6/7 (86%)		
Visual errors	0/2 (0%)		9/15(60%)		
GPC knowledge (/51)	51	+1.14	48	−0.23	48.50(2.13)
Spelling					
Consistent words (/40)	37	+0.33	33	-1.72^{*}	36.35 (1.90)
Irregular words (/40)	22	−1.43	12	-3.09^{**}	29.55 (5.53)
Pseudo-word (/40)	33	-2.42^{*}	35	−1.33	37.45(1.80)
PPEs	19/21 (90%)		34/35 (97%)		86% (2.4)
Phonological processing					
Pseudo-word repetition (/92)	83	-3.13^{**}	89	−0.23	89.45(2.01)
Phoneme segmentation (/28)	14	−1.62	20	−0.39	21.90(4.74)
Spoonerisms (/10)	1	-5.22^{***}	8	−0.35	8.50(1.40)
Visual attention span					
Global report – five-letters (/100)	58	−0.92	11	-3.97^{***}	73.10(16.01)
Global report – six-letters (/144)	115	−0.30	74	-2.88^{**}	119.75(15.49)
Partial report – six-letters (/72)	48	−0.84	44	−1.38	54.20(7.17)

Catégorisation formes (lettres/non-lettres)

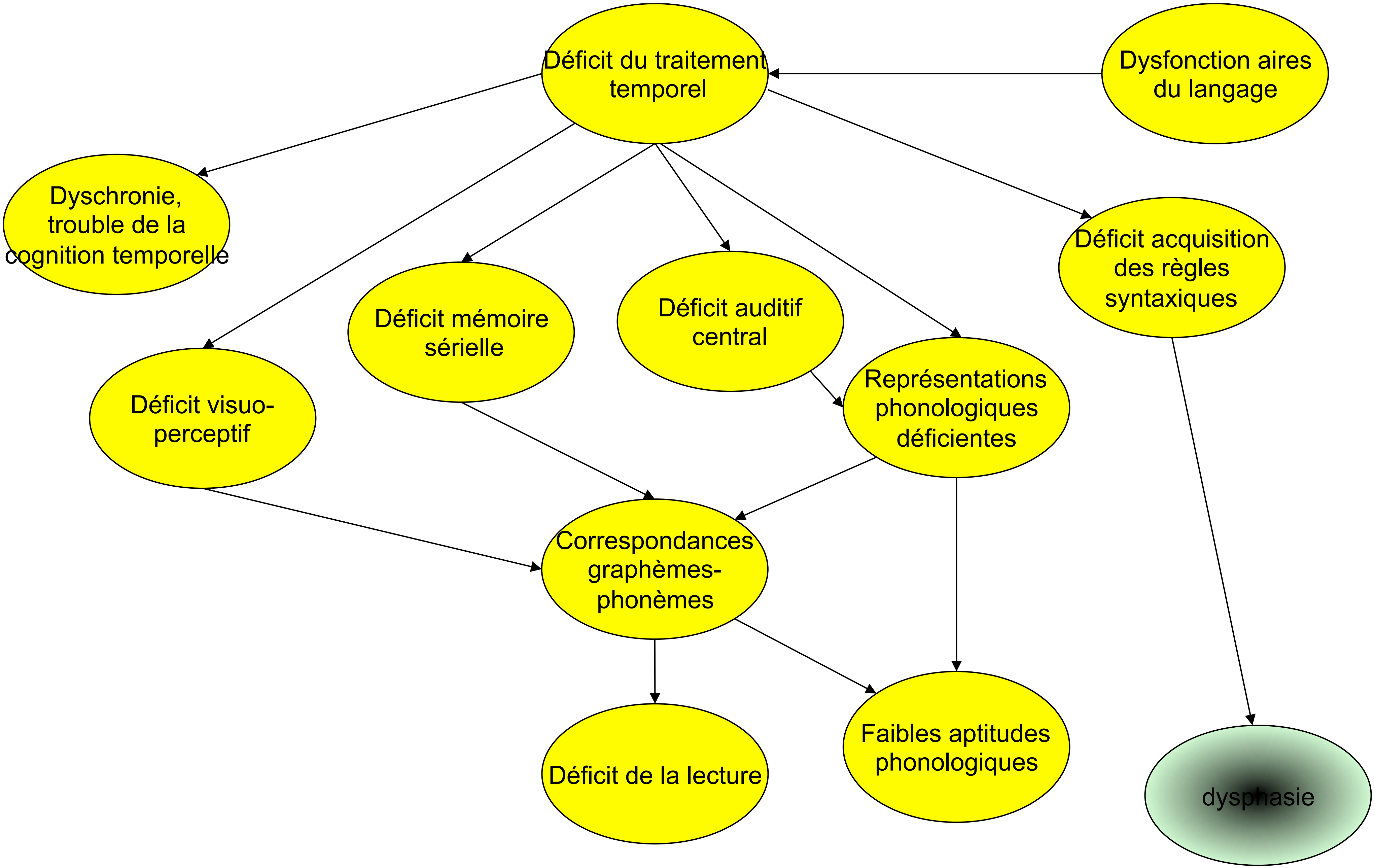


Détection de rimes (lettre écrite rime avec 'b')

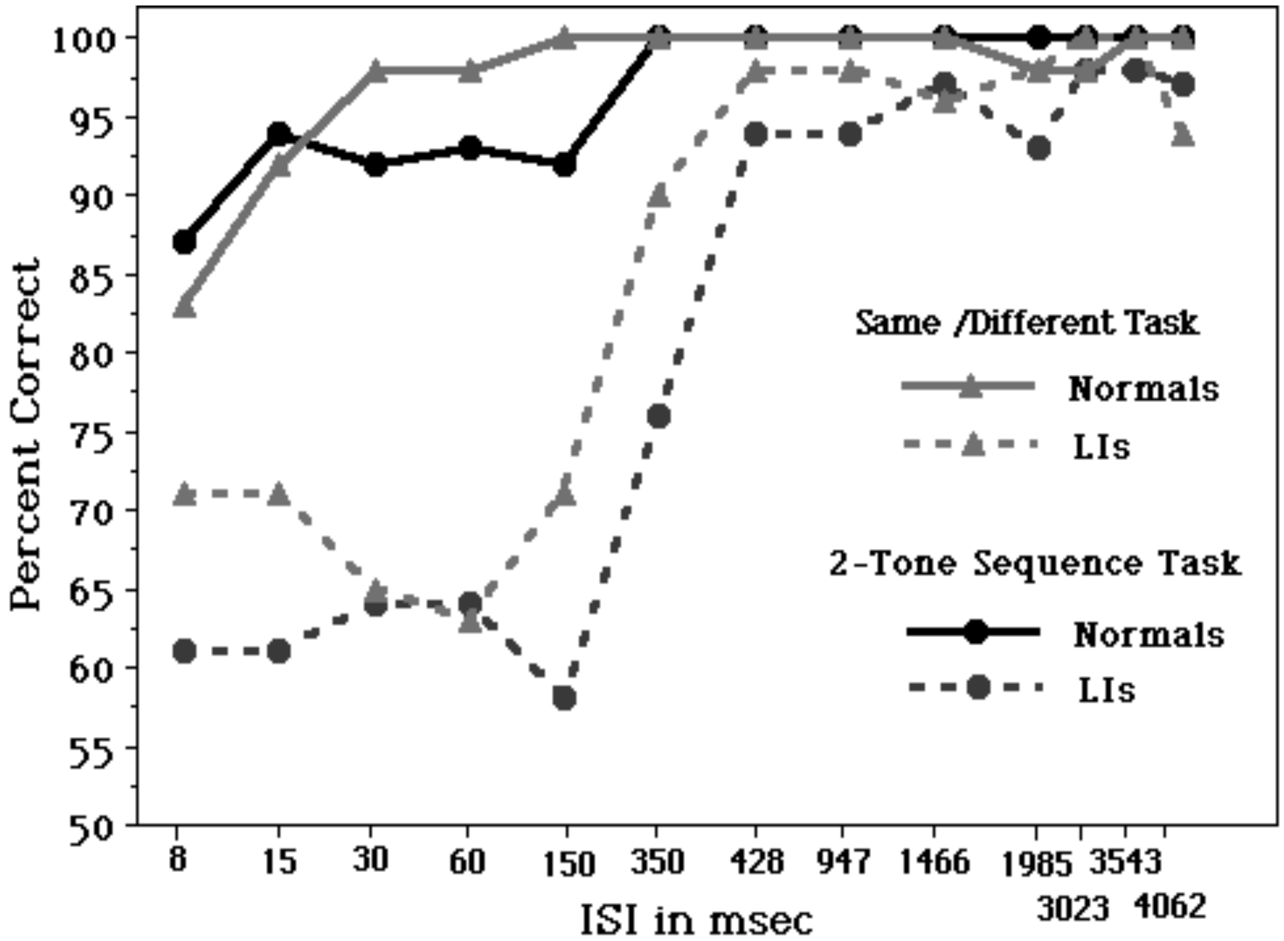




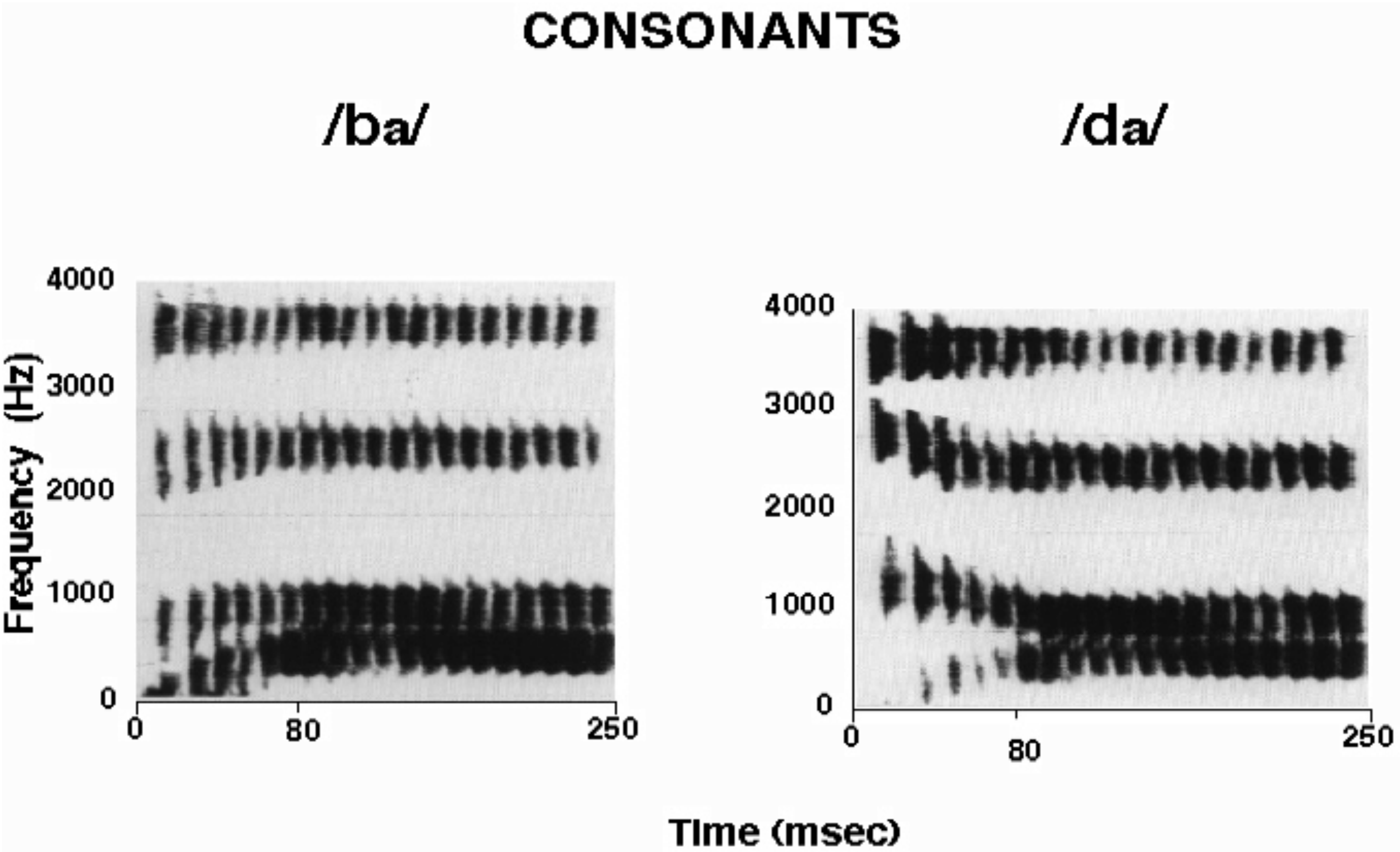
Les trois théories "attentionnelles"



déficit du traitement temporel (Tallal)



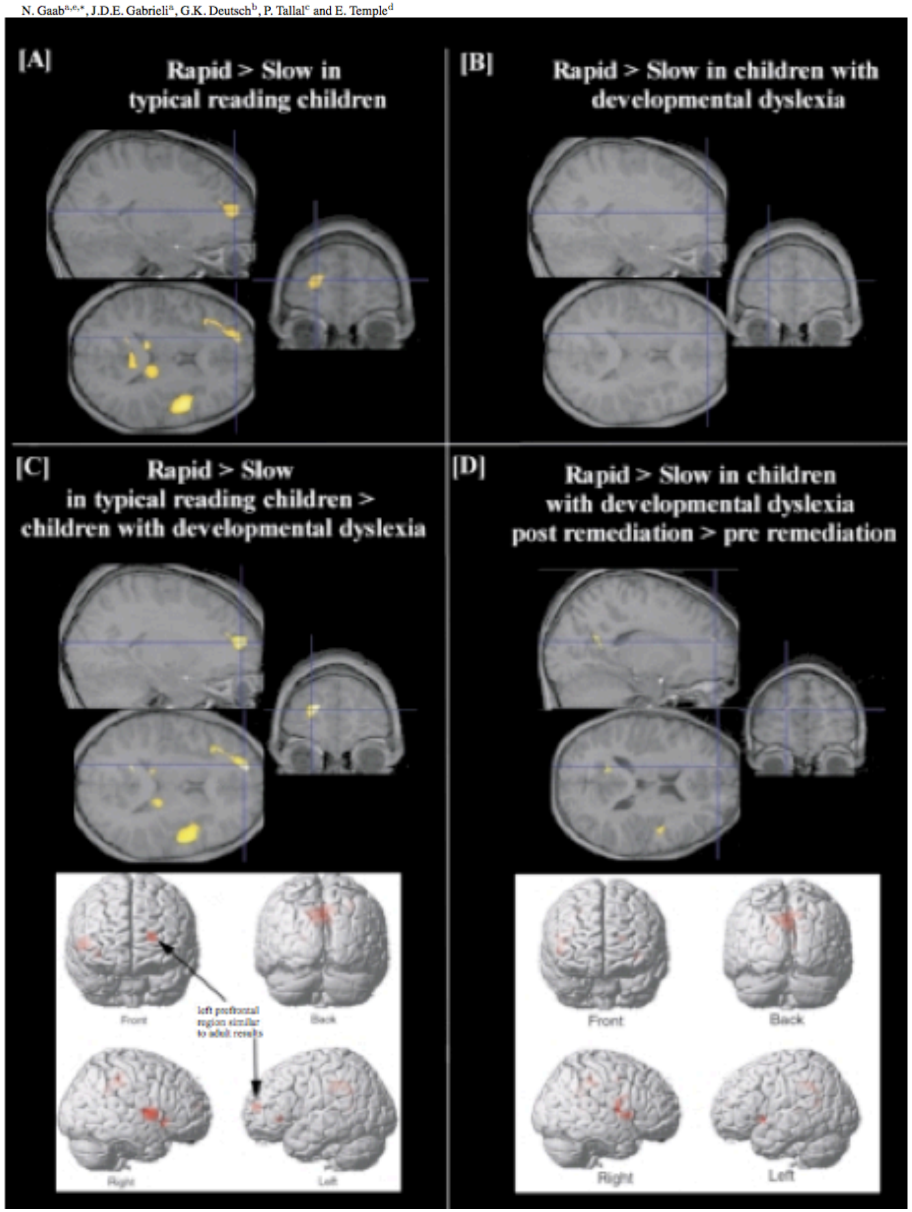
Tallal et al., 1973-76

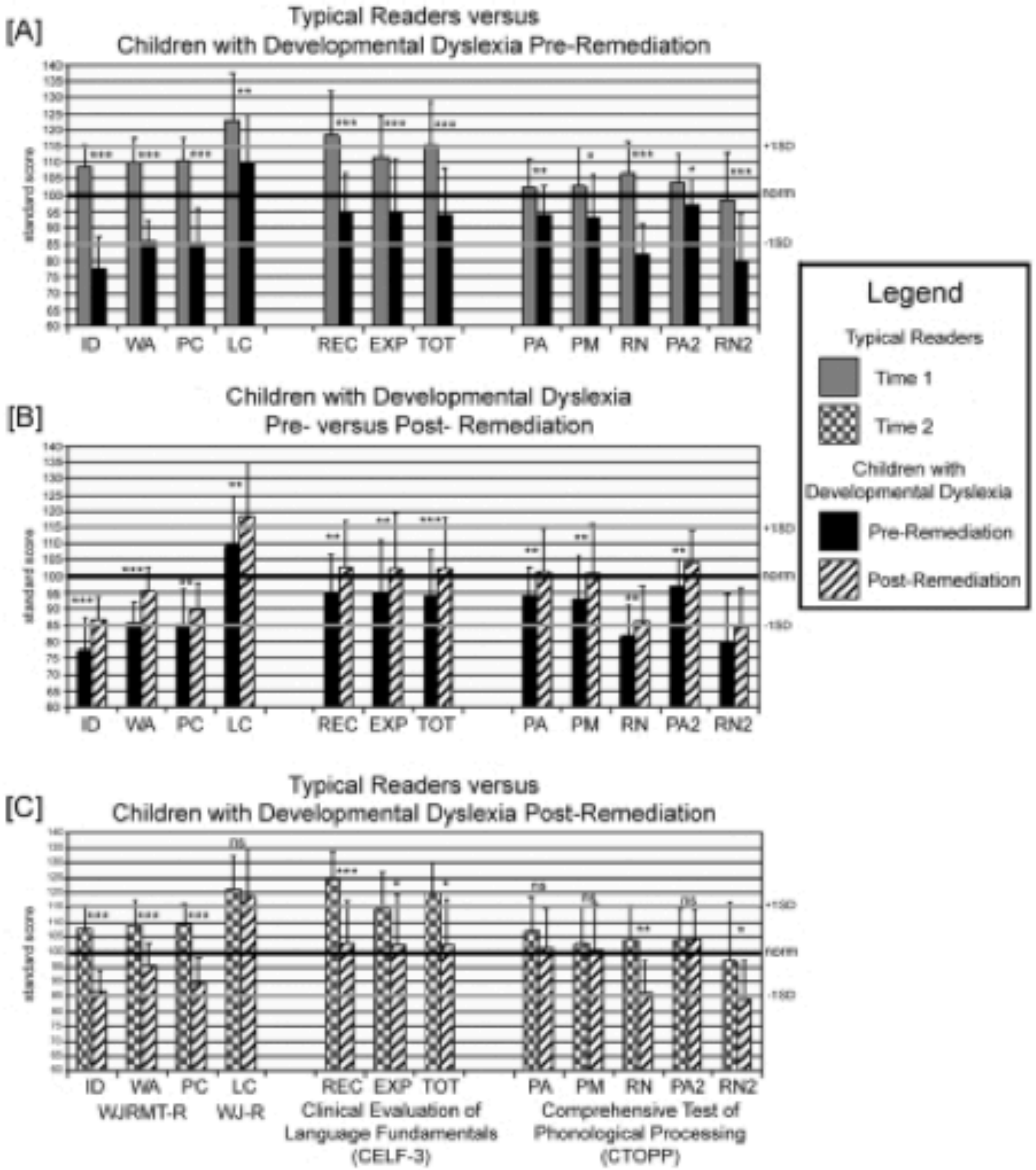

CONSONANTS
/ba/
/da/
Frequency (Hz)
4000
3000
2000
1000
0
0
80
250
Time (msec)

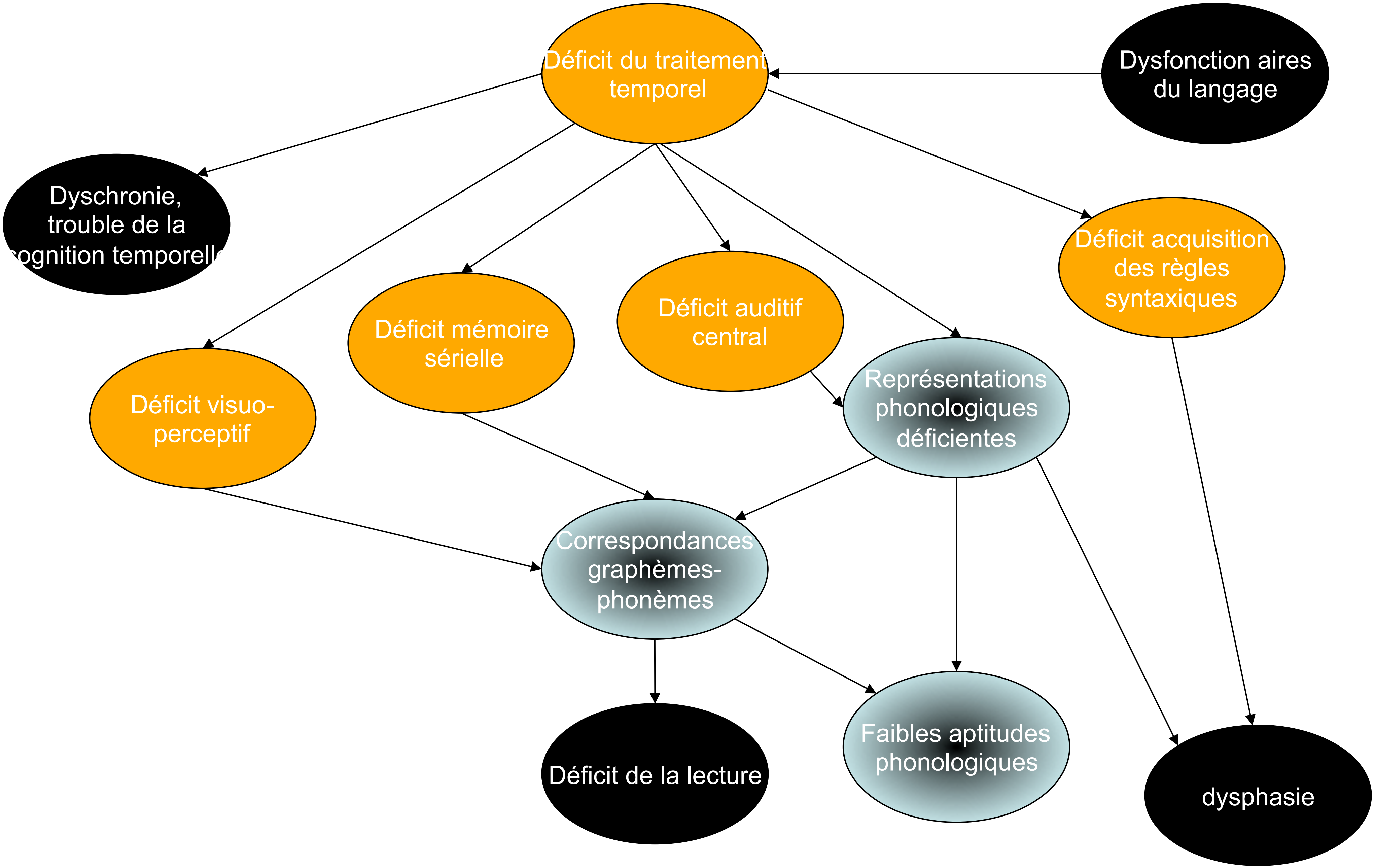
Restorative Neurology and Neuroscience 25 (2007) 295–310
IOS Press

Neural correlates of rapid auditory processing are disrupted in children with developmental dyslexia and ameliorated with training: An fMRI study

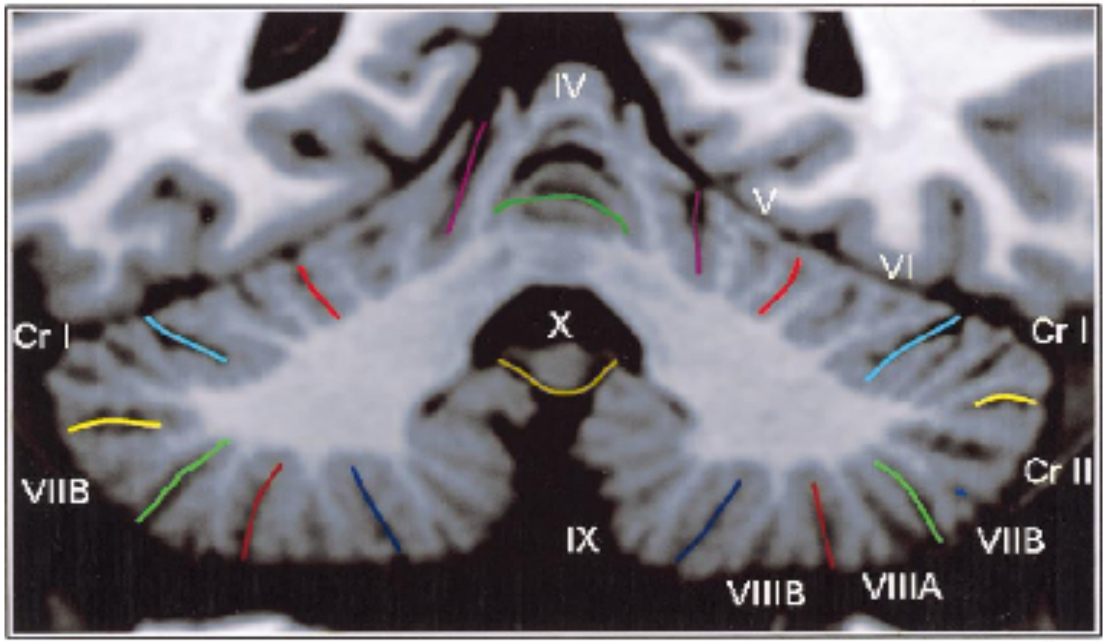
N. Gaab[a,e,*], J.D.E. Gabrieli[a], G.K. Deutsch[b], P. Tallal[c] and E. Temple[d]

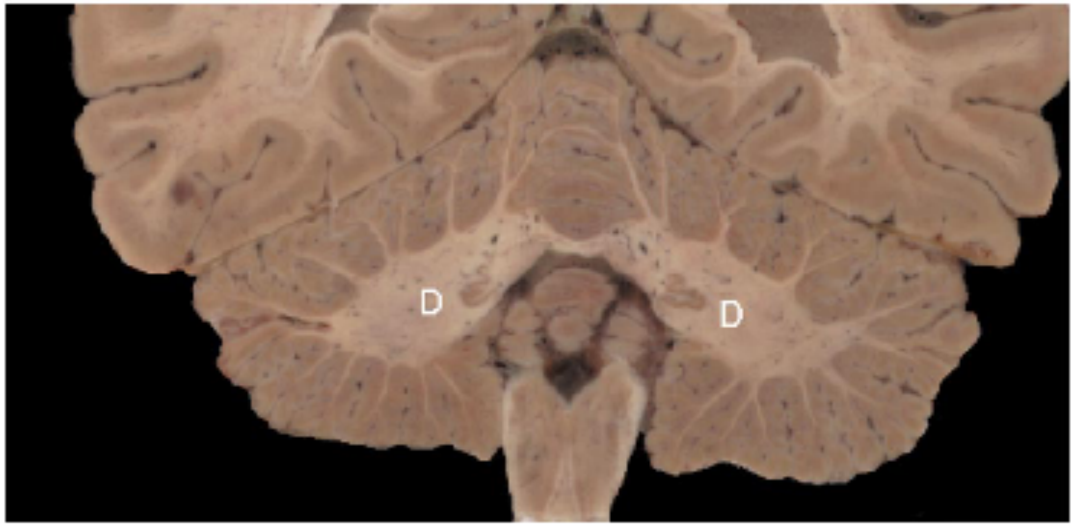






déficit du traitement temporel (Tallal)





Le cervelet : un organe aux fonctions multiples et émergentes

-motricité, coordination, posture

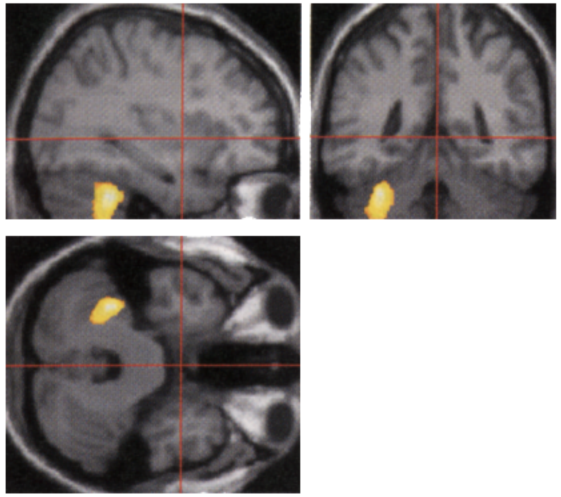
-Modulateur des apprentissages procéduraux et des automatismes (sensori-moteurs et cognitifs)

- Pace-maker des structures sus-jacentes?

Developmental dyslexia: the cerebellar deficit hypothesis

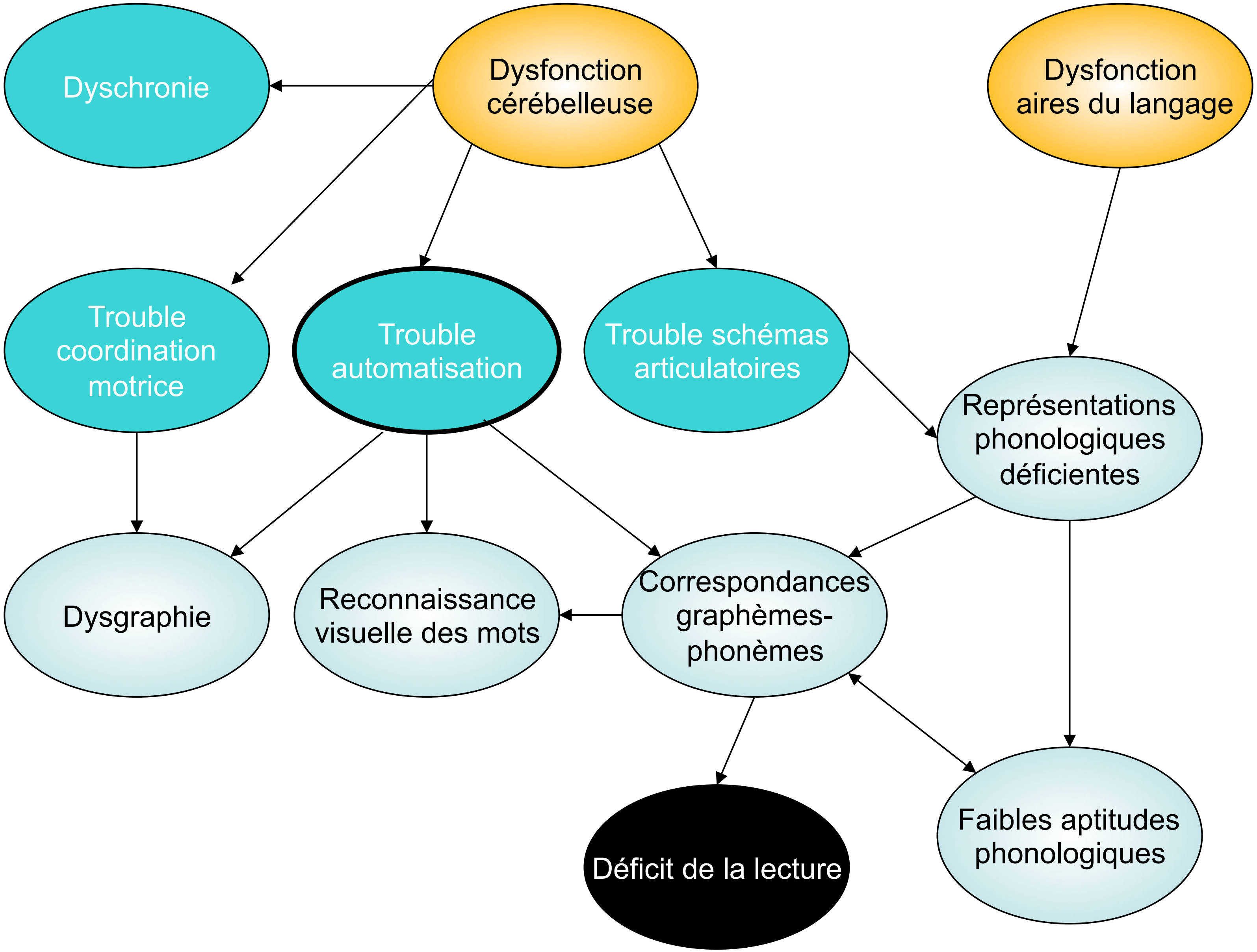
Roderick I. Nicolson, Angela J. Fawcett and Paul Dean

Surprisingly, the problems faced by many dyslexic children are by no means confined to reading and spelling. There appears to be a general impairment in the ability to perform skills automatically, an ability thought to be dependent upon the cerebellum. Specific behavioural and neuroimaging tests reviewed here indicate that dyslexia is indeed associated with cerebellar impairment in about 80% of cases. We propose that disorders of cerebellar development can in fact cause the impairments in reading and writing characteristic of dyslexia, a view consistent with the recently appreciated role of the cerebellum in language-related skills. This proposal has implications for early remedial treatment.



Nicolson et al., 1999

Nicolson et al., T.I.N.S., 2001



dysfonction cérébelleuse (Nicolson)

McGurk effect : an auditory /ba/ presented with a visual /ga/ is typically “heard” as /da/ (the reverse, i.e., auditory /ga/ and visual /ba/, tends to yield /bga/).

ELSEVIER

Neuroscience Letters 351 (2003) 46–50

www.elsevier.com/locate/neulet

Integration of heard and seen speech: a factor in learning disabilities in children

Erin A. Hayes[a,*], Kaisa Tiippana[b], Trent G. Nicol[a], Mikko Sams[b], Nina Kraus[a,c,d]

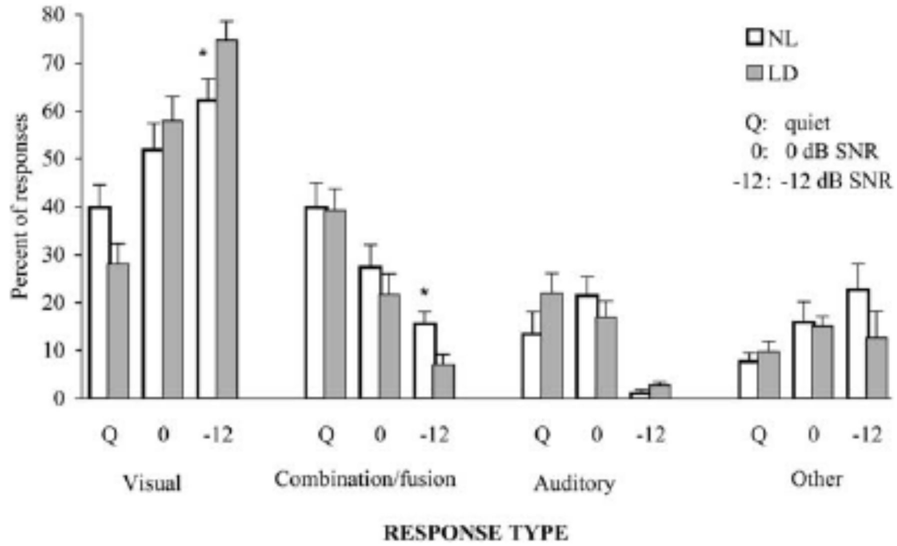


Fig. 1. Response types averaged across the four incongruent stimulus pairs. Presented here are the adjusted means for the response type, calculated with audio-alone and visual-alone scores as covariates; error bars represent one standard error of the mean. At −12 dB SNR, LD children reported a higher proportion of visual responses to incongruent stimuli. Conversely, combinations/fusions were more likely to be reported by NL children. A similar pattern of results can be seen at 0 dB SNR, but the differences were not statistically significant. In addition, there was an interaction between noise level and diagnostic group such that LDs exhibited a greater increase in perception of the visual component of incongruent stimuli with increased noise level. Auditory and other responses did not differ between groups at any noise level.

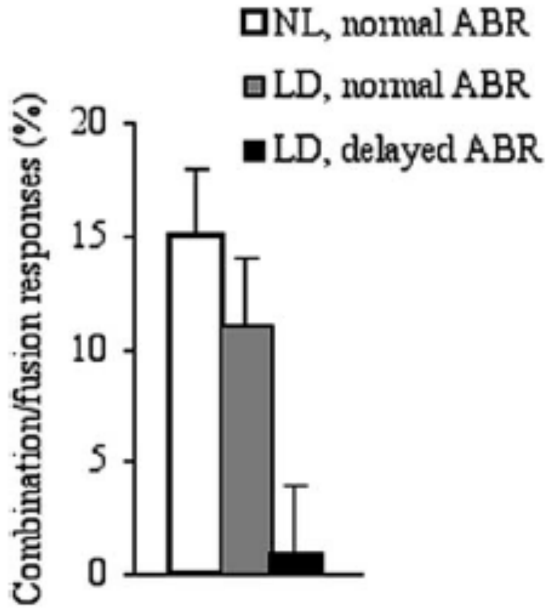


Fig. 2. Combination and fusion responses to incongruent stimuli at −12 dB SNR for children grouped according to brainstem latency elicited by /da/. Presented here are the adjusted means calculated with audio-alone and visual-alone scores as covariates; error bars represent one standard error of the mean. LD children with delayed latencies reported fewer combination and fusion responses to incongruent audiovisual stimuli than NL children with a normal latency. The frequency of combination/fusion responses in LD children with a latency within normal limits was intermediate between the other two groups.

Effet McGurk chez des adultes dyslexiques et normo-lecteurs

- 9 adultes gardant des séquelles de dyslexie (4 M, 5 F; Age moyen : 38, range: 34-52) et 10 adultes normo-lecteurs (5 M, 5 F; Age moyen 30, range: 20-40)
- 81 présentations separées par intervalles de 10 sec.
- 3 stimuli auditifs (/aba/, /ada/, ou /aga/) associés à des séquences vidéo, sous 2 conditions : congruente vs incongruente.
- Validation préalable du matériel : /aba/-/aga/, --> /ada/; /ada/-/aba/, --> /abda/; /aga/-/aba/, --> /abga/ (Cathiard et al., 2001).

K. Giraud, M. Habib, C. Liégeois-Chauvel, in press

Effet McGurk chez des adultes dyslexiques et normo-lecteurs

	COHERENT AUDIO-VISUAL : ABA								
	ABA	ADA	AGA	ABDA	ABGA	ADBA	ADGA	AGBA	Autres
Non-dyslexic	93	1	0	3	0	2	0	0	0
Dyslexic	100	0	0	0	0	0	0	0	0

	COHERENT AUDIO-VISUAL : ADA								
	ABA	ADA	AGA	ABDA	ABGA	ADBA	ADGA	AGBA	Autres
Non-dyslexic	0	80	0	9	0	0	1	0	10
Dyslexic	0	77	0	20	0	0	1	0	2

	COHERENT AUDIO-VISUAL : AGA								
	ABA	ADA	AGA	ABDA	ABGA	ADBA	ADGA	AGBA	Autres
Non-dyslexic	0	0	94	0	0	0	6	0	0
Dyslexic	0	1	91	0	4	0	4	0	0

Les trois conditions cohérentes

Effet McGurk chez des adultes dyslexiques et normo-lecteurs

Audio ADA / Visual ABA

	AUDIO	VISUAL	FUSION	COMB*	OTHER
Non-dyslexics	17 *(19.1)*	0	0	83 *(19.1)*	0
Dyslexics	38 *(41.5)*	0	0	57 *(38.2)*	6 *(8.4)*

Audio AGA / Visual ABA

	AUDIO	VISUAL	FUSION	COMB	OTHER
Non-dyslexics	14 *(21.0)*	0	0	84 *(23.0)*	1 *(3.5)*
Dyslexics	31 *(35.5)*	0	0	65 *(34.3)*	4 *(8.3)*

Audio ABA / Visual AGA

	AUDIO	VISUAL	FUSION	COMB	OTHER
Non-dyslexics	44 *(46.3)*	3 *(7.5)*	50 *(43.0)*	0	2 *(4.7)*
Dyslexics	67 *(34.6)*	3 *(5.1)*	25 *(31.3)*	3 *(5.1)*	3 *(5.1)*

- Conditions incongruentes : moins de combinaisons ou de fusions chez les dyslexiques <-- déficit d'intégration intermodale

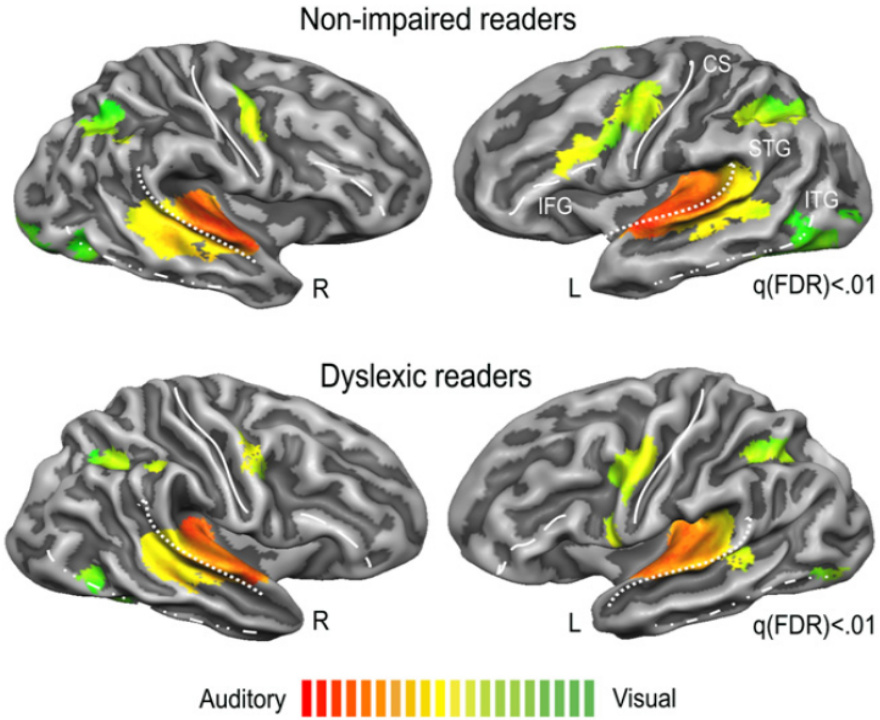
- preference générale pour stimuli auditifs

Current Biology 19, 1–6, March 24, 2009 ©2009 Elsevier Ltd All rights reserved DOI 10.1016/j.cub.2009.01.

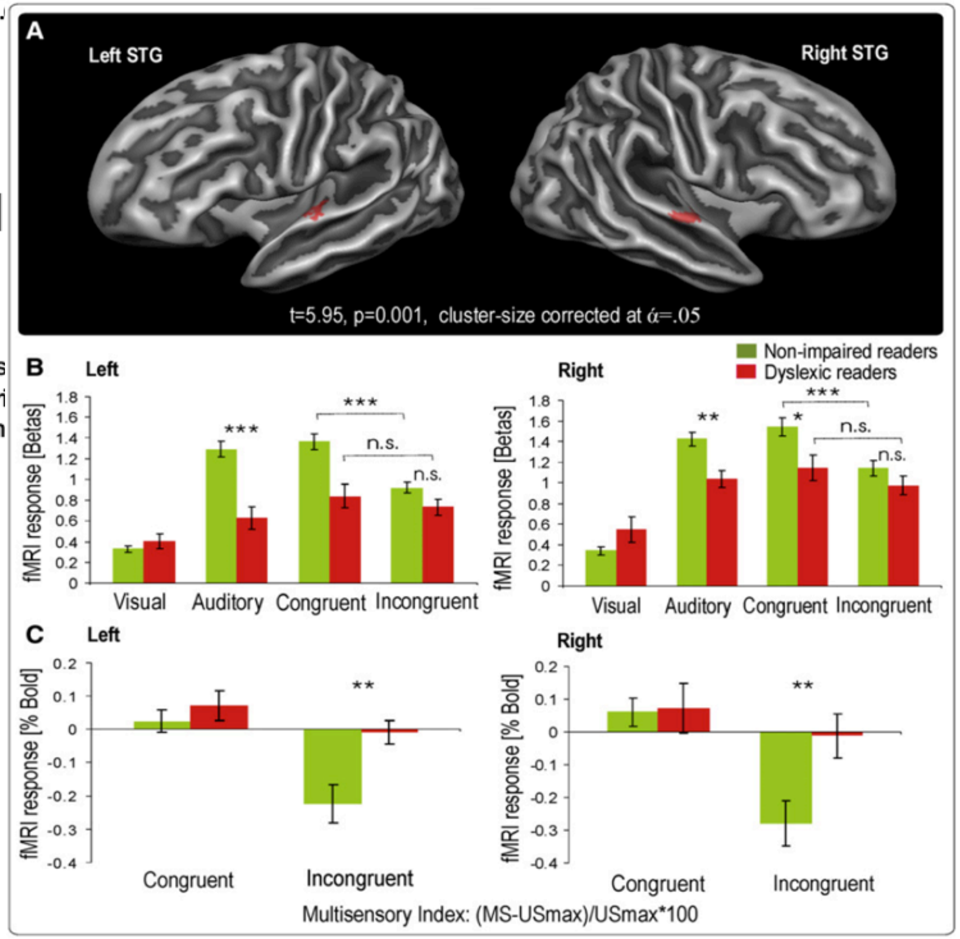
Reduced Neural Integration of Letters and Speech Sounds Links Phonological and Reading Deficits in Adult Dyslexia

Vera Blau,[1,2,*] Nienke van Atteveldt,[1,2] Michel Ekkebus,[3] Rainer Goebel,[1,2] and Leo Blomert[1,2]
[1]University of Maastricht

for letters and speech s
dyslexia have been pri
adequately representin



Zones activées par des stimuli unimodaux (parole=rouge, lettres=vert, commun=jaune)



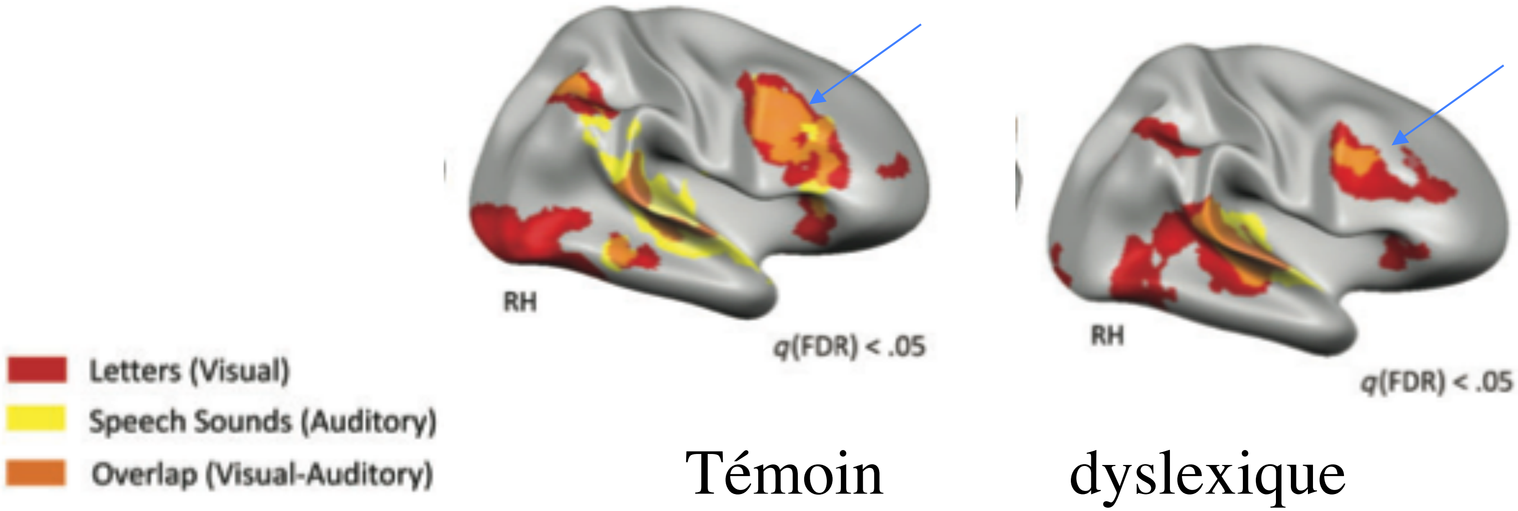
4 conditions : unimodal visuel, unimodal auditif, multimodal congruent et multimodal incongruent

A/ l'interaction groupe condition est significative dans les deux régions auditives moyennes

B/ dyslexiques activent moins en unimodal et en multimodal

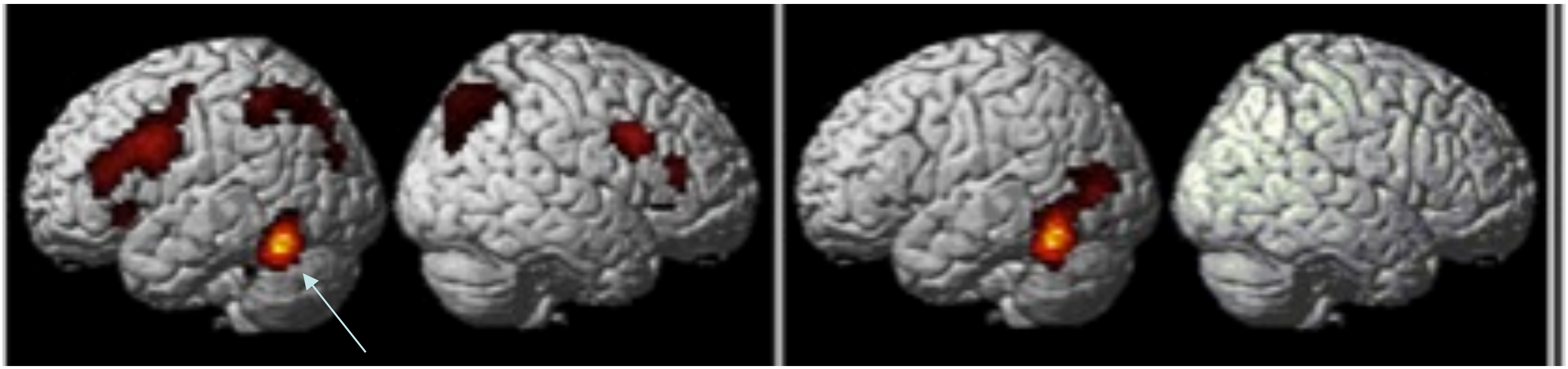
C/ témoins ont une moins forte activation pour les paires incongruentes, pas les dyslexiques

Blau et al., Brain, 2010

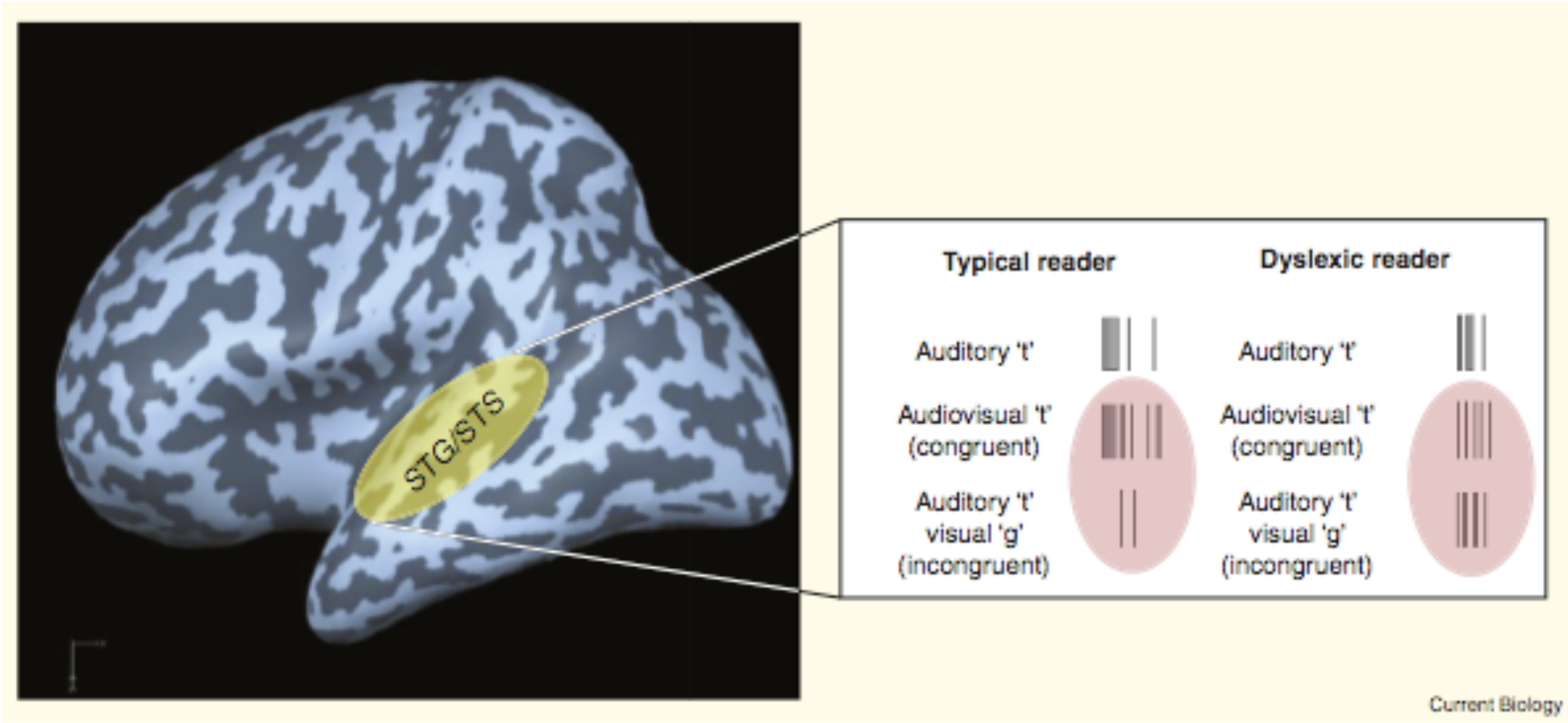


Témoin dyslexique

Van den Mark, Neuroimage, 2011

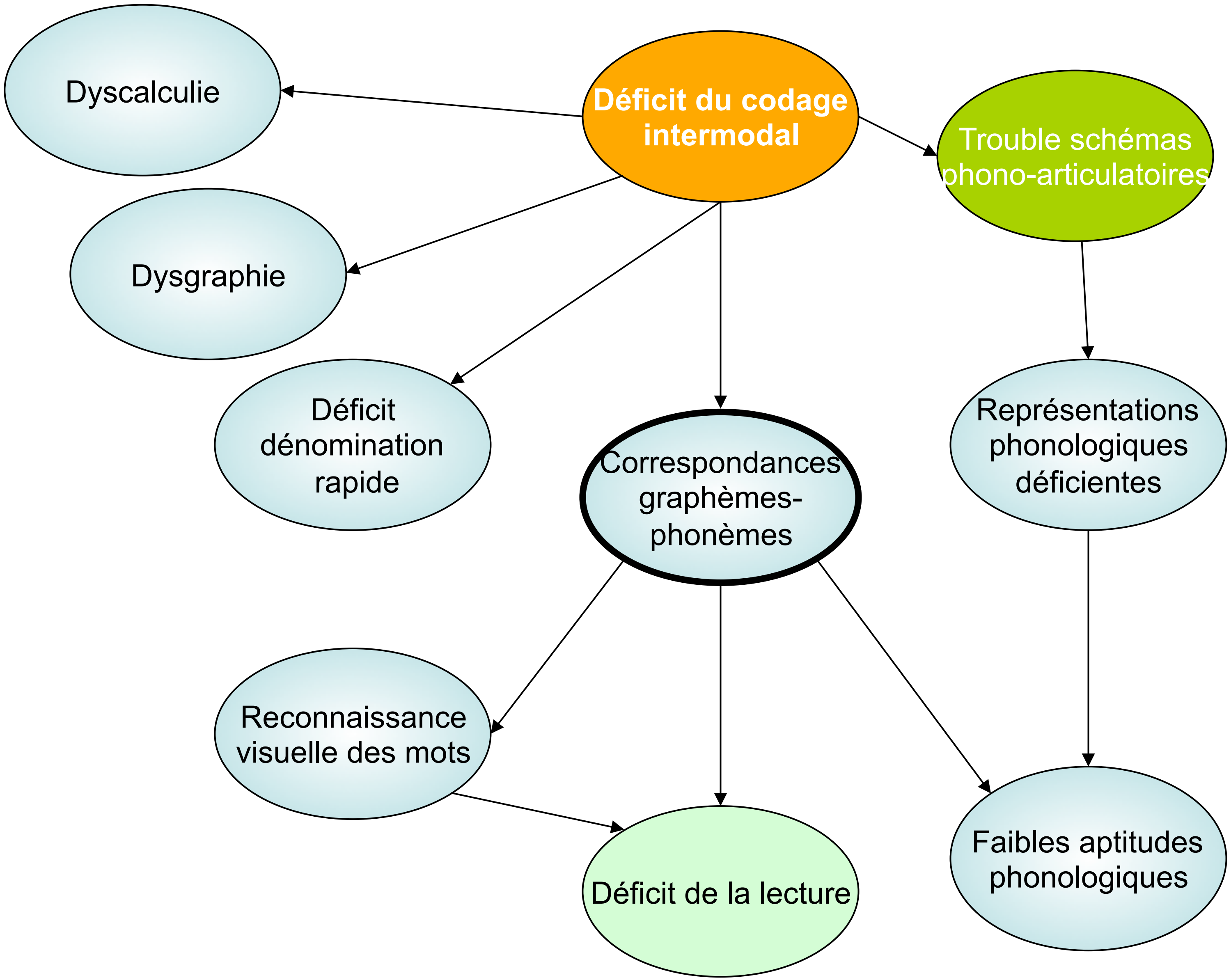


Témoin dyslexique



lorsque le stimulus est congruent (le sujet entend 't' et voit la lettre T), la décharge neuronale est moins bien organisée que chez le témoin; en outre, celle-ci est beaucoup plus importante qu'elle ne devrait l'être pour un stimulus incongruent (le sujet entend 't' et voit la lettre G).

--> pb d'intégration intermodale



déficit transcodage intermodal

doi:10.1093/brain/awp308 Brain 2010: 133; 868–879 | 868

BRAIN
A JOURNAL OF NEUROLOGY

Deviant processing of letters and speech sounds as proximate cause of reading failure: a functional magnetic resonance imaging study of dyslexic children

Vera Blau,[1,2] Joel Reithler,[1,2] Nienke van Atteveldt,[1,2] Jochen Seitz,[1,2] Patty Gerretsen,[3] Rainer Goebel[1,2] and Leo Blomert[1,2]

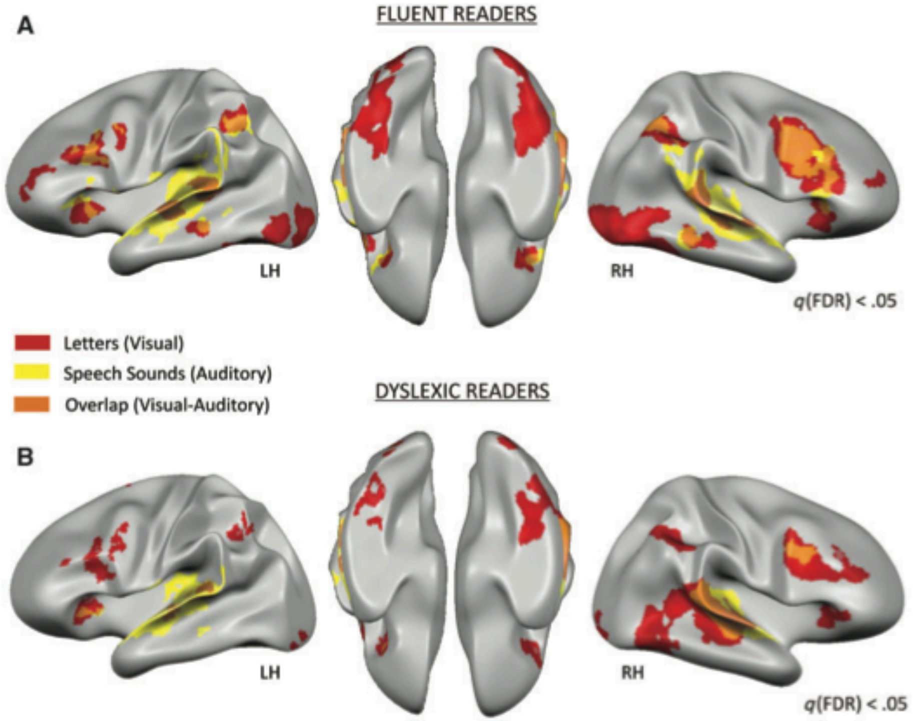


Figure 1 Spatial cortical networks involved in processing letters (red), speech sounds (yellow) or both unisensory conditions (orange) in fluent (**A**) and dyslexic readers (**B**). FDR = false discovery rate.

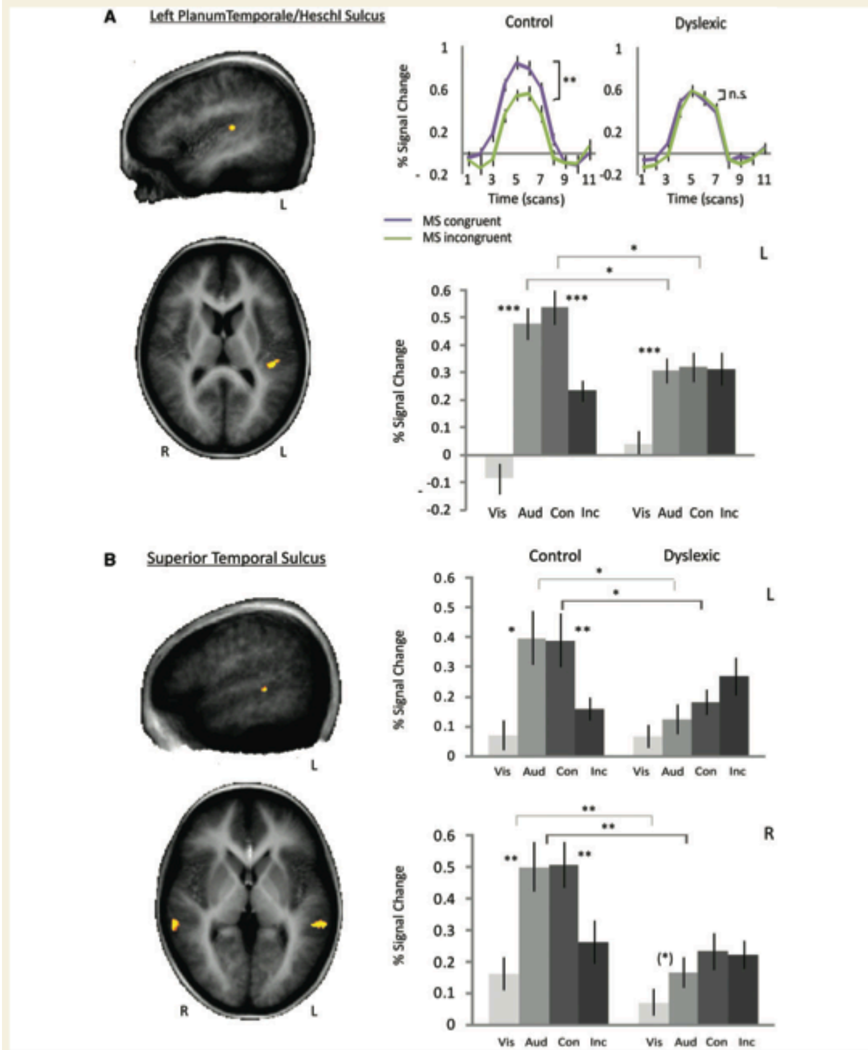
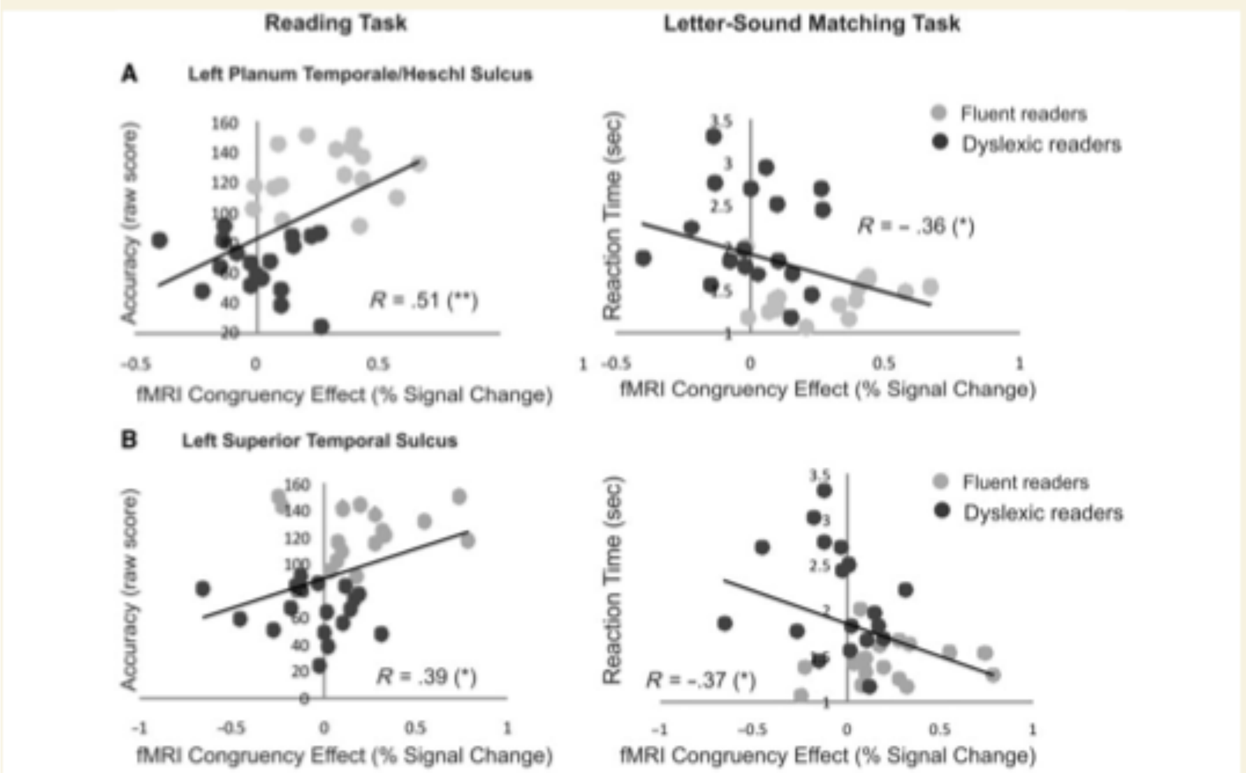
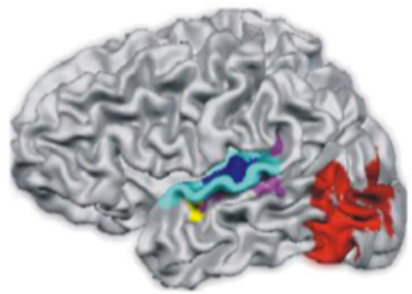


Figure 3 Interaction effect between 'reading group' and 'multisensory condition' (congruent, incongruent) in the planum temporale/ Heschl sulcus of the left hemisphere (**A**) projected on the average anatomy. The right side of the figure depicts the percent signal change and corresponding SEM as a function of time for fluent and dyslexic readers in multisensory congruent (purple line) and incongruent (green line) conditions. Bar graphs illustrate the percent signal change and SEM for the multisensory and unisensory

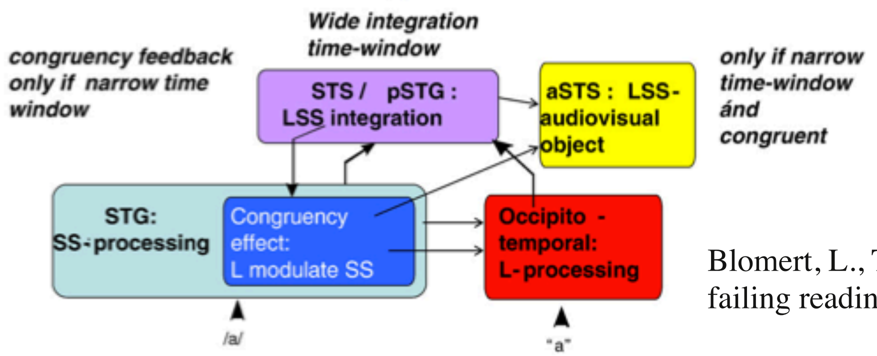
18 dysl vs 16 controls; mean age 9,4y.
fMRI = visual letters / auditory sound of letters / let/sound simultaneous : congr. / non congruent



Correlations between reading accuracy as well as speed of letter-speech sound matching and the neural response to congruent versus incongruent letter-speech sound pairs in planum temporale/ Heschl sulcus and left superior temporal sulcus (fMRI congruency effect)



Sources:
VanAtteveldt e.a. 2004; 2007a;
Blau e.a., 2009
Froyen e.a., 2008



… letter-speech sound integration is an emergent property of learning to read that develops inadequately in dyslexic readers, presumably as a result of a deviant interactive specialization of neural systems for processing auditory and visual linguistic inputs.

Blomert, L., The neural signature of orthographic-phonological binding in successful and failing reading development, NeuroImage (2010), doi:10.1016/j.neuroimage.2010.11.003

Developmental Science (2010), pp 1–14 DOI: 10.1111/j.1467-7687.2010.01007.x

PAPER

Evidence for a specific cross-modal association deficit in dyslexia: an electrophysiological study of letter–speech sound processing

Dries Froyen, Gonny Willems and Leo Blomert

ERP 2 conditions : congruent 0ms vs congruent 200ms

2 measures : MMN & late negativity (650ms)

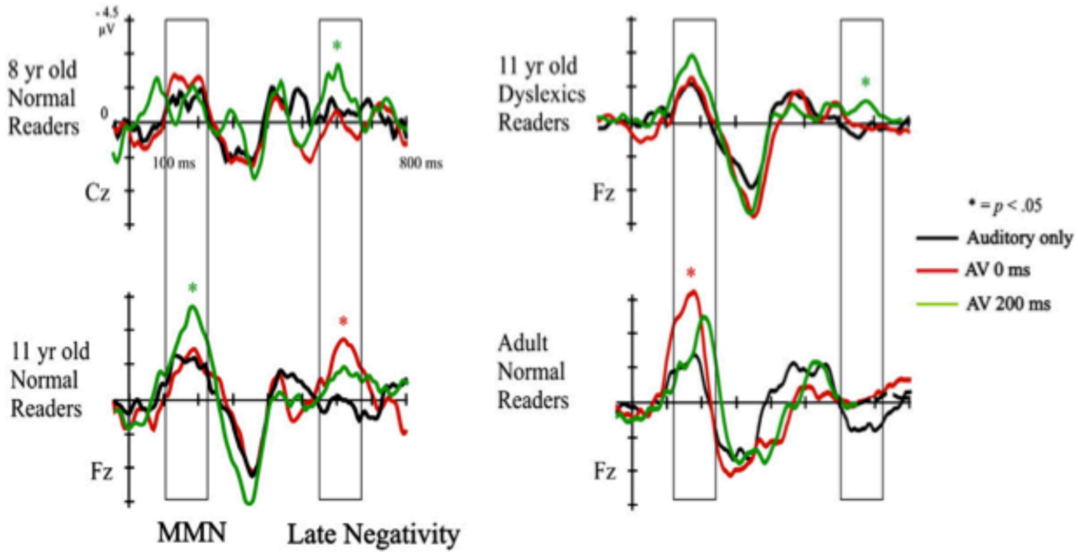


Fig. 2. A comparison of letter–speech sound association and integration in beginner, advanced, experienced and dyslexic readers by means of a cross-modal MisMatchNegativity paradigm. Legend: Mean amplitude of MMN (measured over the four frontocentral electrodes: Fz, Cz, Fc3 and Fc4) (top) and Late Negativity. Auditory only: standard auditory MMN design. AV–0 ms = simultaneous presentation of letters and speech sounds. AV–200 ms: letter appeared 200 ms before the speech sound.
Sources: Froyen et al., 2008, 2009, in press.

8/9 year old beginning readers did not reveal an influence of letters on the MMN, hence no sign of automatic letter-speech sound integration. In contrast, eleven year old advanced readers in grade five did show early automatic integration, however only when letters and speech sounds were presented with a 200 ms interval. Interestingly, these advanced readers also showed a strong late effect of letters on speech sound processing at about 650 ms and this time only when the stimuli were presented simultaneously. Beginner readers also revealed this late effect of letters, but much weaker and again with a 200 ms interval, after one year of reading instruction.

NeuroImage 54 (2011) 2426–2436

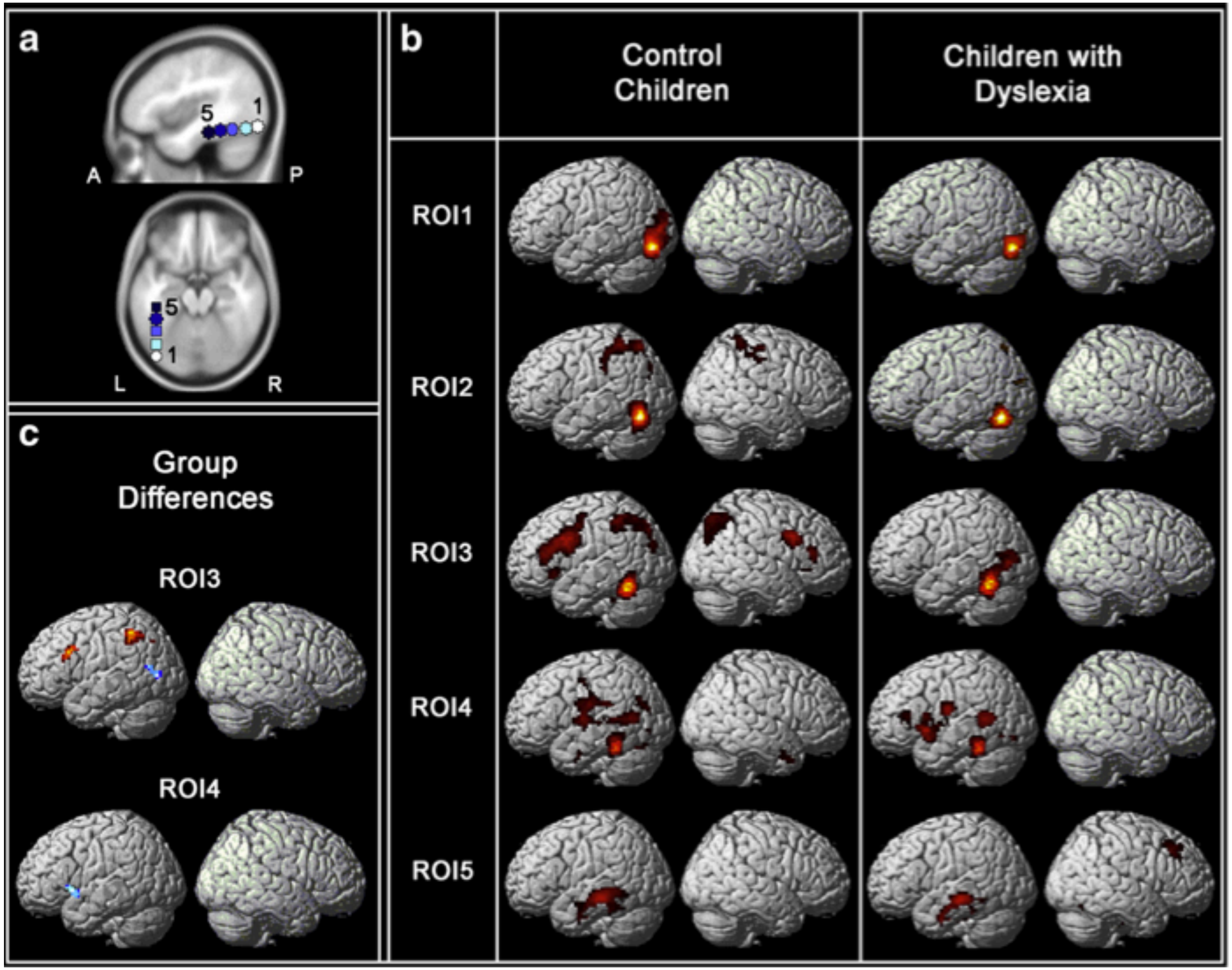
Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

The left occipitotemporal system in reading: Disruption of focal fMRI connectivity to left inferior frontal and inferior parietal language areas in children with dyslexia

Sanne van der Mark [a,1], Peter Klaver [a,b,c,1], Kerstin Bucher [a], Urs Maurer [d,e], Enrico Schulz [d,f], Silvia Brem [d,g], Ernst Martin [a,c], Daniel Brandeis [c,d,h,*]



MRI was used to assess connectivity of the VWF-System in 18 children with dyslexia and 24 age-matched controls (age 9.7-12.5 years) using five neighboring left occipitotemporal regions of interest (ROIs) during a continuous reading task requiring phonological and orthographic processing.

First, the results revealed a focal origin of connectivity from the VWF-system, in that mainly the VWFA was functionally connected with typical left frontal and parietal language areas in control children. Adjacent posterior and anterior VWF-System ROIs did not show such connectivity, confirming the special role that the VWFA plays in word processing.

Second, we detected a significant disruption of functional connectivity between the VWFA and left inferior frontal and left inferior parietal language areas in the children with dyslexia.

frontiers in
PSYCHOLOGY

ORIGINAL RESEARCH ARTICLE
published: 02 March 2012
doi: 10.3389/fpsyg.2012.00060

Mapping symbols to sounds: electrophysiological correlates of the impaired reading process in dyslexia

Andreas Widmann[1]*, Erich Schröger[1], Mari Tervaniemi[2,3], Satu Pakarinen[2] and Teija Kujala[2,4]

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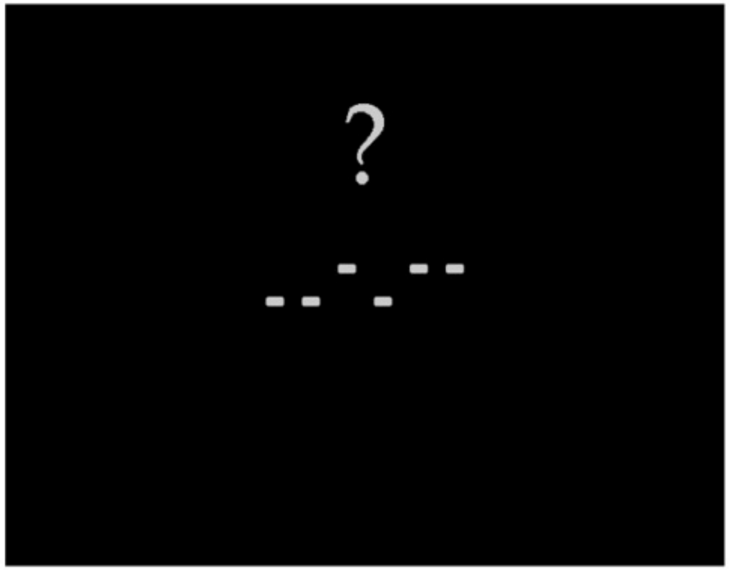


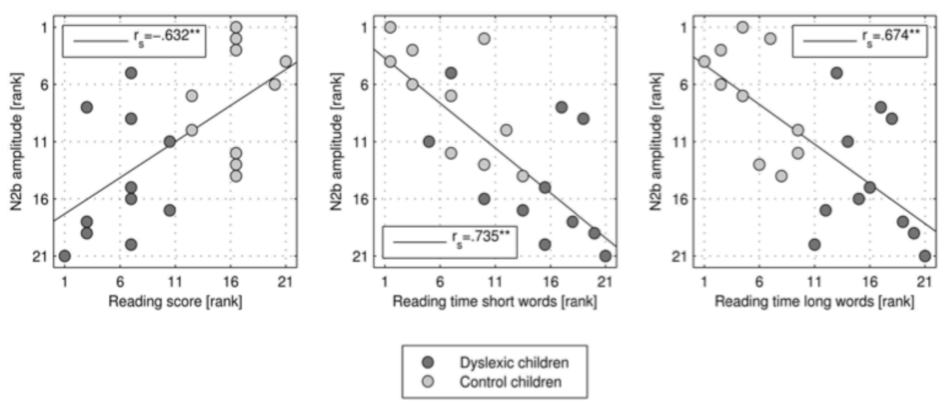
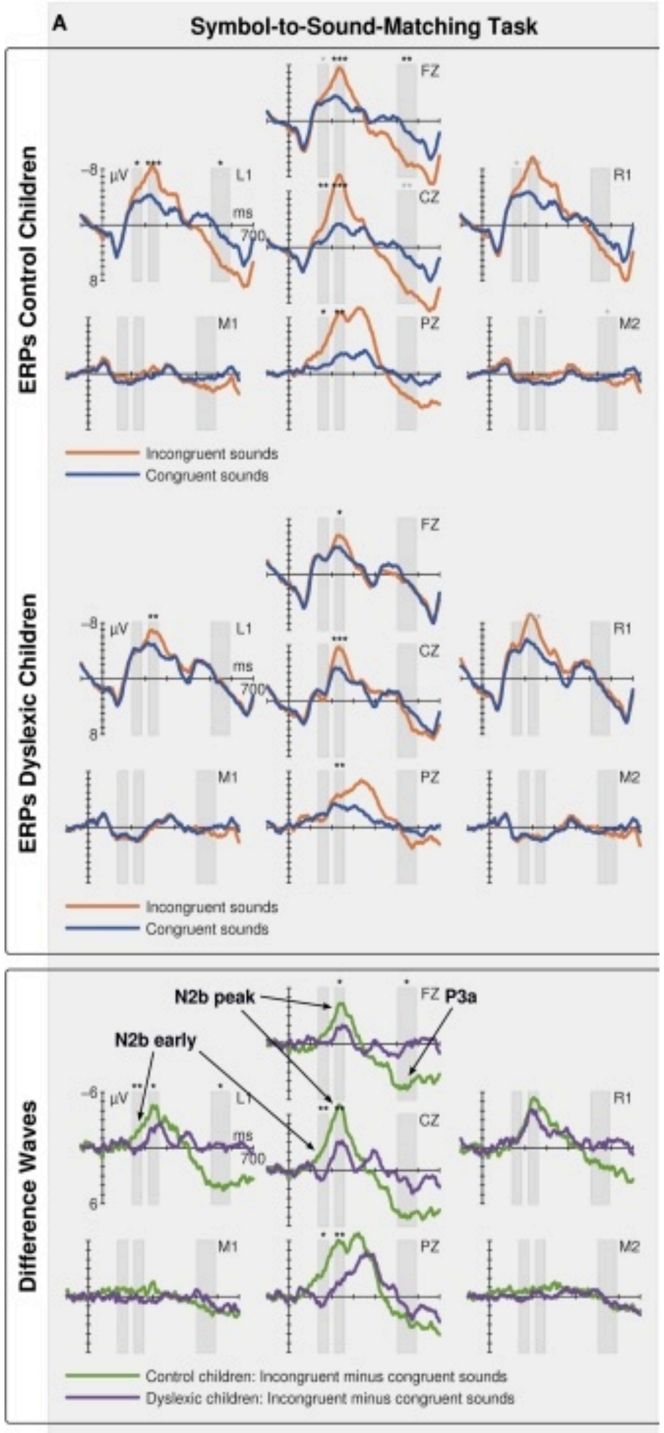


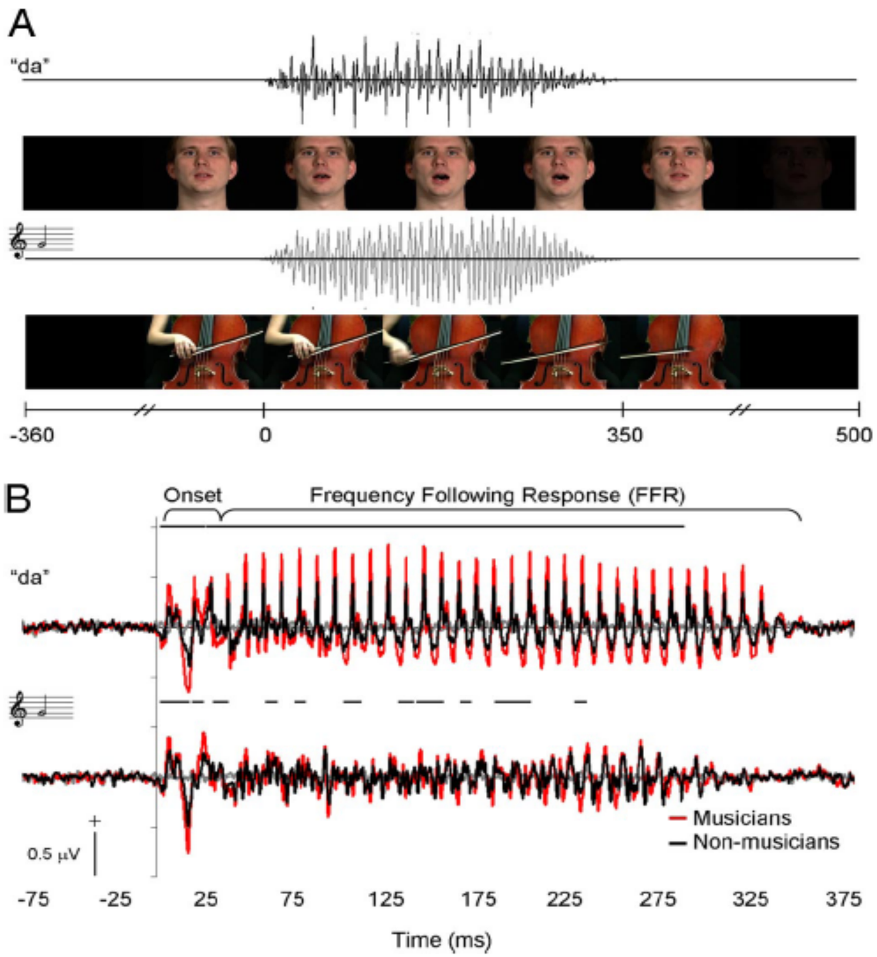
FIGURE 3 | Scatter plot and correlation of N2b amplitude rank (negative up) at electrode location Cz and rank of reading score, and reading time of short and long words, respectively.



Musicians have enhanced subcortical auditory and audiovisual processing of speech and music

Gabriella Musacchia[*], Mikko Sams[†], Erika Skoe[*], and Nina Kraus[*‡§¶]

[*]Auditory Neuroscience Laboratory, Department of Communication Sciences, [‡]Department of Neurobiology and Physiology, and [§]Department
eering, Helsinki University of



unimodal acoustic (UA) and audiovisual (AV) duration discrimination tasks : more phase locking in musicians than non musician for both speech and music. These findings demonstrate practice-related changes in the early sensory encoding of auditory and audiovisual information

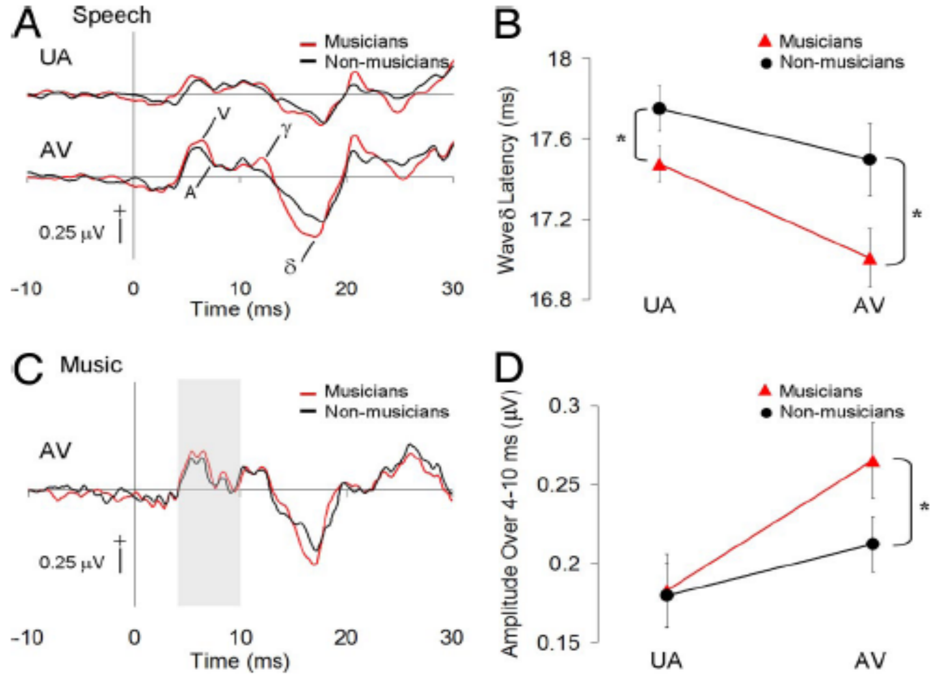


Fig. 2. Musicians have enhanced onset response timing and magnitude. (*A*) Grand average onset responses of the musicians and control subjects to the AV (*Upper*) and UA (*Lower*) speech stimuli. UV speech and music stimuli elicited little activity, as indicated by the gray traces. Prominent peaks of the onset response (V, A, γ, δ) are indicated. Wave δ latencies were earlier in musicians than in controls. (*B*) Mean wave δ latencies for musicians and controls are shown with error bars denoting ± SEM. Musicians had significantly earlier latencies than controls in both the UA and AV conditions. (*C*) Musician and control grand average responses to AV cello stimuli. Mean rectified mean amplitude values were calculated over 4–10 ms (shaded gray) to test whether musicians (red) had larger response magnitude early in the subcortical stream, before cortical excitation. (*D*) Rectified mean amplitudes over 4–10 ms of the AV cello response indicated larger onset responses in musicians than controls to music stimuli.

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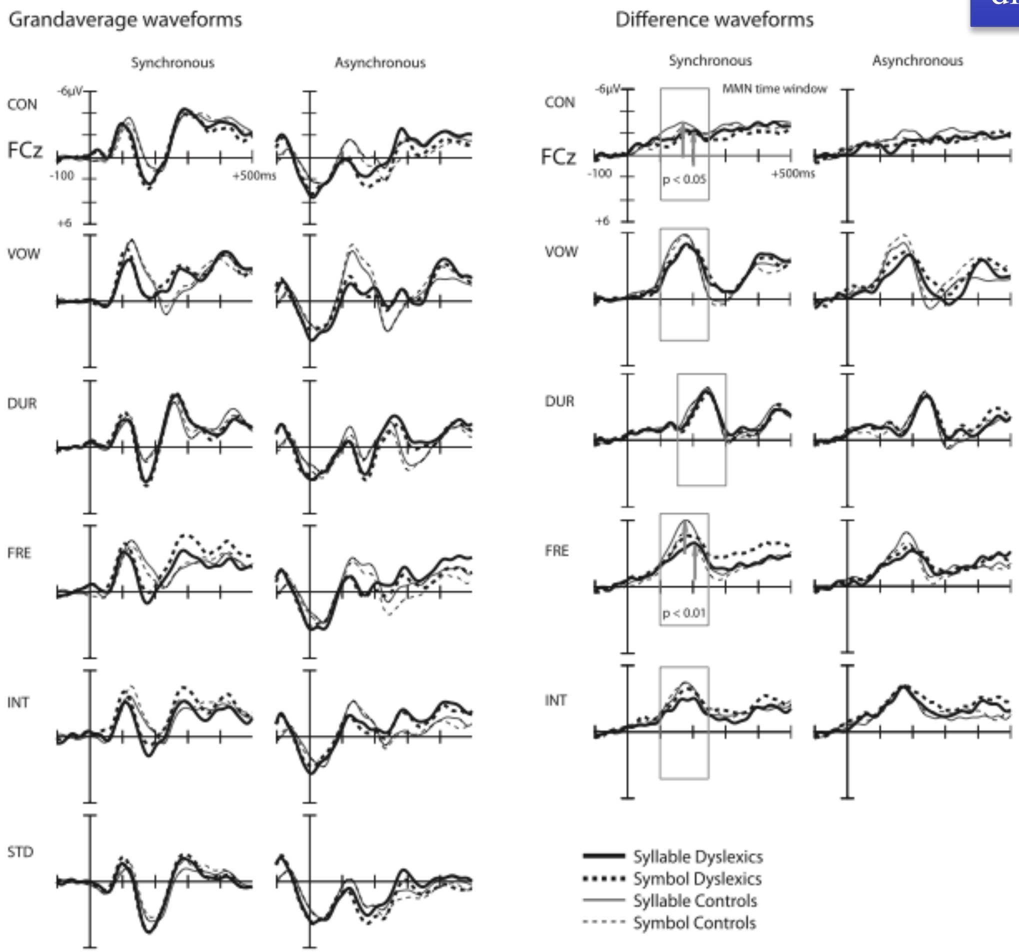
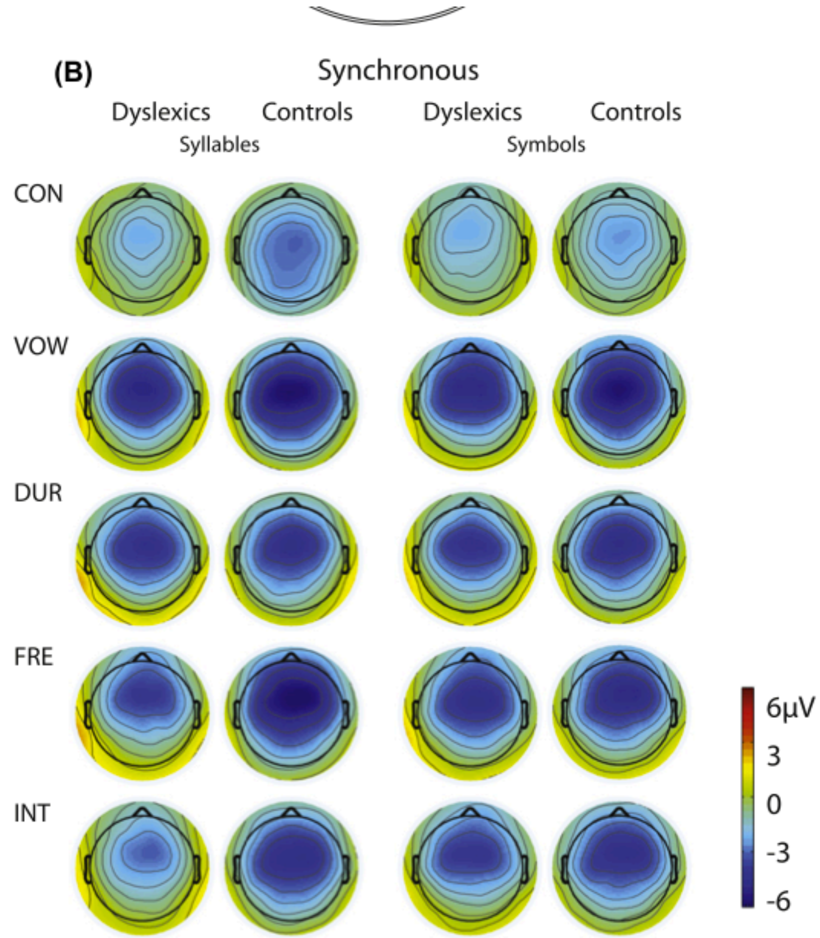
The neurophysiological basis of the integration of written and heard syllables in dyslexic adults

Maria Mittag [a,*], Paula Thesleff [a], Marja Laasonen [b,c], Teija Kujala [a,d]

The main aim of our study was to investigate whether dyslexic readers are impaired in integrating speech sounds with written syllables as reflected by the MMN. To test this, syllable sounds were presented together with either written syllables or symbols. MMNs were larger for written syllables than for symbols in fluent readers indicating a generally greater effect of printed text than nonsense visual material on early auditory speech discrimination. However, no such MMN differences were found between the conditions in dyslexic readers.





Neuroimage. 2011 August 1; 57(3): 704–713. doi:10.1016/j.neuroimage.2010.10.057.

Emergence of the neural network for reading in five-year old beginning readers of different levels of pre-literacy abilities: an fMRI study

Yoshiko Yamada[1], **Courtney Stevens**[2,1], **Mark Dow**[1], **Beth Harn**[3], **David J. Chard**[4,3], and **Helen J. Neville**[1]
[1]Brain Development Laboratory, Department of Psychology, 1227 University of Oregon, Eugene, Oregon 97403, USA

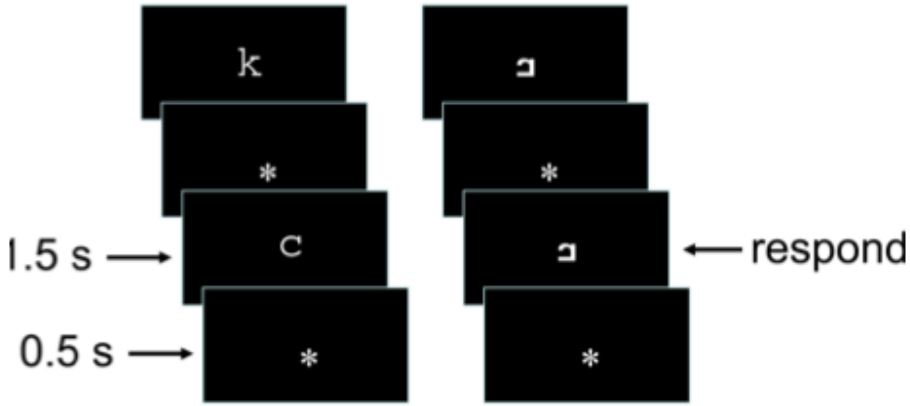
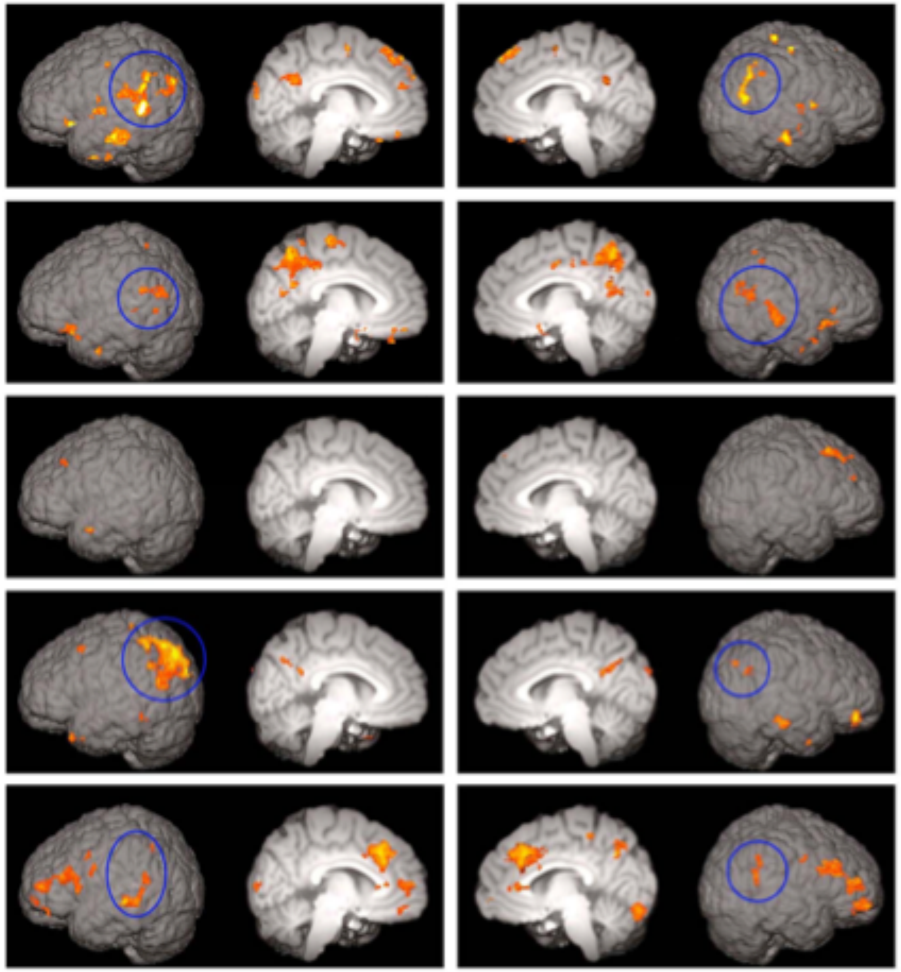


Figure 1.
In-scanner one-back task. Letters (LT) and false fonts (FF) were presented separately in six alternating blocks, interleaved by asterisk fixation blocks (*). Each block lasted for 20 s. Within each task block, ten letter or false font stimuli were presented one at a time. False font stimuli were created by rearranging the parts of corresponding lower-case letter. Each stimulus appeared for 1.5 s, separated by a 0.5 s presentation of a fixation asterisk. Participants were asked to respond by pressing a button with the thumb when the same stimulus was repeated twice in a row.



adultes

Norm dev (sess1)

À risque (sess1)

Norm dev (sess2)

À risque (sess2)

14 children, seven were considered to be on track for reading development (OT) and seven were considered to be at (some) risk for later reading difficulties (AR)

Following 3 months of kindergarten and, for AR children, supplemental reading instruction, OT children showed left-lateralized activation in the temporo-parietal region, whereas AR children showed bilateral activation and recruitment of frontal regions including the anterior cingulate cortex. These data suggest that typical reading development is associated with initial recruitment and subsequent disengagement of right hemisphere homologous regions while atypical reading development may be associated with compensatory recruitment of frontal regions.

Cerebral CORTEX

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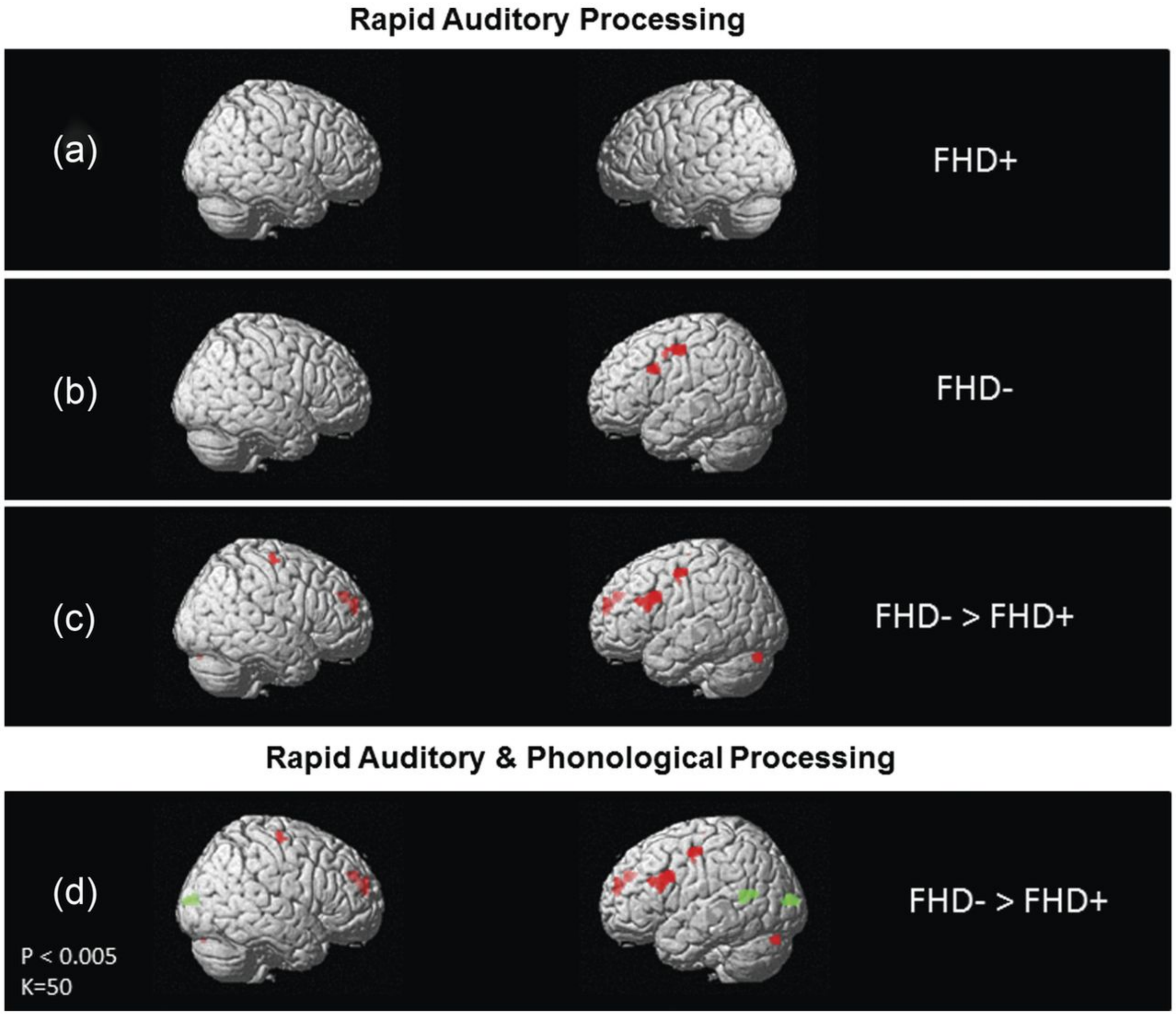
Altered Neuronal Response During Rapid Auditory Processing and Its Relation to Phonological Processing in Prereading Children at Familial Risk for Dyslexia

Nora M. Raschle[1,2], Patrice L. Stering[1], Sarah N. Meissner[1] and Nadine Gaab[1,2,3]

We investigate functional networks during RAP in 28 children with (n = 14) and without (n = 14) a familial risk for DD before reading onset (mean: 5.6 years).
Results reveal functional alterations in left-hemispheric prefrontal regions during RAP in prereading children at risk for DD, similar to findings in individuals with DD. Furthermore, activation during RAP in left prefrontal regions positively correlates with prereading measures of PP and with neuronal activation during PP in posterior dorsal and ventral brain areas.



Maternal history of reading difficulty is associated with reduced language-related gray matter in beginning readers

Jessica M. Black [a,1], Hiroko Tanaka [a,b], Leanne Stanley [a,b], Masanori Nagamine [c], Nahal Zakerani [a,b], Alexandra Thurston [a,b], Shelli Kesler [a], Charles Hulme [d], Heikki Lyytinen [e], Gary H. Glover [f], Christine Serrone [a], Mira M. Raman [a], Allan L. Reiss [a], Fumiko Hoeft [a,*]

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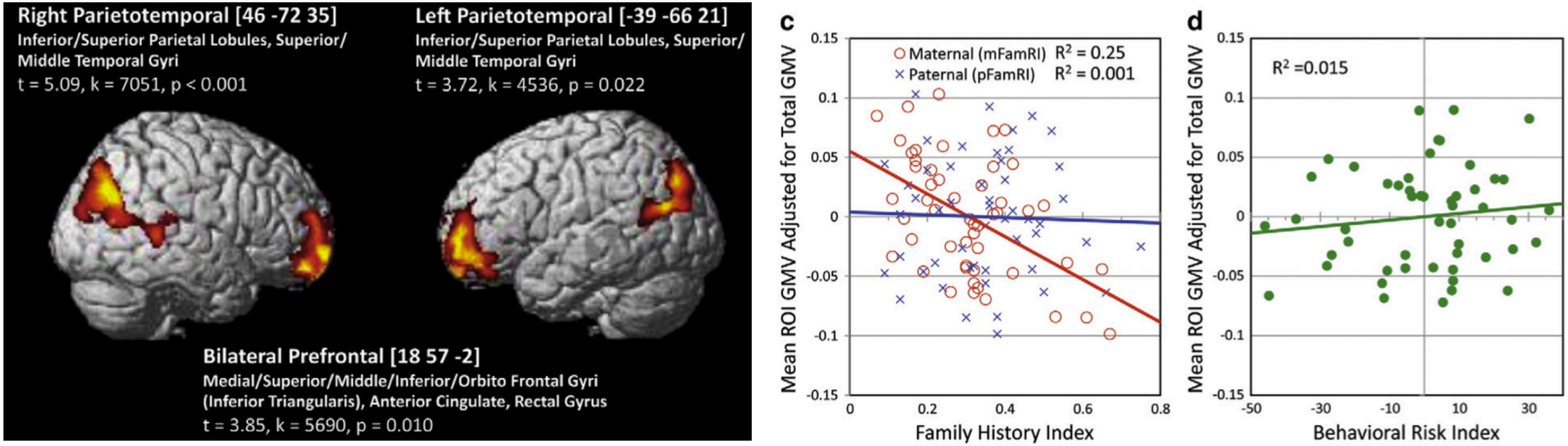


51 enfants de 5-6 ans. Corrélation inverse entre la présence de difficultés de lecture chez la mère et le volume de substance grise dans régions fronto-pariétale chez l'enfant. Pas chez le père, pas de corrélation avec un index de risque (Consc phono + dénom rapide + ident lettres)

Corrélation avec surface pariéto-temporale (influence prénatale) et non épaisseur (infl post-natale)

NeuroImage (2011), doi:10.1016/j.neuroimage.2011.10.024

En conclusion

- Une approche modulaire des troubles des apprentissages et de la dyslexie reste plus que jamais pertinente tant pour la description des faits cliniques que pour la compréhension des mécanismes sous-jacents
- L'hypothèse d'un trouble constitutionnel du traitement auditif des phonèmes reste la plus plausible et la mieux explorée, en particulierpar les méthodes électrophysiologiques (PE chez le nourrisson, l'enfant et l'adulte, et EEG chez l'enfant et l'adulte)
- La notion de co-occurrence ou de comorbidité est un puissant outil de réflexion non seulement pour le clinicien mais également pour le chercheur qui peut y puiser des pistes pertinentes et des modèles potentiellement utiles
- Parmi ces modèles, les plus plausibles — ceux aptes à rendre compte du plus grand nombre de faits cliniques et expérimentaux — sont sans doute ceux faisant appel à la notion de connectivité intermodalitaire.

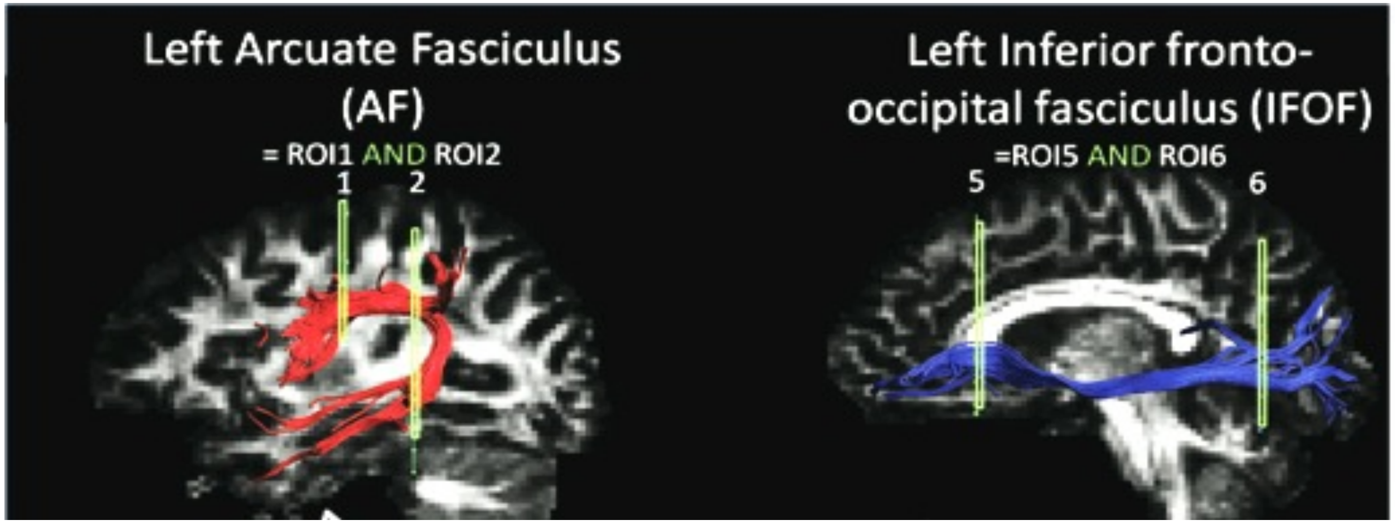
doi:10.1093/brain/awr363 Brain 2012: 135; 935–948 | 935

BRAIN
A JOURNAL OF NEUROLOGY

A tractography study in dyslexia: neuroanatomic correlates of orthographic, phonological and speech processing

Maaike Vandermosten,[1,2,3] Bart Boets,[1,2,4] Hanne Poelmans,[1,2] Stefan Sunaert,[3] Jan Wouters[2] and Pol Ghesquière[1]

1 Parenting and Special Education Research Unit, Katholieke Universiteit Leuven, A. Vesaliusstraat 2, PO Box 3765, 3000 Leuven, Belgium



Estudio en tractografía de déficits fono-auditivo y ortográfico en disléxicos : disociación entre une vía inferior (ortográfica) y superior (fonológica y percepción de la habla).

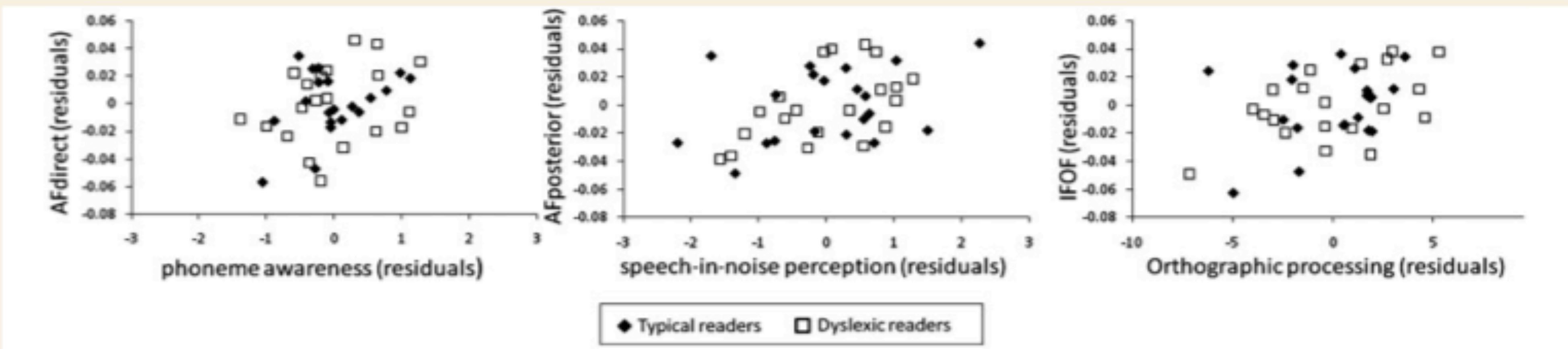


Figure 2 Correlations between (residual) fractional anisotropy values and (residual) reading-related behavioural measures after controlling for group, IQ and quality index of DTI acquisition. AFdirect = acuate fasciculus-direct; AFposterior = arcuate fasciculus-posterior; IFOF = inferior fronto-occipital fasciculus.

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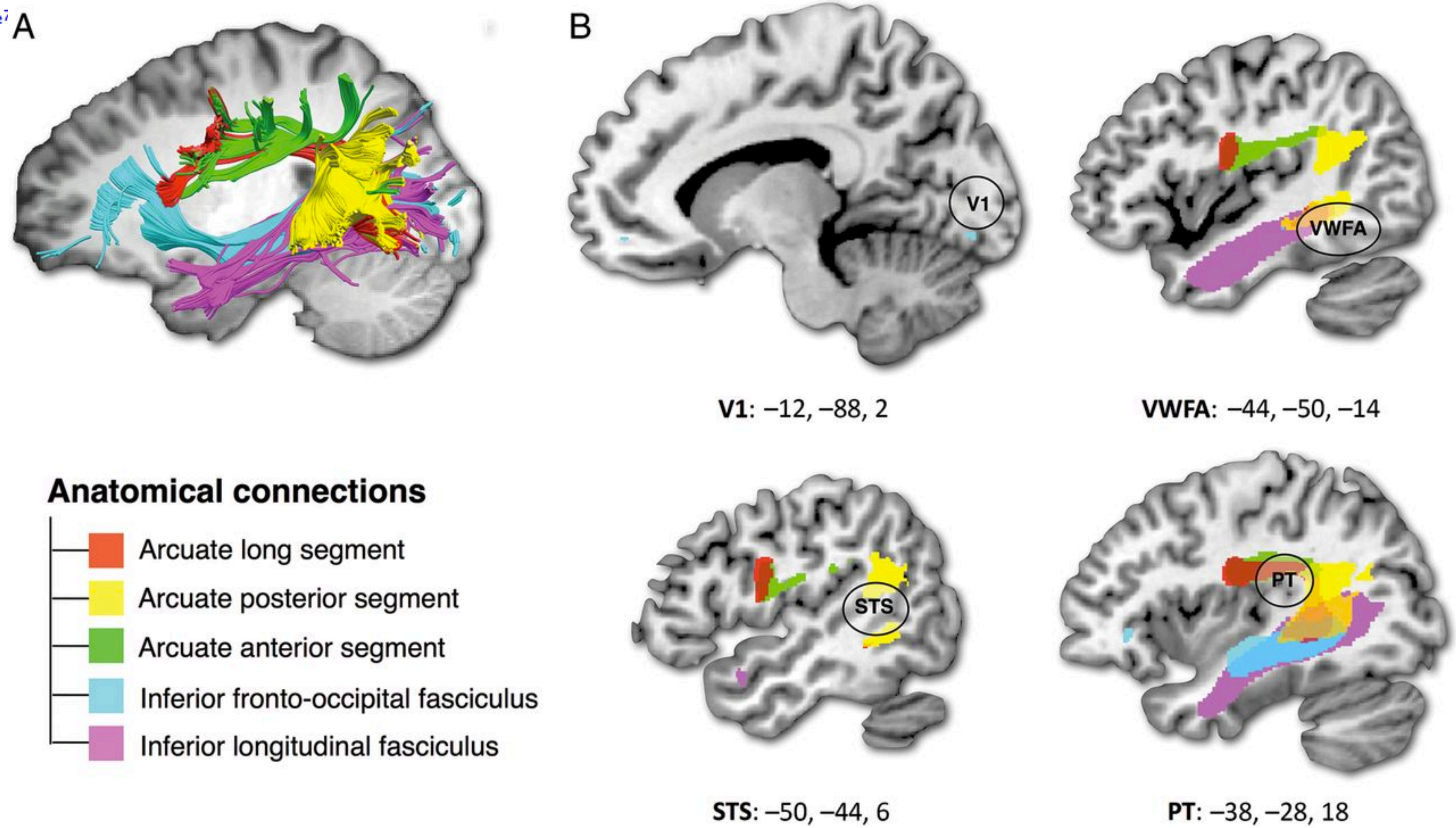
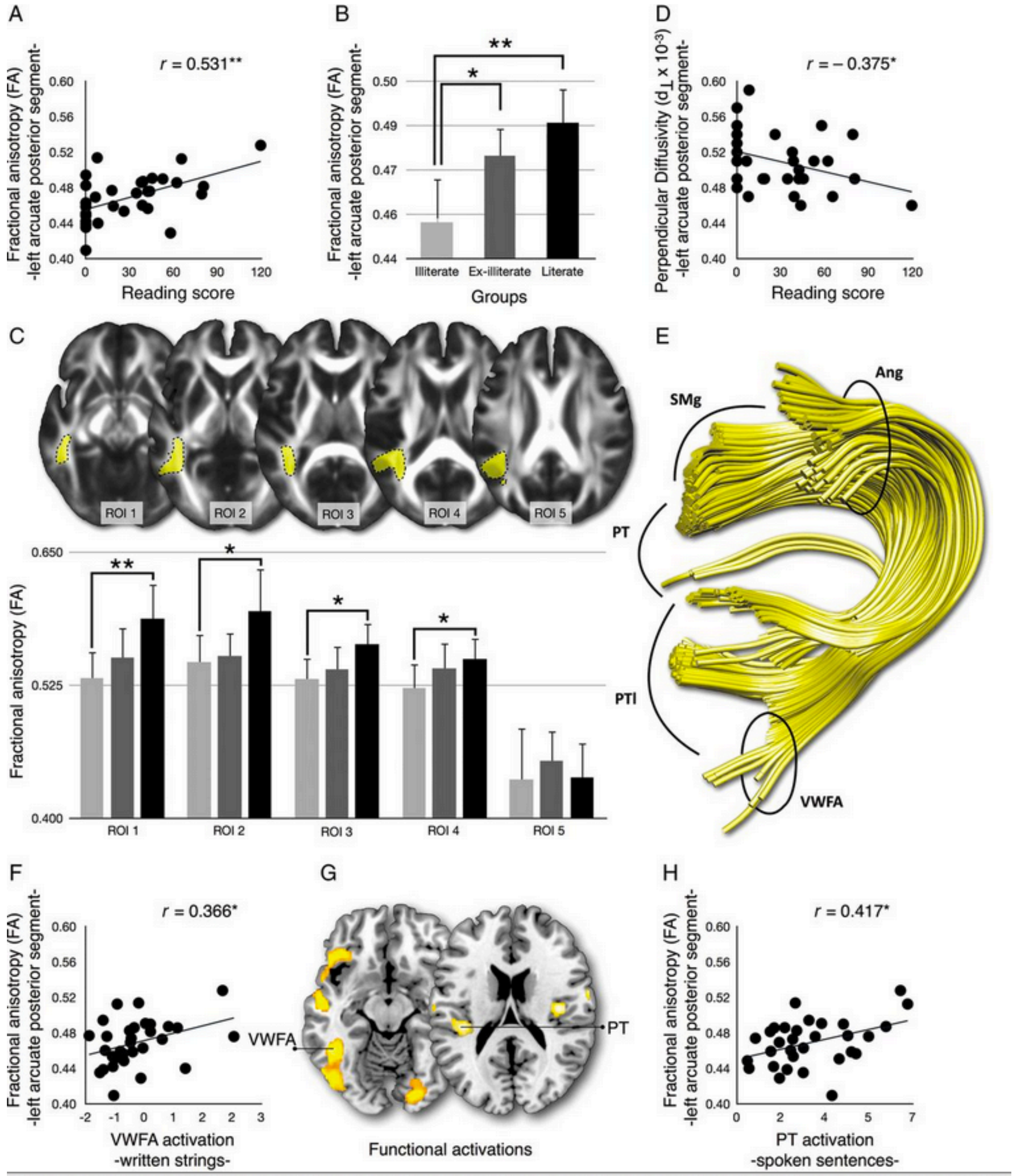
Learning to Read Improves the Structure of the Arcuate Fasciculus

Michel Thiebaut de Schotten[1,2,3], Laurent Cohen[3,4,5], Eduardo Amemiya[6], Lucia W. Braga[6] and Stanislas Dehaene[7]



Literacy related to an increase in fractional anisotropy and a decrease in perpendicular diffusivity in the temporo-parietal portion of the left arcuate fasciculus. The microstructure within this pathway correlated with the reading performance and the degree of functional activation within 2 dominant brain regions involved in reading: The Visual Word Form Area in response to letter strings, and the posterior superior temporal cortex in response to spoken language

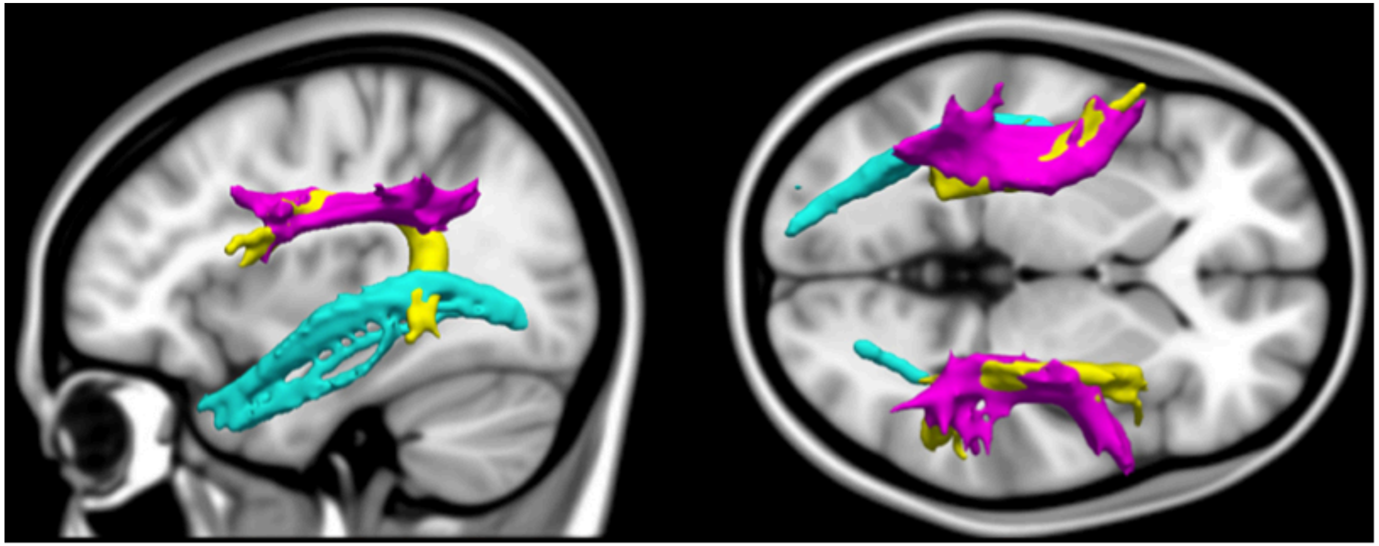


The Journal of Neuroscience, August 14, 2013 • 33(33):13251–13258 • 13251

Behavioral/Cognitive

Tracking the Roots of Reading Ability: White Matter Volume and Integrity Correlate with Phonological Awareness in Prereading and Early-Reading Kindergarten Children

Zeynep M. Saygin,[1]* Elizabeth S. Norton,[1]* David E. Osher,[1] Sara D. Beach,[1] Abigail B. Cyr,[1] Ola Ozernov-Palchik,[3] Anastasia Yendiki,[4] Bruce Fischl,[2,4] Nadine Gaab,[3] and John D.E. Gabrieli[1]
[1]McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences and [2]Computer Science and Artificial Intelligence Laboratory



In kindergarten children, we found a correlation between pho- nological awareness for spoken language and indices of white matter organization of the left arcuate fasciculus, specifically vol- ume and FA. This relationship was both anatomically and behav- iorally specific; it was not observed in other tracts (left ILF, left SLFp, or right hemisphere homologs) or for other behavioral predictors of dyslexia. These results were observed in the whole group of 40 children with varied reading abilities in the first half of kindergarten and also in the subset of 18 children who were prereaders. The specific relation between phonological awareness and the left arcuate fasciculus was corroborated by an indepen- dent whole-brain analysis. The discovery that such a relation between white matter organization and one of the strongest behavioral predictors of dyslexia, poor phonological awareness, ex- ists before formal reading instruction and substantial reading experience favors the view that differences in white matter orga- nization are not only the consequence of dyslexia, but also may be a cause of dyslexia.

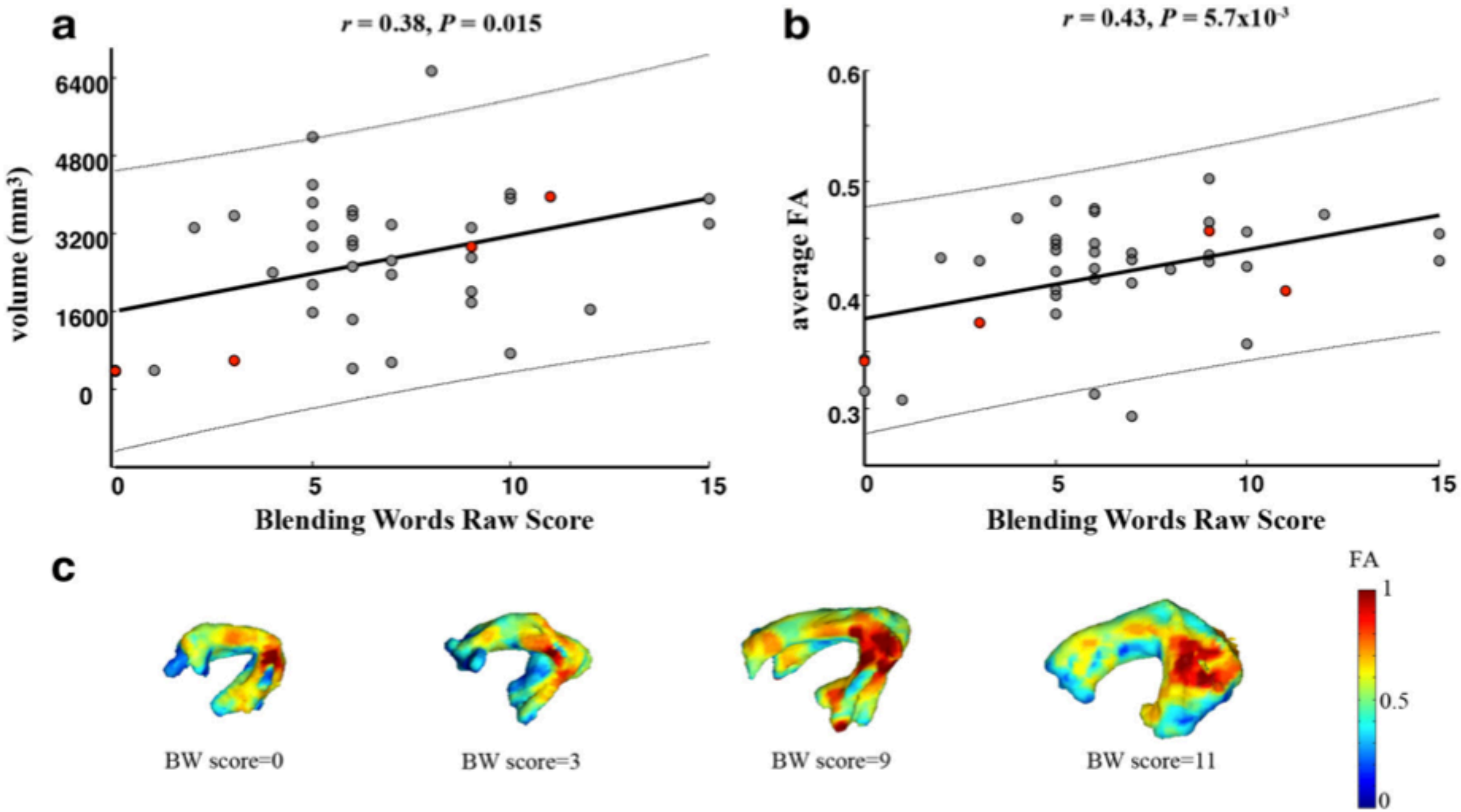


Figure 2. Greater volume and FA of the left arcuate fasciculus are associated with superior phonological awareness. ***a***, Volume of the left arcuate fasciculus plotted against individual raw scores of the Blending Words subtest. ***b***, Phonological awareness, illustrated by Blending Words raw scores, was significantly correlated with average FA of the left arcuate fasciculus. In ***a*** and ***b***, thick lines represent the best fits and thin outer lines represent the 95% confidence intervals. ***c***, To illustrate the relation between the behavioral phonological awareness scores with left arcuate volume and FA, this tract was rendered from example participants (filled red circles in ***a*** and ***b***) and colored according to FA. The tracts are ordered by Blending Words raw score increasing from left to right.

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Proc Natl Acad Sci U S A. 2012 October 30; 109(44): E3045–E3053. PMCID
Published online 2012 October 8. doi: 10.1073/pnas.1206792109
PNAS Plus
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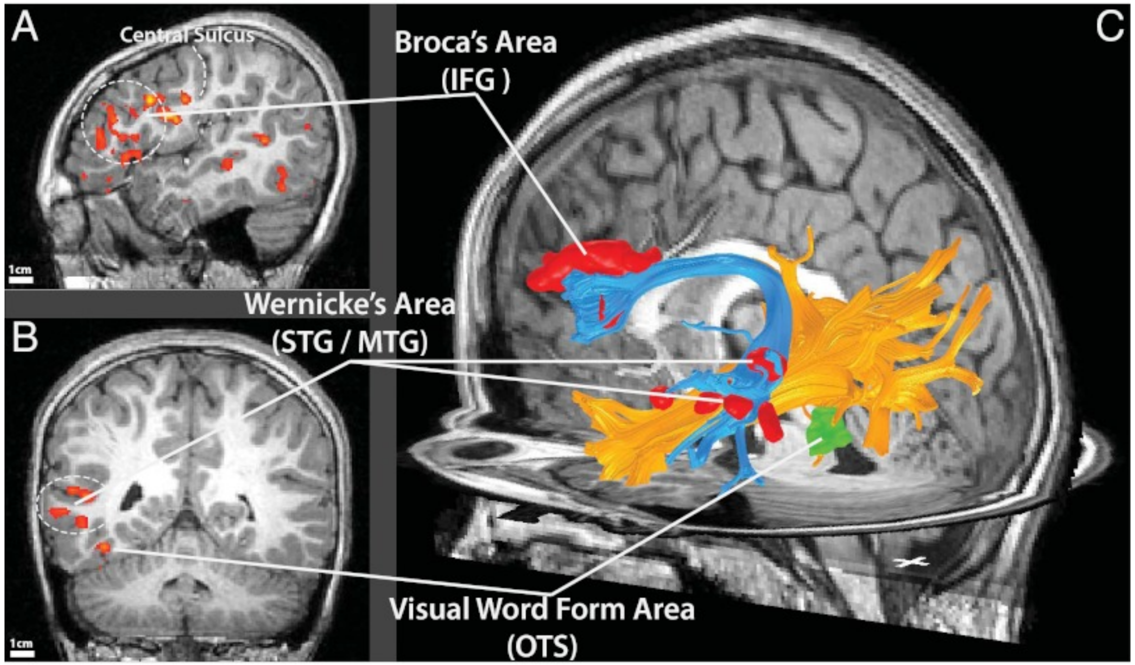
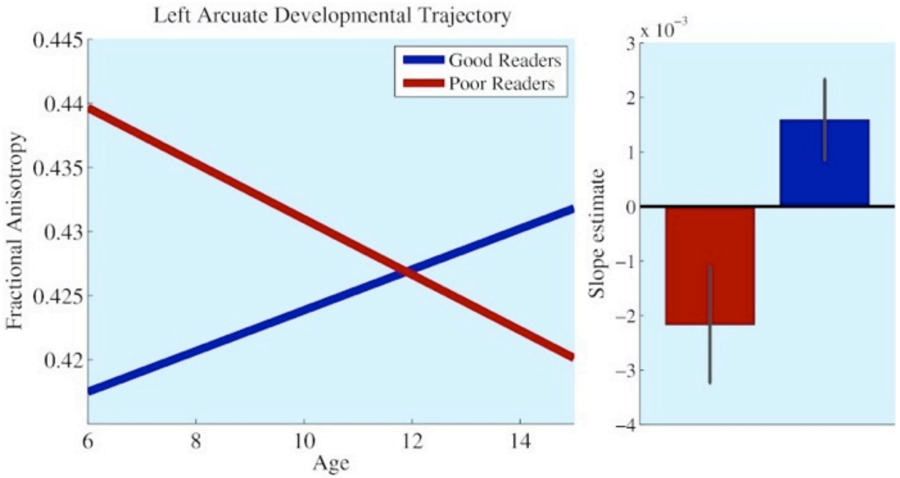
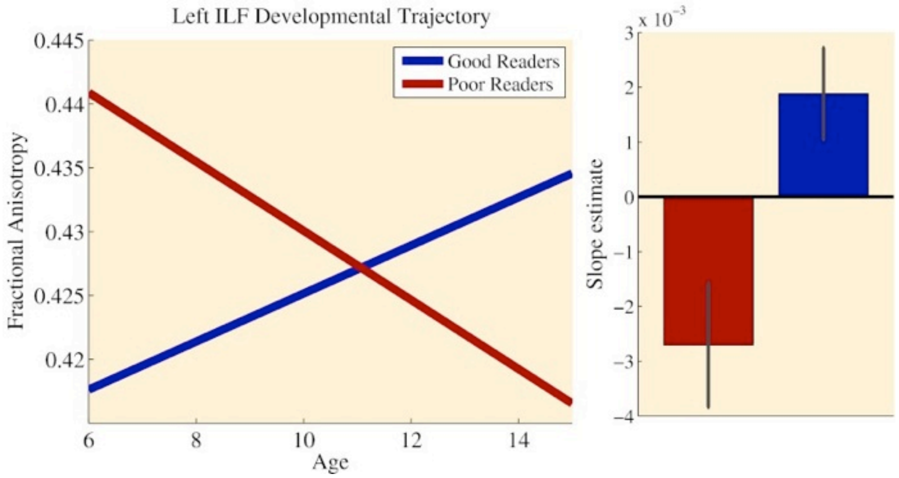
Development of white matter and reading skills

Jason D. Yeatman,[a,b,1] Robert F. Dougherty,[b] Michal Ben-Shachar,[c,d] and Brian A. Wandell[a,b]



we performed a longitudinal study to measure white-matter development (diffusion-weighted imaging) and reading development (behavioral testing) in individual children (age 7–15 y). The pattern of white-matter development differed significantly among children. In the left arcuate and left inferior longitudinal fasciculus, children with above-average reading skills initially had low fractional anisotropy (FA) that increased over the 3-y period, whereas children with below-average reading skills had higher initial FA that declined over time.





mean developmental trajectory for each group

mean developmental rate for the two groups in each pathway.

The FA-development rate correlates positively with reading skills (Basic Reading, Woodcock–Johnson) for both the left arcuate (*A*) and the left ILF (*B*).